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Lower carbon concrete trials

Technical report

Scalable Low Carbon Demonstrator Project

ACT Ecocem Low-Carbon Cement Technology

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VERSION HISTORY		
Issue	**Date**	**Pages / section amended**
00	Dec 2025	First issue

Foreword

This technical report has been funded by Innovate UK as part of its contracts for innovation. The initiative represents a significant step toward accelerating the adoption of sustainable construction practices.

The primary aim of this report is to share the key findings, insights, and the results of the tests carried out throughout the Scalable Low Carbon Demonstrator project. By documenting these, we hope to provide practical guidance for industry stakeholders, researchers, and policymakers who are committed to advancing low-carbon solutions. These learnings are intended to inform future projects, encourage innovation, accelerate standards and support the transition to a more sustainable built environment.

In keeping with the spirit of collaboration and transparency, this report is freely available to the industry. We believe that open access to knowledge is essential for driving meaningful change and fostering collective progress toward net zero goals.

We extend our gratitude to all partners and contributors whose expertise and dedication have made this project possible. Together, we are shaping a future where scalable, low carbon solutions become the standard for construction and infrastructure development.

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1.0 Introduction

1.1 Trials participants and stakeholders

The Scalable Low Carbon Demonstrator project brings together a leading expert consortium providing an integrated solution: John Sisk and Son, Ecocem, Ramboll Group, Loughborough University, Creagh Concrete, Capital Concrete, BRE Group and Quintain Ltd, with a common desire: *to rapidly decarbonise concrete and construction.*

We have scaled up, tested and demonstrated Ecocem's ACT Technology on a full-scale live construction site (Technical Readiness Level - TRL 7) marking the world's first structural use of ACT and consequently advancing the decarbonisation of global cement, concrete and construction.

Ecocem ACT is a ternary cement that is based on **20% CEM I, 30% supplementary cementitious materials (SCM), and 50% ground limestone filler** that offers a 70% reduction in embodied carbon in concrete. The SCM proportion of ACT is adaptable to the local supply chain and in this case **30% GGBS**, ground granulated blast furnace slag, was used. Other versions of ACT could be developed using alternative SCMs such as natural pozzolans, calcined clay, fly-ash or reconstituted lagooned fly-ash and other sources. Utilising 50% ground limestone makes the SCM proportion more efficient and scalable, essentially getting more with less which along with the abundance of limestone makes ACT a globally scalable low carbon technology.

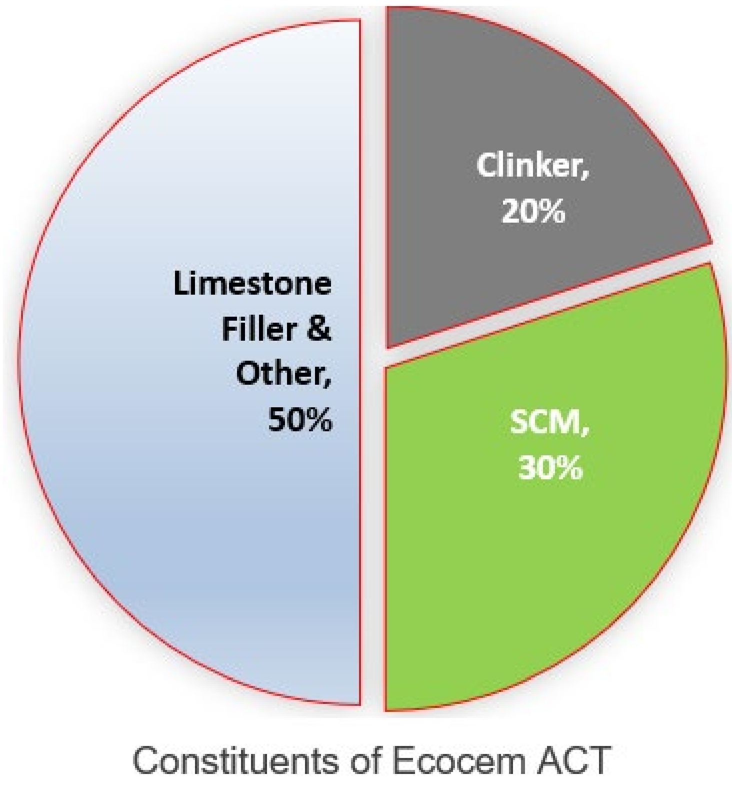

Figure 1 - Constituents of Ecocem ACT

This project, via a thorough and rigorous testing program and whole life cycle analysis, provides the data and validation for a wide range of mechanical, environmental and durability properties and considerations.

Table 1 - Scalable Low Carbon Demonstrator Project Stakeholders

Stakeholder	Stakeholder function	Representative	Position
John Sisk & Son	Project Manager and Main Contractor	Maria Estrada	Project Manager
Ecocem	Clean-tech IP owner / Manufacturer ACT cement	John Reddy	Director of Concrete Technology Deployment
Ramboll	Structural engineer	Tom Dillon	Design Engineer
Quintain	Client / Developer	Ahmed Barkatali	Head of Infrastructure
Capital Concrete	Ready-mix Concrete supplier	Jack Sindhu	Technical Director
Creagh Concrete	Precast Concrete Supplier	William Doherty	Technical Director
BRE	Independent Test laboratory	Chris Yapp	Senior Consultant
Loughborough University	Academic Test laboratory	Prof. Chris Goodier M. Umer Jadoon	Professor of Construction Engineering and Materials. Research Associate

1.2 References and abbreviations

Table 2 - References and Abbreviations

Ref.	Description
$f_{ck, cyl}$	Characteristic cylinder strength
$f_{ck, cube}$	Characteristic cube strength
f_{tm}	Target Mean Strength
σ	Standard Deviation of test results
f_{ctm}	Mean value of axial tensile strength of concrete
E_{cm}	Secant modulus of elasticity of concrete
$\phi(t,to)$	Creep coefficient

1.3 Standards, specifications, and technical documents

In pursuit of sustainable construction practices, this project evaluates the performance of Ecocem ACT low-carbon concrete technology in alignment with current industry guidance. Specifically, the testing has been conducted in accordance with the BSI FLEX 350 V1 standard, ensuring rigorous assessment criteria that align with modern construction requirements. At the time of project commencement version 1 was current version and since that time version 2 of BSI FLEX 350 has been published but is not considered in the scope of this project.

This BSI Flex 350 provides recommendations for the assessment and use of alternative binder systems (ABS) as part of a strategy for meeting the proposed Net Zero 2050 target when building structures in accordance with BS 8500 and BS EN 1992.

This BSI Flex 350 covers properties of ABS and provides recommendations on testing and monitoring to demonstrate conformity with the recommended performance for different applications. BSI Flex 350 is not currently referenced or part of BS 8500 but could be considered as a valid "Design by testing" method to BS EN 1992 or the equivalent concrete performance concept in BS 8500.

Ecocem ACT low-carbon cement technology, a groundbreaking advancement in sustainable materials, is designed to significantly reduce embodied carbon while maintaining structural integrity and durability; this innovative cement alternative presents a viable solution for helping decarbonize the built environment. The following section outlines the relevant technical documents and specifications guiding this investigation, ensuring comprehensive analysis within established frameworks.

Table 3 - BSI Flex 350 V1 Edition

Document Ref.	Edition	Internal ref (optional)	Document title
BSI Flex 350 v1.0:2023-10	October 2023 Version 1		Alternative binder systems for lower carbon concrete – Code of Practice – testing as per table below

Table 4 - BSI Flex 350 v1.0:2023-10 –Scalable Low Carbon Demonstrator Project Particulars

BSI Flex 350 v1.0:2023-10 –Scalable Low Carbon Demonstrator project particulars							
Property	**Test Procedure**	**Verification Testing**			**Project Specific**		**Flex 350 v1 Compliance**
		Ages	Structural Criteria	Non-structural Criteria	Age	Frequency	
Consistence	EN 12350 –2 slump/slump flow	-	Reported	Reported	-	Every truck	YES
Setting time	ISO 1920-14 penetration needle	-	Reported	Reported	-		Yes
Heat of Hydration	EN 12390-14 semi adiabatic	Optional	-	-	-	-	YES
Co-efficient of thermal expansion	EN 1770/Soundness	Optional	-	-	-	-	YES
Compressive strength	EN 12390-3	1,3,7,28,56,90, 180, 365	fck, Strength development class	fck	7, 28, 56	Every 50m3 or part thereof	YES
Tensile strength	EN 12390-6 Tensile splitting	7,28,90,180, 365	Mean fctm≥ 90%	Mean fctm < 90%	If specified	Every 250 m3	YES

						or part thereof	
Secant modulus of elasticity	BS EN 12390-13	7, 28, 90, 180, 365	Mean Ecm≥ 60%	Mean Ecm < 60%	If specified	Every 250 m3 or part thereof	YES
Shrinkage	BS EN 12390-16	7, 28, 90, 180	Ɛcd,0 reported	n/a	-	-	YES
Creep	EN 12390-17	7,14,28,90, 180, 365	Φ(t,t0) reported	n/a	-	-	Testing Complete
Fire resistance	BS 476	28	Reported	n/a			Testing Complete
Carbonation	BS EN 12390-12 Accelerated	28	Reported	n/a	-	-	Testing Complete
Chloride migration	Nordtest NT build 492 [N4]	28, 91	Reported	n/a	If specified	Every 250 m3 or part thereof	Testing Complete
Freeze-thaw resistance without de-icing agents	CEN/TR 15177/CEN 12390	28	≥ 75% after 28 cycles	N/A	-	-	YES
Freeze-thaw resistance without de-icing salts	CEN/TS 12390-9	28	<1000 g/m2 after 28 cycles	N/A	-	-	YES
Acid resistance	pH 2.5 immersion. Reference concrete.	28 (12 months)	Equivalent DC -4z	N/A	-	-	YES
Sulfate resistance	Class 2/Class 5 sulfate. Reference concrete.	28 (12 months)	Equivalent DC-2/DC-4	N/A	-	-	YES
Additional Tests carried out outside Flex 350 v1 scope							
Early age strength monitoring/Maturity	Converge	1 – 10 DAYS					Testing Complete
Material characterisation	SEM, XRD	28 1, 7, 28	Reported	N/A			Testing Complete
Large Scale Flexural Testing		28 Days	Reported				Testing Complete
Water penetration	BS EN 12390-8	28 days					Testing Complete

1.4 Executive summary

The construction industry is rapidly evolving to meet the challenges of climate change, and the Lower Carbon Concrete Trials mark a significant milestone in this transition. This report presents findings from the **Scalable Low Carbon Demonstrator project,** a rigorous investigation of **ECOCEM's ACT low-carbon cement technology**, an innovative solution designed to push the boundaries of sustainable concrete production and implementation.

Following successful lab-scale investigations at the Ecocem R&D centre in Paris, their development has now progressed to full-scale production, assessing ACT's feasibility across various construction applications on a full-scale live construction site (Technical Readiness Level - TRL 7). Unlike traditional concrete formulations, ACT surpasses the 30% limestone filler limitation of BS 8500, incorporating up to 50% ground limestone filler, placing it outside the scope of BS 8500. However, ACT aligns with the BS FLEX 350 V1, providing a pathway for certification and validation. Its composition - **20% CEM I, 30% supplementary cementitious materials (SCM), and 50% ground limestone filler** - marks a departure from conventional cement production methods. Instead of energy-intensive clinker manufacturing, ACT prioritizes **limestone grinding**, significantly reducing CO_2 emissions and enhancing global scalability. Additionally, ACT's low-water content requirements contribute to further resource efficiency.

The **Scalable Low Carbon Demonstrator project**, delivered by John Sisk and Son, centred around a full-sized 2 storey structure at Quintain's Wembley Park NE02/03 site. The reinforced concrete structure designed by Ramboll to existing industry codes and standards explores ACT's suitability across both ready-mix and precast concrete applications. The structure incorporated C40/50 and C50/60 grade concrete with varying workability, from S4 slump to self-compacting concrete (SCC).

A total of 55m^3 of ready-mix concrete, batched by Capital Concrete, was placed using pumps and skips, while 5m^3 of precast concrete, manufactured by Creagh Concrete, was also tested for various structural elements. These included steel reinforced and post-tensioned in-situ slabs, in-situ wall elements, round and square columns both in-situ and precast, and precast stairs, demonstrating ACT's adaptability to different formwork and finishing techniques such as floating, brushing, and power floating.

Through rigorous performance testing conducted by Loughborough University's School of Architecture, Building and Civil Engineering and BRE, and life cycle analysis carried out by John Sisk & Sons, this project establishes a reference benchmark for the practical demonstration and validation of the potential technical, environmental, and durability benefits of ACT as a low carbon construction material. By demonstrating and rigorously **evidencing a 70% reduction in embodied carbon** with minimal additional costs, ACT emerges as a scalable and globally deployable solution for reducing embodied carbon in concrete.

The Scalable Low Carbon Demonstrator Project further reinforces ACT's credibility by quantifying its mechanical, physical and durability properties and carbon credentials, under diverse environmental and loading conditions. These tests demonstrate compliance with contemporary industry design specifications and standards, optimizing ACT's performance for long-term structural integrity and reliability. By systematically evaluating these parameters, the project provides critical insights into the feasibility of a widespread adoption of ACT technology, hence supporting the acceleration of the construction sector's progress toward a net-zero future.

1.5 Project Milestones

Figure 2 - Project Milestones

2.0 SCOPE

2.1 Purpose

The Scalable Low Carbon Demonstrator Project aims to drive the adoption of innovative, low-carbon concrete technologies, focusing on the research, development, and demonstration of Ecocem ACT, a non-standard cement designed to significantly reduce embodied carbon in concrete structures. This project leverages a full supply chain approach to deliver a representative mock-up demonstration site, ensuring that the findings reflect real-world application and feasibility.
The reference site, developed with contributions from leading experts across structural engineering, materials science independent testing, cement and concrete manufactures, holds significant structural merit. It has undergone technical and environmental validation, reinforcing ACT's potential as a viable alternative to traditional cement.

The purpose of this report is to disseminate the results of extensive testing and performance assessments conducted throughout this Research & Development initiative. By sharing these insights openly, we aim to accelerate the specification and adoption of lower-carbon concretes, providing structural designers, engineers, and industry stakeholders with the knowledge required to implement ACT in future projects. Furthermore, this report contributes to ongoing efforts in standardization, ensuring the industry transitions toward validated, scalable decarbonization solutions.

2.2 Scope

The testing program for ACT low-carbon concrete encompasses a comprehensive assessment of its structural and durability performance, adhering to the BS FLEX 350 V1 standard. The evaluation has been structured into three distinct testing categories:

1. Fresh Concrete Properties – Assessing workability, setting times, and placement characteristics to evaluate ACT's behaviour during concrete batching and pouring.
2. Engineering Properties – Measuring compressive strength, flexural behaviour, and load-bearing capacity to determine ACT's mechanical performance under typical structural conditions.
3. Durability Properties – Examining resistance to environmental factors such as, carbonation, chloride ingress, and long-term degradation by sulfate attack to validate ACT's suitability for extended service life.

Each testing category is designed to provide critical insights into ACT's capabilities, supporting its adoption and certification as a lower-carbon concrete solution.
The findings presented in this report highlight key performance metrics essential for industry-wide implementation.
By documenting this research, we aim to facilitate informed decision-making for designers and engineers, ultimately supporting broader industry transition towards sustainable concrete technologies.

2.3 Structure

A live work site was selected at Quintain's development, Wembley Park NE02/03 to build the structure. A reinforced concrete frame was designed by Ramboll to represent the different modes of construction that could be deployed in follow on developments on this site using ACT.

The two-storey frame incorporates a mix of ready-mix and precast concrete applications. The structure incorporated C32/40, C40/50 and C50/60 grades of concrete with varying workability, from S4 slump to self-compacting concrete (SCC) for assessment to usual construction methods and schedules.

The outline design is given in figure 3 with the breakdown of the construction elements given in table 5.

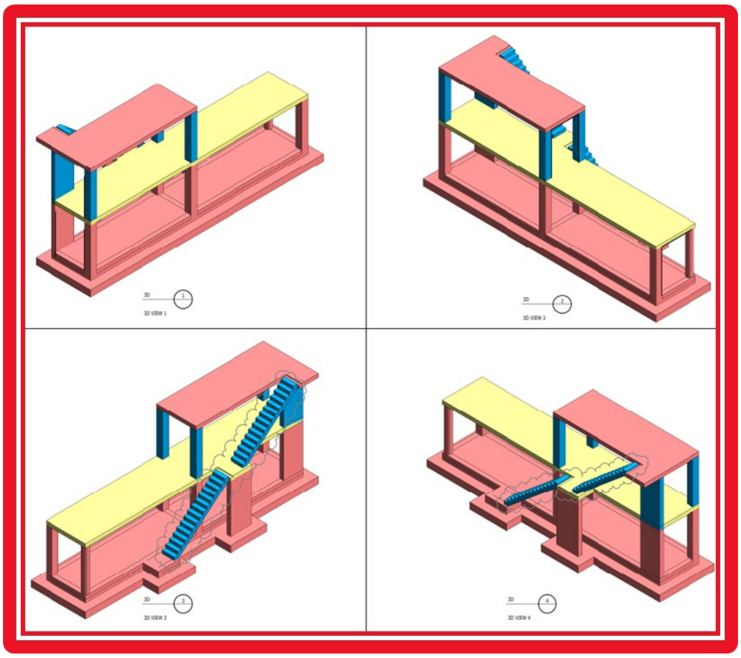

Figure 3 - Outline Structural Design

Table 5 – Structural elements

Element	Type	Placement	Concrete mix	Consistence	Volume	Design (Figure 3)
Raft foundation	Ready-mix	Pump	C40/50	S4	26.5 m^3	Pink
Ground floor slab	Ready-mix	Pump	C40/50	S4	10 m^3	Pink
GF Columns, walls	Ready-mix	Skip	C50/60	S4	4.5 m^3	Pink
Stairs	Precast	Crane	C32/40	S3	3 m^3	Blue
1st Floor slab (post-tensioned)	Ready-mix	Pump	C40/50	S4	9 m^3	Yellow
1st Floor Columns, walls	Precast	Crane	C40/50	SCC	2 m^3	Blue
2nd Floor slab	Ready-mix	Pump	C40/50	S4	5 m^3	Pink

A total of 55m^3 of ready-mix concrete, batched by Capital Concrete, was placed using pumps and skips, while 5m^3 of precast concrete, manufactured by Creagh Concrete, was also tested for various structural elements. These included steel reinforced and post-tensioned slabs, walls, round and square columns with ready-mix. ACT's adaptability to different formwork and finishing techniques such as floating, brushing, and power floating was also assessed. Precast components of stairs, walls and columns where cast off-site demonstrating ACT's suitability to precasting operations and as a multipurpose cement.

2.4 Trials specification

The Lower Carbon Concrete Trials rigorously evaluates the performance of Ecocem ACT low-carbon cement technology under real-world conditions. These trials aim to validate ACT's structural integrity, durability, and environmental benefits in accordance with BSI FLEX 350, which provides a framework for certification beyond the limitations of BS 8500 for novel cements.

The trial specification includes comprehensive testing industrial concrete scale, ensuring ACT's suitability for a range of construction applications. The following parameters define the scope of assessment:

1. **Concrete Mix Designs**
    - C40/50, C50/60 strength classes (in situ) and C32/40, C50/60 (precast).
    - Workability variations from S3 slump to self-compacting concrete (SCC).
    - Optimized low-water content mixes to enhance resource efficiency.
2. **Production & Placement Methods**
    - 55m^3 of ready-mix concrete batched by Capital Concrete, placed via pump and skip.
    - 5m^3 of precast concrete manufactured by Creagh Concrete.
    - Application in structural elements, including reinforced and post-tensioned slabs, columns, and precast components.
3. **Testing Methodology**
    - Fresh concrete properties – Workability, setting times and slump flow.
    - Engineering performance – Compressive strength, flexural behaviour, load stability, shrinkage, heat of hydration and temperature profile.
    - Durability assessments – Accelerated carbonation, chloride ingress, sulfate and acid resistance, freeze- thaw resistance, fire resistance and material characterisation to examine the microstructure and composition of ACT Concrete for susceptibility to any potential deleterious effects.
4. **Surface finished and concrete placement evaluations**
    - Finishing techniques: floating, brushing, power floating.

Through this structured trial process, the project aims to provide robust technical validation of ACT's performance, scalability, and environmental impact, supporting wider adoption within the construction industry. The findings outlined in this report will serve as a critical reference for designers, engineers, and industry stakeholders seeking proven lower-carbon concrete solutions that align with net-zero ambitions.

2.5 Methods of assessment (basis of trials design and assessment)

The Lower Carbon Concrete Trials have been designed to evaluate the fresh, engineering and durability properties of Ecocem ACT low-carbon cement technology. This assessment follows a structured methodology to ensure ACT's performance, scalability, and environmental impact are rigorously tested in alignment with BSI FLEX 350 Version 1.

Basis of Trials Design

The trials aim to:

- Establish comparative performance benchmarks against conventional cement-based concrete.
- Validate ACT's structural integrity, environmental resilience, and suitability for long-term use.
- Demonstrate ACT's applicability in both precast and ready-mix concrete for full-scale construction projects.

- Ensure compliance with industry testing protocols and emerging standards for novel ABS (alternative binder systems) cement technologies.

Assessment Methodology

To ensure comprehensive evaluation the assessment methodology has been selected to validate ACT's long-term reliability and sustainability. The insights gathered from this research provide a critical reference for designers, engineers, and construction professionals, supporting broader standardization and industry adoption of ACT technology. The assessment methodology was categorised into four primary areas:

2.5.1 Fresh Concrete Properties:

- Consistence and consistence retention (workability, flowability, slump behaviour)
    1. BS EN 12350-2:2019
- Setting time (initial and final setting stages)
    1. ISO 1920-14:2019

2.5.2 Engineering Performance Testing:

Determines the concrete's workability and consistence against design requirements.

- Compressive strength (7, 28, and 56 day performance)
    1. BS EN 12390-3:2019

    Determines the concrete's ability to withstand crushing forces and loads without failure or deformation.
- Flexural strength (7, 28 & 90 days)
    1. BS EN 12390-5:2019

    Determines the concrete's ability to withstand bending forces and loads without failure or deformation.
- Tensile strength (tensile splitting)
    1. BS EN 12390-6:2023

    Quantifies the material's resistance to tensile (pulling) forces and the likelihood of cracking by applying a compressive load to a cylindrical specimen until it splits.
- Secant modulus of elasticity
    1. BS EN 12390-13:2021

    Determines concrete's stiffness and deformation characteristics under stress, particularly its behaviour under initial loading and after multiple load cycles.
- Heat of hydration (thermal profile during early-stage curing)
    1. Heat of hydration (BS EN 12390-14:2018)
    2. Heat of Hydration Semi-adiabatic method (EN 196-9 Methods of testing cement)

    Monitor the temperature rise in ACT concrete and mortar during early-age hydration. This helps in understanding the thermal behaviour of the mix, particularly in mass concrete or restrained conditions where temperature gradients may cause cracking.
- Co-efficient of thermal expansion (response to temperature variations)
    1. Coefficient of thermal expansion (BS EN 1770:1998 / AASHTO T336-11 [N3])

    Determine how ACT mortar deforms in response to temperature changes. This test provides insight into the thermal dimensional stability of the material, which is important for avoiding thermal cracking in restrained conditions.
- Shrinkage
    1. BS EN 12390-16:2019

    The drying shrinkage test was carried out to quantify the total shrinkage (early-age and long-term volumetric changes) of ACT concrete and assess its dimensional stability over time.

- Creep
    1. BS EN 12390-17:2019

  Determine the time dependent deformation under sustained load conditions out to 1 year to predict performance and structural integrity.
- Early age concrete maturity assessment using Converge maturity system.

2.5.3 Durability Assessment:

- Carbonation resistance (depth progression over time)
    1. BS EN 12390-12:2020

  Accelerated test to determine resistance of concrete by subjecting it to an accelerated carbonation process in a controlled environment with increased levels of carbon dioxide. This test helps assess how well the concrete will resist degradation over time from exposure to atmospheric conditions, which is crucial for predicting its service life and preventing premature corrosion of embedded steel.
- Chloride migration (permeability and corrosion risk analysis)
    1. EN 12390-18 / Nordtest NT Build 492

  The rapid chloride migration test was performed to evaluate the resistance of ACT concrete to chloride ion ingress. This test helps assess the potential durability and service life of concrete in chloride-rich environments, such as marine conditions. It provides a measure of the concrete's ability to limit chloride transport, which is critical for reinforcement protection.
- Freeze-thaw resistance (with and without de-icing agents)
    1. PD CEN/TS 12390-9:2016

  Determine how well concrete surfaces withstand deterioration from repeated freezing and thawing, particularly in environments where de-icing salts are used, such as roads and bridges.
- Acid resistance (chemical degradation behavior)
    1. BSI Flex 350

  Determine the acid resistance of concrete through a wear rating test to predict and ensure its long-term durability in acidic environments like industrial zones, agricultural areas, and sewage systems. Cubes are placed in a citric acid solution for 1 year and have the level of concrete loss assessed through mass loss.
- Sulfate resistance (chemical attack resilience)
    1. BSI Flex 350

  Determine the performance of concrete through a wear rating test to see if it can withstand deterioration in sulfate rich environments like sewage treatment plants or areas with polluted groundwater. Cubes are placed in two sulfate solutions for at least 1 year and have the level of concrete loss assessed through mass loss and corner to corner wear rating.
- Fire resistance (performance under high-temperature exposure compared to the reference concrete, CIIIA+SR)
    1. Modified EFNARC 132F r3, test methodology shown in Appendix P

  Evaluate concretes fire resistance and spalling behaviour, crucial for ensuring the structural integrity of building and tunnels during a fire.
- Material Characterisation

  Understanding the microstructural evolution of cementitious materials is essential for optimising performance in blended cement systems. The interaction between ordinary Portland cement (CEM I), limestone, and supplementary cementitious materials (SCMs), in this case GGBS, influences both early-age and long-term properties through complex microstructural developments.

To investigate these effects, a material characterisation study was carried out using X-ray diffraction (XRD) and scanning electron microscopy (SEM) to characterise and compare the microstructural features of ACT and CEM I cement pastes. The analysis focused on the identification of hydration products, porosity evolution, filler effects, the reactivity of Limestone (LS) over time and the presence of any potential deleterious materials. The results provide insight into the mechanisms driving strength development and microstructural densification in these systems.

The samples used in these experiments were paste samples containing only ACT binder and water, with the water-to-binder ratio kept the same as that used for the concrete in the demonstrator project at Wembley Stadium. For comparison purposes, paste samples containing CEM I 52.5N cement were also prepared using the same water-to-binder ratio.

2.5.4 Life Cycle Assessment:

In order to understand the environmental benefits of this new product, we conducted a life cycle assessment for the 'as built' design and compared it to a baseline equivalent for the same geometry but with 'business as usual' materials. All calculations scoped for 'Cradle to Gate' carbon emissions (lifecycle modules A1-A3), accounting for raw material extraction, transportation to manufacturing plant and manufacturing processes. The carbon factors associated with the concrete mix designs have been benchmarked using the Low Carbon Concrete Group (LCCG) Market Benchmark 2024 with sources taken from ICE Database V3, Mineral Products Association Factsheet 18 R.03 issued 17-09-2019, BREEAM V6.1 New Construction England 1.0, Table 10.10 and specific EPDs.

Reference concrete:

A reference concrete was selected to compare performance in some instances by direct comparison of mixes. In other instances, known performance characteristics for established market concretes was used.

Table 7 - Reference concrete

Characteristic	Details
Strength designation	**Portland cement CEM I-based concrete mixes C40/50 CIIIA +SR**
Density	2400 kg/m^3
DC class	DC 1
Assessment age	28 days
Consistence class	S4
Carbon intensity (kgCO_2e/m^3)	223.57
LCCG Benchmark rating	Refer to LCCG Market benchmark for embodied carbon, version 3.0 sept 24

2.6 Arrangements for long-term in-situ durability monitoring and reporting

Monitoring Strategy

The long-term durability assessment will be conducted through systematic data collection and analysis at the demonstration site. The monitoring program includes:

- Regular post pour in-situ inspections of ACT-based concrete mock up structure.
- Coring of the structure at one and two years to assess carbonation depth and potentially other durability performance criteria.
- Other considerations outside the scope of this study include:
  - Use of C&D materials as constituents in concrete.

Reporting Framework

The findings from durability monitoring will be documented and disseminated as further revisions to this report to support industry-wide knowledge sharing and standardisation efforts. The reporting framework includes:

- Structured data analysis to inform performance.
- Durability review reports, summarizing in-situ testing outcomes and key performance metrics.
- Collaborative industry engagement, ensuring findings contribute to broader construction and materials research.

By implementing this long-term assessment framework, the project aims to provide clear, evidence-based insights into ACT's durability, enabling engineers, designers, and industry stakeholders to confidently specify ACT technology in future construction applications.

Should the demonstrator structure be demolished a condition survey will be completed and specimens will be taken for further testing.

2.7 Risks and opportunities for the product / technology being trialled

Opportunities

The adoption of Ecocem ACT low-carbon cement technology presents a significant opportunity to accelerate standardisation and implementation of novel low carbon concrete cements which doesn't fall under BS 8500, offering tangible environmental and technical benefits:

- Carbon Reduction Impact – ACT technology enabled a 70% reduction in embodied CO_2 emissions for concrete poured, contributing to global climate targets and net-zero commitments.

- Scalability & Industry Adoption – ACT is manufactured using existing industrial infrastructure, making it easily deployable across international markets without significant capital investment.

- Standardisation & Certification – Alignment with BS FLEX 350 provides a clear route for validation, paving the way for broader industry acceptance and regulatory inclusion.

- Performance & Workability – ACT's optimized mix designs support high-strength applications (C40/50, C50/60), varied workability (S3 slump to SCC), and enhanced durability, ensuring long-term reliability in structural applications.

- Water Resource Efficiency – ACT's low-water content requirement reduces overall water consumption, supporting sustainability initiatives in resource management.

- This demonstrator confirmed ACT as TRL 7, System prototype demonstrated in operational environment. Follow on qualification of this demonstrator should lead to opportunities to reach TRL 9. Actual system proven in operational environment and use of ACT in structural concrete in permanent works in 2025.
- ACT will have full commercial launch in Q4 2026 and be priced at similar rates to existing market cements with no green premium charged. It is expected to be licenced to existing cement manufacturers to accelerate its adoption and reduction of CO2 emissions. It offers risk mitigation to the associated potential cost of the deployment of Carbon Capture and Storage (CCUS) in cement manufacture.
- ACT fits in perfectly with EU Taxonomy and Environmental and Social Governance as it offers carbon reduction with low entry requirements.

Risks

As groundbreaking low carbon cement, ACT's adoption might address certain challenges to ensure implementation

- Material performance variability – raw material sourcing and variability could adversely affect performance. Rigorous product design and established Quality Assurance processes can mitigate this risk.
- Long term performance: Established accelerated durability tests were used to assess performance for design considerations. ACT's long-term durability is not established as a new innovation and performance in diverse environmental conditions may require continued monitoring and refinement.
- Industry awareness & specification barriers – Adoption will depend on education, specification guidance, and acceptance by structural designers, engineers, contractors and the insurance sector of BSI Flex 350, necessitating further industry outreach and collaboration.
- Regulatory & compliance evolution – Future regulatory frameworks may need adaptation to accommodate non-standard cement technologies, ensuring ACT can be integrated into mainstream construction approvals.

Strategic path forward

To maximize ACT's potential while addressing challenges, we recommend the following strategic measures.

- Continued durability monitoring through in-situ testing at the reference site, reinforcing long-term reliability for future projects.
- Expanded engagement with industry stakeholders, including designers, engineers, and regulatory bodies, to drive market acceptance.
- Advancement in standardisation efforts, ensuring ACT's inclusion in broader regulatory frameworks such as including BSI Flex 350 as part of BS 8500.
- Further demonstration pilots of ACT concrete across a range of mix designs and applications to enhance performance, workability, and application versatility with different partners to establish repeatability and reproducibility to enhance confidence in adoption.

By addressing these risks and capitalizing on opportunities, ACT technology standardisation can serve as a foundation for sustainable low carbon cements production, supporting the industry's decarbonization ambitions while delivering high performance and environmentally responsible solutions.

2.8 Predicted resource implications

By addressing the following resource implications the transition of ACT technology can be managed, ensuring scalability and contribution to industry wide carbon reductions initiatives towards NetZero

Table 8 - Material Resources

Material resources	
Raw Material	Clinker reduction with 50 % ground limestone filler and 30% of GGBS (this project). Limestone is available as used in clinker production. GGBS proportion is lower than reference concrete. ACT is adaptable for other SCMs such as fly-ash, calcined clay, natural pozzolans and reduces dependency on GGBS. In fact, ACT extends the existing resources of GGBS by 3.
CO_2 emissions reduction	Grinding of limestone instead of clinker significantly lowers the carbon footprint
Water efficiency	Low water content at 0.35 w/c ratio in concrete reduced water demand using admixture technology.
Chemical admixtures	Superplasticising admixtures are used in ACT concrete that are readily available from existing supply chains.

Table 9 - Manufacture and supply chain implications

Manufacture and supply chain implications	
Compatibility with Existing Infrastructure	ACT has been designed to be produced and delivered using existing cement production facilities, batching plants, and supply networks, minimizing capital investment for industry transition.
Batching & Quality Control Adjustments	Batching is as normal in a concrete plant. ACT requires a dedicated silo but is treated as a normal cement thereafter. Due to ACT's unique composition, placement, and curing protocols may be necessary to ensure consistent performance across different project scales.

Material Availability & Scaling	While limestone is widely available, the procurement and consistency of supplementary cementitious materials (SCMs) require careful supply chain coordination to ensure long-term stability. ACT is adaptable to different SCMs and GGBS was used in this project. Other SCMs could be used instead of GGBS making it ACT more scalable.

Table 10 - Operations and economic factors

Operations and economic factor	
Minimal green premium	ACT technology presents minimal additional costs compared to traditional cement, making it an economically viable lower-carbon alternative.
Construction Process Adaptations	Mix design refinements, curing time considerations, and placement methodologies must be factored into operational workflows to optimize ACT's performance in diverse construction applications. Monitoring of QA process on site.
Exploitation Plan	Ecocem will have 350,000 tonnes/pa of ACT from Q4 2026 as they are installing a new manufacturing line at their facility in Dunkirk France. This will be shipped to their port facility at Sheerness on Sea or to other port facilities. ACT Technology can be licenced meaning any cement company can produce it.

3.0 Concrete mix designs

The development of optimal low-carbon concrete mix designs has progressed through a systematic research and validation process, moving from lab-scale testing at the Ecocem R&I centre in Paris to full-scale plant trials at Capital Concrete and Creagh Concrete aimed at achieving specified mix designs as outlined by Ramboll.

During the initial laboratory trials, assessments were conducted to refine the mixes composition, workability, strength development, and durability properties. These findings provided the foundation for scaling up trials to verify mix designs under real-world application conditions for both, concrete in situ and self-compacting for the precast elements.

The following sections provide a detailed breakdown of the mix design specifications, performance expectations, and industry benchmarks guiding ACT's full-scale implementation.

3.1 Ecocem R&I LAB Trial Results – Capital Concrete

Ready-mix: Mix 1

Samples of fine and coarse aggregates were sourced from Capital Concrete. A 0/4 mm washed sand and a 4/20mm gravel were assessed for initial lab scale concrete mix designs. This work was carried out at the Ecocem R&I centre in Paris at standard lab conditions of 20 ± 2°C. Trial mixes were assessed against the design requirements of C40/50 strength classification; S4 consistence class; viscosity measured by inverted cone test of < 6 seconds, slump retention to 2 hours and suitable for pumping.

The details of the best performing candidate mix, "Mix 1" are given in table 11.

Refer to Appendix A for R&I lab trials Capital Concrete.

Following the lab optimisation, plant trials were then carried out using "Mix 1" at Capital Concrete's Cricklewood plant. Results are given in Table 27 (Section 9) showing that all the design criteria were met.

Ready-mix: Mix 2

Following on from the positive C40/50 lab trials and initial plant trials a second mix to meet the requirements of C50/60 was designed. This mix was also required to have S4 consistence class; viscosity measured by inverted cone test of < 6 seconds, slump retention to 2 hours and suitable for placement using skip.
This mix was not tested in the lab and was trialled at Capital Concretes batching plant. The mix details are given in table 13 and is referred to as "Mix 2". The same sand source was used as Mix 1. The coarse aggregate was changed to a crushed limestone source.

Results from the C50/60 plant trial are given in Table 27 (Section 9) showing that all the design criteria were met.

3.2 Concrete mix 1 – Capital Concrete C40/50 ECOCEM ACT

Designed characteristics:

Table 11 - Designed characteristics C40/50

Characteristic	Details
Strength designation	C40/50
DC class	DC-2 (Ramboll Concrete Spec E10)
Density	2,400 kg/m^3
Assessment age	28 days
Consistence class	S4
Carbon intensity (kgCO_2e/m^3)	77.55
LCCG Benchmark rating	"Market Beating"

Concrete composition C40/50 and total embodied carbon:

Table 12 - Concrete composition C40/50

Constituent and source	Quantity	Unit	kgCO_2e/m^3	Source used for CO_2e calculation*
4/10mm Gravel	303	kg	1.04	CEM I, GGBS and Limestone cement: - Mineral Products Association Factsheet 18 R.03 issued 17-09-2019 Aggregates: - BREEAM V6.1 New Construction England 1.0, Table 10.10. Mains water: - https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023 Admixtures: - ICE Database V3.0
10/20mm Gravel	707	kg	2.43	
Sand 0/4	910	kg	3.12	
Water	123	li	-	
Ecocem ACT	350	kg	70.00	
Superplasticiser	5600	ml	.90	
Total kgCO_2e/m^3			**77.55**	

* ICE Database v.3 / MPA factsheet 18 / specific EPD etc…

3.3 Concrete mix 2 – Capital Concrete C50/60 ECOCEM ACT

Designed characteristics:

Table 13 - Designed characteristics C50/60

Characteristic	Details
Strength designation	C50/60
DC class	DC-2 (Ramboll Concrete Spec E10)
Density	2,400 kg/m^3
Assessment age	28 days

Characteristic	Details
Consistence class	S4
Carbon intensity (kgCO_2e/m^3)	93.34
LCCG Benchmark rating	"Market Beating"

Concrete composition C50/60 and total embodied carbon:

Table 14 - Concrete composition C50/60

Constituent and source	Quantity	Unit	kgCO_2e/m^3	Source used for CO_2e calculation*
4/20mm Limestone	990	kg	3.40	CEM I, GGBS and Limestone cement: - Mineral Products Association Factsheet 18 R.03 issued 17-09-2019 Aggregates: - BREEAM V6.1 New Construction England 1.0, Table 10.10. Mains water: - https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023 Admixtures: - ICE Database V3.0
Sand 0/4	840	kg	2.88	
Water	151	li	-	
Cement Ecocem ACT	430	kg	86.00	
Superplasticiser	6000	ml	.96	
Total kgCO_2e/m^3			**93.34**	

* ICE Database v.3 / MPA factsheet 18 / specific EPD etc...

3.4 Ecocem R&I LAB Trial Results – Creagh Concrete

Samples of fine and coarse aggregates were sourced from Creagh Concrete. Fine aggregate samples are as follows: 0/2 mm sand sourced from Magheraglass and a 0/4 mm sand sourced from Draperstown. 6/14 mm and 10/20 mm coarse aggregate samples were sourced from Draperstown. Limestone filler from Omya Glenarm was also sourced. These samples were assessed for initial lab scale concrete mix designs for C32/40 precast stair mix with consistence of S3 and C40/50 SCC mix for precast walls and columns. This work was carried out at the Ecocem R&I centre in Paris at standard lab conditions of 20 ± 2°C. Trial mixes were assessed against the design requirements of strength classification; consistence class; viscosity and slump retention to suitable for precasting operations.

Refer to Appendix B. for R&I lab trials Creagh Concrete

Once the criteria were met and the mix designs established these went forward for pre-production industrial plant trials at Creagh Concrete.

3.5 Concrete mix 3 –Creagh Concrete C32/40 Mix Design

Designed characteristics:

Table 15 - Designed characteristics Precast concrete C32/40

Characteristic	Details
Strength designation	C32/40
DC class	n/a
Density	2400 kg/m^3
Assessment age	28 days
Consistence class	S3
Carbon intensity (kgCO_2e/m^3)	83.38
LCCG Benchmark rating	LCCG 1

Concrete composition C32/40 and total embodied carbon:

Table 16 - Concrete composition Precast concrete C32/40

Constituent and source	kg/m^3	kgCO_2e/kg	Source used for CO_2e calculation*
6/14mm aggregate	1036	3.55	CEM I, GGBS and Limestone cement: - Mineral Products Association Factsheet 18 R.03 issued 17-09-2019 Aggregates: - BREEAM V6.1 New Construction England 1.0, Table 10.10. Mains water: - https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023 Admixtures: - ICE Database V3.0
0/4 sand	465	1.59	
0/2 sand	362	1.24	
Limestone filler	-	0	
Superplasticiser	6.44	0	
Cement Ecocem ACT	390	78	
Water	171	-	
Total kgCO_2e/m^3		83.38	

* ICE Database v.3 / MPA factsheet 18 / specific EPD etc...

3.6 Concrete mix 4 – Creagh Concrete C40/50 Self Compacting Mix Design

Designed characteristics:

Table 17 - Designed characteristics Precast concrete C40/50

Characteristic	Details
Strength designation	C40/50
DC class	n/a
Density	2400 kg/m3
Assessment age	28 days

Characteristic	Details
Consistence class	SCC
Carbon intensity (kgCO_2e/m^3)	109.98
LCCG Benchmark rating	LCCG 1

Concrete composition C40/50 and total embodied carbon:

Table 18 - Concrete composition Precast concrete C40/50

Constituent and source	kg/m^3	kgCO_2e/kg	Source used for CO_2e calculation*
6/14mm aggregate	770	2.64	CEM I, GGBS and Limestone cement: - Mineral Products Association Factsheet 18 R.03 issued 17-09-2019 Aggregates: - BREEAM V6.1 New Construction England 1.0, Table 10.10. Mains water: - https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023 Admixtures: - ICE Database V3.0
0/4 sand	580	1.99	
0/2 sand	300	1.03	
Limestone filler	40	0.32	
Superplasticiser	7.84	0.00	
Cement Ecocem ACT	520	104	
Water	176	-	
Total kgCO_2e/m^3		109.98	

* ICE Database v.3 / MPA factsheet 18 / specific EPD etc...

4.0 Sampling and testing locations

Refer to table 19.

4.1 Sampling and testing locations - Fresh properties

Table 19 - Sampling and testing locations - Fresh properties

Test Name	Tester/Company	Location
Consistence	Capital Concrete	At Batch Plant and On Site.
Setting time	Capital Concrete	Amtest lab
Heat of hydration	Loughborough University	For the Heat of Hydration test, concrete samples were prepared and cast into insulated moulds, with each sample measuring 100 mm^3. For the Thermal Expansion test, mortar samples were mixed and cast into steel moulds, with final dimensions of 25x25x300 mm. All samples for both tests were prepared at the Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab).
Coefficient of thermal expansion		The thermal expansion test, conducted on 25 × 25 × 300 mm mortar specimens prepared at the Sir Frank Gibb Laboratory, Loughborough University.

4.2 Sampling and testing locations - Engineering properties

Table 20 - Sampling and testing locations - Engineering properties

Test Name	Tester/Company	Location
Compressive strength	Capital Concrete	Main Laboratory – CCL Wembley
Compressive strength	Harringtons	Concrete testing solutions ltd.
Tensile strength	BRE	Sampling – CCL Wembley Testing – BRE, Garston
Secant modulus of elasticity	BRE	
Creep	BRE	
Fire resistance	BRE	Sampling – BRE, Garston Testing – BRE, Garston
Shrinkage	Loughborough University	The shrinkage test samples were collected from the demonstrator project building on 02/12/2024. The specimens were concrete prisms with dimensions of 63 × 63 × 405 mm.

4.3 Sampling and testing locations - Durability properties

Table 21 - Sampling and testing locations - Durability properties

Test Name	Tester/Company?	Location
Carbonation resistance	BRE	Sampling – BRE, Garston Testing – BRE, Garston
Freeze-thaw resistance WITH salt solution	BRE	Sampling – CCL Wembley Testing – BRE, Garston
Freeze-thaw resistance WITHOUT salt solution	BRE	
Acid resistance	BRE	
Sulfate resistance	BRE	
Early-age strength monitoring/maturity testing	Converge	On site
Material characterization	Loughborough University	For material characterization tests, paste samples were prepared at the Sir Frank Gibbs Laboratory, Loughborough University. These samples were subsequently tested using X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) at the Loughborough Materials and Characterization Centre (LMCC).
Chloride migration	Loughborough University	For the Rapid Chloride Migration Test, cylindrical concrete samples measuring 100 mm in diameter and 200 mm in length were collected from the demonstrator project on 04/09/2024.

5.0 Sampling and testing plans – Fresh concrete properties

This list is neither mandatory nor restrictive; it is a guide to the most commonly expected characteristics in general applications. The headings are to be tailored to the trial's specification.

5.1 Consistence and consistence retention (BS EN 12350-2:2019 / BS EN 12350-5:2019 / BS EN 12350-8:2019)

Ambient and fresh concrete temperature should be recorded for each sample taken, recorded to the nearest 1°C.

- Tests conducted: Slump test.
- Measurements recorded: Ambient temperature.
- Purpose: Evaluating placement characteristics.
-

5.2 Setting time (BS ISO 1920-14:2019)

- Tests conducted: Initial and final setting time assessment.
- Measurements recorded: Transition period from fresh to hardened state.
- Purpose: Determining ACT’s hydration rate and suitability for construction schedules

6.0 Sampling and testing plans – Engineering properties

6.1 Compressive strength (BS EN 12390-3:2019)

- Tests conducted: Compressive strength at 7, 28, and 56 days.
- Measurements recorded: Load-bearing capacity, strength development curve.
- Purpose: Evaluating ACT's structural performance against reference concrete mixes.

6.2 Flexural strength (BS EN 12390-5:2019)

- Tests conducted: Flexural Tensile Strength at 7, 28 & 90 days.
- Measurements recorded: Maximum load at failure.
- Purpose: Evaluating ACT's structural performance against BSI Flex 350 v1.0.

6.3 Tensile splitting strength (BS EN 12390-6:2023)

- Tests conducted: Direct tensile strength, splitting tensile test.
- Measurements recorded: Resistance to tensile stress, fracture patterns.
- Purpose: Understanding ACT's behaviour under tensile loading conditions.

6.4 Secant modulus of elasticity (BS EN 12390-13:2021 method B)

- Tests conducted: Elastic modulus testing via standard loading procedures.
- Measurements recorded: Deformation characteristics under stress.
- Purpose: Assessing stiffness and adaptability in structural applications.

6.5 Shrinkage (BS EN 12390-16:2019)

- Tests conducted: Long-term volumetric changes, sustained load deformation.
- Measurements recorded: Shrinkage strain progression, creep coefficient.
- Purpose: Ensuring ACT's dimensional stability and reliability over time.

6.6 Compressive Creep (BS EN 12390-17:2019)

- Tests conducted: Long-term volumetric changes, sustained load deformation.
- Measurements recorded: Shrinkage strain progression, creep coefficient.
- Purpose: Ensuring ACT's dimensional stability and reliability over time.

6.7 Coefficient of thermal expansion (BS EN 1770:1998 / AASHTO T336-11 [N3])

This test is performed to evaluate and quantify how much the ACT material expands or contracts in response to temperature changes.
It measures the dimensional stability under thermal cycling, which is critical for structures exposed to fluctuating or extreme temperature conditions.

6.8 Heat of hydration (BS EN 12390-14:2018)

- Tests conducted: Semi-adiabatic calorimetry measurements.
- Measurements recorded: Thermal profile during curing.
- Purpose: Assessing early-age temperature rise and hydration kinetics.

6.9 Maturity testing/early strength

- Tests conducted: Strength gain analysis over early curing periods.
- Measurements recorded: Converge Maturity Sensors, Time/Temperature : Strength curve assessment, early compressive strength estimation. Sensor placed in sections for each pour.
- Purpose: Optimizing construction timelines and early-formwork removal.

6.10 Large-scale flexural testing of reinforced slabs

- Tests conducted: Large scale flexural testing of reinforced slabs.
- Measurements recorded: Load applied and deflections of the slab.
- Purpose: Assess full-scale loading response.

7.0 Sampling and testing plans – Durability properties

7.1 Accelerated Carbonation (BS EN 12390-12:2020)

- Tests conducted: Depth progression analysis over time.
- Measurements recorded: Carbonation depth.
- Purpose: Evaluating long-term material stability against accelerated exposure.

7.2 Chloride migration (BS EN 12390-18:2021 / Nordtest NT Build 492)

- Tests conducted: Chloride permeability assessment.
- Measurements recorded: Chloride migration coefficient.
- Purpose: Ensuring ACT's longevity in marine and high-salinity environments.

7.3 Freeze-thaw resistance with de-icing agents (PD CEN/TS 12390-9:2016)

- Tests conducted: Cyclic freeze-thaw exposure with de-icing agents/salts.
- Measurements recorded: Surface degradation, mass loss, durability index.
- Purpose: Validating ACT's performance in fluctuating temperature conditions.

7.4 Freeze-thaw resistance without de-icing salts (PD CEN/TS 12390-9:2016)

- Tests conducted: Cyclic freeze-thaw exposure without de-icing agents/salts.
- Measurements recorded: Surface degradation, mass loss, durability index.
- Purpose: Validating ACT's performance in fluctuating temperature conditions.

7.5 Sulfate resistance (BSI Flex 350 Class 2/Class 5 sulfate immersion)

- Tests conducted: Exposure to sulfate-rich solutions.
- Measurements recorded: Structural integrity retention over time.
- Purpose: Assessing ACT's suitability for sulfate-contaminated soil applications.

7.6 Acid resistance (BSI Flex 350 pH2.5 immersion)

- Tests conducted: Exposure to acidic solutions under controlled conditions.
- Measurements recorded: Structural deterioration rates, mass loss.
- Purpose: Evaluating ACT's resilience to aggressive chemical environments.

7.7 Fire Resistance

- Tests conducted: Heat exposure and degradation analysis.
- Measurements recorded: Structural integrity post-exposure and thermocouple measurements.
- Purpose: Validating ACT's resilience under extreme temperature condition

Refer to Appendix P for test methodology.

7.8 Material Characterization

- Tests conducted: Microstructural analysis, X-ray diffraction, SEM imaging.
- Measurements recorded: Mineral composition, phase behaviour.
- Purpose: Understanding ACT's fundamental material properties.

7.9 Water Penetration (BS EN 12390-8:2019)

- Tests conducted: Water penetration to BS EN 12390-8:2019.
- Measurements recorded: Maximum water penetration.
- Purpose: Providing standard test result for design purposes.

8.0 Assessment of test results – Fresh concrete properties

8.1 Consistence and consistence retention (BS EN 12350-2:2019)

Mix 1 C40/50 date poured 25/11/2024

The specified consistence class was S4 which has a permitted range of 140mm – 230mm.

Consistence retention was carried out at on arrival to site. Refer to Appendix M for of slump test pictures.

Table 22 - Consistence and consistence retention Mix 1

Characteristic	Load 1	Load 2	Load 3	Load 4
Delivery ticket no.	34025863	34025866	34025872	34025877
Load volume (m^3)	7	7	7	5.5
Time batched	10.07	10.43	11.36	12.04
Time received (start of testing)	11.05	11.41	12.31	13.06
Age (mins) at start of testing	58	58	55	62
Temperature: - Ambient - Fresh concrete	- 10 °C -	- 10 °C -	- 11°C -	- 11°C -
Consistence as received				
Water addition (litres)				
Final consistence EN12350-2	190mm	200mm	210mm	190mm
Consistence retention (mm): - 30 minutes - 60 minutes - 90 minutes - 2 hours	- n/a - - -	- n/a -	- n/a -	- n/a -

Mix 1 C40/50 date poured 02/12/2024:

The specified consistence class was S4 which has a permitted range of 140mm – 230mm.

Consistence retention was carried out at on arrival to site – Refer to Appendix M for of slump test pictures.

Table 23 - Consistence and consistence retention Mix 1

Characteristic	Load 1	Load 2
Delivery ticket no.	34026199	34026205
Load volume (m^3)	7	3
Time batched	8.16	9.50
Time received (start of testing)	9.22	10.32
Age (mins) at start of testing	66	42

Characteristic	Load 1	Load 2
Temperature: - Ambient - Fresh concrete	- 9 **°C** -	- 9 **°C** - -
Consistence as received		
Water addition (litres)		
Final consistence EN12350-2	195mm	190mm
Consistence retention (mm): - 30 minutes - 60 minutes - 90 minutes - 2 hours	- n/a - - -	- n/a -

Mix 2 C50/60 date poured 05/12/2024:

The specified consistence class was S4 which has a permitted range of 140mm – 230mm.

Consistence retention was carried out at on arrival to site. Refer to Appendix M for of slump test pictures.

Table 24 - Consistence and consistence retention Mix 2

Characteristic	Load 1
Delivery ticket no.	34026382
Load volume (m^3)	4.5
Time batched	13.20
Time received (start of testing)	14.04
Age (mins) at start of testing	44
Temperature: - Ambient - Fresh concrete	- **12°C** -
Consistence as received	
Water addition (litres)	
Final consistence EN12350-2	226mm
Consistence retention (mm): - 30 minutes - 60 minutes - 90 minutes - 2 hours	- n/a - - -

Mix 1 C40/50 date poured 12/12/2024:

The specified consistence class was S4 which has a permitted range of 140mm – 230mm.

Consistence retention was carried out at on arrival to site. Refer to Appendix M for of slump test pictures.

Table 25 - Consistence and consistence retention Mix 1

Characteristic	Load 1	Load 2
Delivery ticket no.	34026748	34026755
Load volume (m^3)	5	4
Time batched	13.11	14.31
Time received (start of testing)	14.20	15.27
Age (mins) at start of testing	69	56
Temperature: - Ambient - Fresh concrete	- **8°C** -	- **8°C** -
Consistence as received		
Water addition (litres)		
Final consistence EN12350-2	175mm	170mm
Consistence retention (mm): - 30 minutes - 60 minutes - 90 minutes - 2 hours	- n/a - - -	- n/a -

Mix 1 C40/50 date poured 14/12/2024:

The specified consistence class was S4 which has a permitted range of 140mm – 230mm.

Consistence retention was carried out at on arrival to site. Refer to Appendix M for of slump test pictures.

Table 26 - Consistence and consistence retention Mix 1

Characteristic	Load 1
Delivery ticket no.	34027459
Load volume (m^3)	5
Time batched	7.43
Time received (start of testing)	8.35
Age (mins) at start of testing	52
Temperature: - Ambient - Fresh concrete	- **4°C** -
Consistence as received	
Water addition (litres)	
Final consistence EN12350-2	160mm
Consistence retention (mm): - 30 minutes - 60 minutes - 90 minutes - 2 hours	- n/a - - -

8.2 Bleed (EN 480-4)

This testing was not carried out as ACT concrete exhibits very low bleed.

8.3 Setting time (BS ISO 1920-14)

Mix 1 C40/50

The initial and final setting time of concrete was measured in the lab at standard conditions. Initial set was measured at 8 hours. Final set was measured at 12 hours. Setting time will vary in practice depending on climatic conditions and specifics of concrete mix design and application of concrete pour.

9.0 Assessment of test results – Engineering properties

9.1 Compressive strength and saturated, surface-dry density (EN 12390-3 / EN 12390-7)

All test specimens used were prepared using 100mm cube moulds in accordance with EN 12390-1. Specimens were prepared and cured in accordance with EN 12390-2 and tested for compressive strength in accordance with EN 12390-3. Testing of saturated, surface-dry density (SSD) was conducted in accordance with EN 12390-7.

Saturated, surface-dry density (SDD) testing is conducted as part of the compressive strength testing process, on each test specimen.

Results are summarised below, copies of test reports are available at:
Appendix F – AMTEST Early strength age
Appendix G – Capital Concrete Cube Results
Appendix H – Harringtons Cube Results

AMTEST Trial Cube Compressive Strength C40/50 and C50/60 Results (MPa):

Table 27 - AMTEST Trial Cube Compressive Strength C40/50 and C50/60 Results

Date Cast	Certificate Number	Specimen ID	Specimen Age	Strength (MPa)	Density (Kg/m3)	Comments – Reference
04/09/24	AMT-CRS-000772	CUBE 1 C40.50 04.09.24	24 hours	3.73	2358.0	AT002468
04/09/24	AMT-CRS-000772	CUBE 2 C40.50 04.09.24	24 hours	4.74	23611.0	AT002468.1
04/09/24	AMT-CRS-000772	CUBE 3 C40.50 04.09.24	3 Days	17.37	2361.0	AT002468.2
04/09/24	AMT-CRS-000772	CUBE 4 C40.50 04.09.24	3 Days	16.62	2365.0	AT002468.3
04/09/24	AMT-CRS-000772 – ID9369	CUBE 5 C40.50 04.09.24	5 Days	27	2375.0	AT002468.4
04/09/24	AMT-CRS-000772 – ID9369	CUBE 6 C40.50 04.09.24	5 Days	26.98	2383.0	AT002468.5
04/09/24	AMT-CRS-000772 – ID9369	CUBE 7 C40.50 04.09.24	7 Days	34.39	2367.0	AT002468.6
04/09/24	AMT-CRS-000772 – ID9369	CUBE 8 C40.50 04.09.24	7 Days	33.43	2375.0	AT002468.7

Date Cast	Certificate Number	Specimen ID	Specimen Age	Strength (MPa)	Density (Kg/m3)	Comments – Reference
04/09/24	AMT-CRS-000771	CUBE 1 C50.60 04.09.24	24 hours	6.51	2348.0	AT002467
04/09/24	AMT-CRS-000771	CUBE 2 C50.60 04.09.24	24 hours	6.37	2354.0	AT002467.1
04/09/24	AMT-CRS-000771	CUBE 3 C50.60 04.09.24	3 Days	19.01	2357.0	AT002467.2
04/09/24	AMT-CRS-000771	CUBE 4 C50.60 04.09.24	3 Days	21.66	2362.0	AT002467.3
04/09/24	AMT-CRS-000771 – id 9377	CUBE 5 C50.60 04.09.24	5 Days	33.98	2427.0	AT002467.4
04/09/24	AMT-CRS-000771 – id 9377	CUBE 6 C50.60 04.09.24	5 Days	34.53	2448.0	AT002467.5
04/09/24	AMT-CRS-000771 – id 9377	CUBE 7 C50.60 04.09.24	7 Days	41.36	2443.0	AT002467.6
04/09/24	AMT-CRS-000771 – id 9377	CUBE 8 C50.60 04.09.24	7 Days	42.07	2459.0	AT002467.7

Capital Concrete Results Compressive Strength (N/mm2)

Table 28 - Capital Concrete Results Compressive Strength

Date Cast	Design Mix Strength	Location of Concrete in Works	7 Day	Density kg/m3	28 Day	Density kg/m3	56 Day Result	Density kg/m3
25/11/24	C40/50	Raft Slab	34.5	2349	57.0	2348	67.1	2358
25/11/24	C40/50	Raft Slab	31.9	2356	55.6	2343	60.5	2353
02/12/24	C40/50	GF Slab	34.8	2365	62.3	2370	65.1	2372
05/12/24	C50/60	GF Columns	47.8	2408	74.6	2447	85.9	2445
12/12/24	C40/50	L1 PT Slab	31.8	2345	58.5	2375	65.0	2395
14/01/25	C40/50	L2 Slab	32.1	2343	53.1	2380	60.2	2382

Harringtons Results C40/50 Compressive Strength (N/mm2)

Table 29 - Harringtons Results C40/50 Compressive Strength

Date Cast	Lab Ref.	Specimen ID	Age Days	Strength (MPa)	Density (Kg/m3)	Comments - Reference
25/11/2024	572893	1A	9	34.3	2400	Cube left outside in ambient conditions
25/11/2024	577328	1B	21	47.1	2430	Cube left outside in ambient conditions
25/11/2024	579814	1C	28	57.7	2410	Cube left outside in ambient conditions
25/11/2024	584632	1D	56	63.3	2380	Cube left outside in ambient conditions
25/11/2024	572186	25.11.A	7	37.4	2370	
25/11/2024	575328	25.11.B	14	45.2	2350	
25/11/2024	580111	25.11.C	28	54.3	2400	
25/11/2024	584633	25.11.D	56	62.5	2340	
25/11/2024	572187	25.11.E	7	37.8	2400	
25/11/2024	575347	25.11.F	14	46.3	2390	
25/11/2024	580112	25.11.G	28	52.1	2480	
25/11/2024	584634	25.11.H	56	61.0	2430	
02/12/2024	574539	2A	7	34.3	2410	
02/12/2024	581456	2B	21	49.6	2330	
02/12/2024	581722	2C	28	54.5	2390	
02/12/2024	586036	2D	56	63.0	2340	
12/12/2024	579099	1A	7	23.7	2360	
12/12/2024	581429	1B	15	37.5	2370	
12/12/2024	582212	1C	28	50.1	2410	
12/12/2024	588431	1D	56	57.2	2340	
12/12/2024	576827	2A	1	3.6	2430	Cube left outside in ambient conditions
12/12/2024	577408	2B	4	11.2	2330	Cube left outside in ambient conditions
12/12/2024	578567	2C	6	18.6	2410	Cube left outside in ambient conditions
12/12/2024	579097	2D	7	20.1	2380	Cube left outside in ambient conditions
14/01/2024	584958	/14.01.A	8	32.5	2380	

14/01/2024	590486	1/14.01.B	28	53.4	2380	
14/01/2024	590485	1/14.01.C	28	55.8	2330	
14/01/2024	600954	/14.01.D	56	60.3	2340	
14/01/2024	584735	14.01.A	7	30.0	2390	
14/01/2024	589803	14.01.B	28	52.0	2360	
14/01/2024	589804	14.01.C	28	50.2	2330	
14/01/2024	600955	14.01.D	56	58.9	2340	

Harringtons Results C50/60 Compressive Strength (N/mm2)

Table 30 - Harringtons Results C50/60 Compressive Strength

Date Cast	Lab Ref.	Specimen ID	Age Days	Strength (MPa)	Density (Kg/m3)	Comments - Reference
05/12/2024	574386	05.12.A	2	29.1	2530	
05/12/2024	574387	05.12.B	3	33.2	2420	
05/12/2024	576079	05.12.C	7	45.6	2530	
05/12/2024	578683	05.12.D	14	50.9	2490	
05/12/2024	581994	05.12.E	28	63.5	2480	
05/12/2024	586527	05.12.F	56	68.8	2410	

9.2 Flexural strength (EN 12390-5)

Mix 1 C40/50

The table below shows the results obtained from flexural tensile strength tests at BRE of beam specimens cast at Capital Concrete, Wembley on 4th September 2024.

Table 31 - Flexural strength Mix 1

Age at Test (days)	Specimen ID	Density (kg/m^3)	Flexural Strength (MPa)
7	A24/068/56	2410	4.7
	A24/068/57	2360	2.8
28	A24/068/58	2340	6.1
	A24/068/59	2340	6.2
90	A24/068/60	2390	8.3
	A24/068/61	2390	6.0

For reference, Table 4 of BSI Flex 350 v1.0 would indicate that a C40/50 concrete at 28 days would be expected to achieve a minimum flexural tensile strength of 5.3 MPa, therefore a tested flexural tensile strength of 6.1 MPa is higher than the Flex requires for an ABS concrete in structural applications.

9.3 Tensile splitting strength (EN 12390-6)

Mix 1 C40/50

The table below shows the results obtained from tensile splitting strength tests at BRE of cylinder specimens cast at Capital Concrete, Wembley on 4th September 2024.

Table 32 - Tensile splitting strength Mix 1

Age at Test (days)	Specimen ID	Density (kg/m^3)	Tensile Splitting Strength (MPa)
7	A24/068/18	2350	2.90
	A24/068/19	2350	3.30
	A24/068/20	2340	3.25
28	A24/068/34	2340	4.85
	A24/068/35	2350	4.75
90	A24/068/36	2350	5.90
	A24/068/37	2340	5.55
180	A24/068/40	2330	4.65
	A24/068/41	2230	5.55

For reference, Table 4 of BSI Flex 350 v1.0 would indicate that a C40/50 concrete at 28 days would be expected to achieve a minimum tensile splitting strength of 3.9 MPa, therefore a tested tensile splitting strength of 4.8 MPa is higher than the Flex requires for an ABS concrete in structural applications.

9.4 Secant modulus of elasticity (EN 12390-13 method B)

Mix 1 C40/50

The table below shows the results obtained from modulus of elasticity tests at BRE of cylinder specimens cast at Capital Concrete, Wembley on 4th September 2024.

Table 33 - Secant modulus of elasticity Mix 1

Age at Test (days)	Specimen ID	Elastic Modulus
7	A24/068/43	38.5
	A24/068/44	35.6
	A24/068/46	37.0
	Average	**37.0**
28	A24/068/42	45.3
	A24/068/47	45.3
	A24/068/48	47.7
	Average	**46.1**
90	A24/068/51	49.3
	A24/068/56	52.7
	Average	**51.0**
180	A24/068/53	41.7
	A24/068/54	44.0
	A24/068/55	52.0

	Average	**45.9**

From the results at 28 days, and Clause 6.8 and Equation 1 of BSI Flex 350 v1.0, the Ecocem ACT concrete is a normal modulus concrete.

9.5 Shrinkage (EN 12390-16)

Mix 1 C40/50

The drying shrinkage test was performed on prismatic concrete specimens to evaluate the long-term volumetric stability of the ACT concrete mix under controlled environmental conditions. The test was conducted in accordance with BS EN 12390-16 at the Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab).

The specimens were moulded with dimensions of 63 × 63 mm and a length of 405 mm, using a concrete mix with a water-to-cement ratio of 0.35 and 1.6% ACT superplasticizer dosage. The samples were taken from the demonstrator project at the Wembley site on 02/12/2025

Prior to the start of testing, samples were stored in a room maintained at 20°C without any plastic covering. Throughout the testing period, which spanned 0 to 180 days, specimens were kept in a laboratory environment with an ambient temperature of 20°C and relative humidity of approximately 65%.

Length changes were monitored using a gauge length of 200 mm, with measurements taken regularly to assess shrinkage behaviour over time. The results of this test are reported in the table below.

Table 34 - Shrinkage Mix 1

Test	Drying Shrinkage
Standard followed	**BS EN 12390-16**
Sample	Prismatic concrete samples (moulded)
Dimensions of sample	63x63mm
Length of sample	405mm
Date of casting	02/12/2024
Casting performed by	John Sisk at Wembley Park
Concrete mix ref	ACT concrete
w/c ratio	0.35
ACT SP dosage (%)	1.6
Test age	0 to 180 days continuous
Storage condition before start of the test	Kept inside the room with temperature maintained at 20°C without any plastic on the samples
Storage condition during testing	Kept inside lab with ambient temperature of 20°C and Relative humidity » 65%
Guage length of measuring instrument	200mm
Test performed at	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by	Umer Jadoon

Table 35 - Test Results Shrinkage Mix 1

Date	Age of sample	Sample 1 avg. value	Sample 2 avg. value	Total average	Cumulative Shrinkage	Shrinkage (µmm/mm)
03/12/2024	1	995.0	895.0	945.0	0.0	0.0
04/12/2024	2	979.0	880.0	929.5	-15.5	-196.9
05/12/2024	3	963.0	870.0	916.5	-28.5	-362.0
06/12/2024	4	957.0	863.0	910.0	-35.0	-444.5
07/12/2024	5	954.0	861.0	907.5	-37.5	-476.3
08/12/2024	6	953.0	860.0	906.5	-38.5	-489.0
09/12/2024	7	950.0	860.0	905.0	-40.0	-508.0
16/12/2024	14	942.0	852.0	897.0	-48.0	-609.6
20/12/2024	18	940.0	850.0	895.0	-50.0	-635.0
04/01/2025	33	931.0	839.0	885.0	-60.0	-762.0
13/01/2025	42	923.0	834.0	878.5	-66.5	-844.6
16/01/2025	45	918.0	830.0	874.0	-71.0	-901.7
21/01/2025	50	920.0	829.0	874.5	-70.5	-895.4
29/01/2025	58	917.0	827.0	872.0	-73.0	-927.1
17/02/2025	77	914.0	830.0	872.0	-73.0	-927.1
24/02/2025	84	914.0	826.0	870.0	-75.0	-952.5
02/03/2025	90	910.0	824.0	867.0	-78.0	-990.6
05/03/2025	93	908.0	824.0	866.0	-79.0	-1003.3
10/03/2025	98	905.0	822.0	863.5	-81.5	-1035.1
19/03/2025	107	900.0	820.0	860.0	-85.0	-1079.5
24/03/2025	112	901.0	820.0	860.5	-84.5	-1073.2
10/04/2025	129	900.0	819.0	859.5	-85.5	-1086
01/05/2025	150	899.0	818.0	858.5	-86.5	-1099
31/05/2025	180	898.0	818.0	858.0	-87.0	-1105

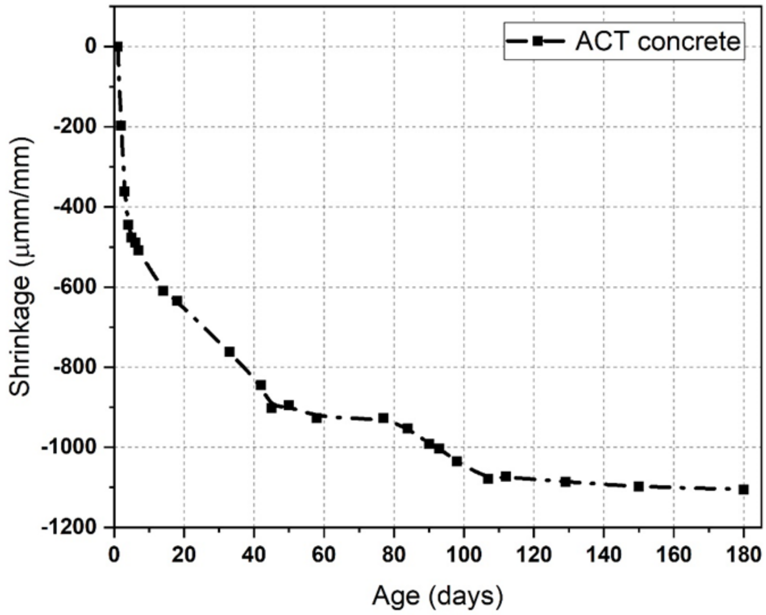

Figure 4 – Shrinkage

The drying shrinkage results indicate that the total shrinkage after 91, and 180 days was -990.6, and -1105 µmm/mm, respectively. According to values reported in the literature, total shrinkage for mixes incorporating CEM I, slag, and limestone typically ranges between 800–1200 µm/m at 180 days, depending on various factors such as mix design, curing conditions, section size and material properties. The shrinkage observed in the ACT sample falls well within this range, demonstrating behaviour comparable to conventional CEM I concrete mixes [1, 2]. It is also worth noting that for high-strength concrete, total shrinkage can reach values as high as 1400 µmm/mm [3].

References:
[1] Itim, A., Ezziane, K. and Kadri, E.H., 2011. Compressive strength and shrinkage of mortar containing various amounts of mineral additions. Construction and Building Materials, 25(8), pp.3603-3609. https://doi.org/10.1016/j.conbuildmat.2011.03.055
[2] Fu, D., Xia, C., Xu, S., Zhang, C. and Jia, X., 2022. Effect of concrete composition on drying shrinkage behavior of ultra-high-performance concrete. Journal of Building Engineering, 62, p.105333. https://doi.org/10.1016/j.jobe.2022.105333
[3] Al-Ameen, E., Blanco, A. and Cavalaro, S., 2023. Durability, permeability, and mechanical performance of sprayed UHPC, as an attribute of fibre content and geometric stability. Construction and Building Materials, 407, p.133393. https://doi.org/10.1016/j.conbuildmat.2023.133393

9.6 Creep (EN 12390-17)

Mix 1 C40/50

The following graph shows the results of compressive creep testing at BRE. The total, basic, and drying creep at the end of one year of loading can be calculated using the following equations from Clause 8.1 of BS EN 12390-17:2019.

$$\varepsilon_{cc}(t,t_0) = \varepsilon_{cc}(t) - [\varepsilon_{cs}(t,t_0) + \varepsilon_{cc}(t_0)]$$

Where:
$\varepsilon_{cc}(t)$ is the mean strain of the unsealed specimens under load at time (*t*) = 867 x 10^{-6}
$\varepsilon_{cs}(t, t_0)$ is the mean strain of unsealed shrinkage specimens at time (*t*) = 39 x 10^{-6}
$\varepsilon_{cc}(t_0)$ is the mean initial strain of the loaded unsealed specimens = 420 x 10^{-6}

Therefore, the total creep at time (*t*) $\varepsilon_{cc}(t, t_0)$ = 407 x 10^{-6}

$$\varepsilon_{bc}(t, t_0) = \varepsilon_{bc}(t) - [\varepsilon_{ca}(t, t_0) + \varepsilon_{bc}(t_0)]$$

Where:
$\varepsilon_{bc}(t)$ is the mean strain of the sealed specimens under load at time (*t*) = 609 x 10^{-6}
$\varepsilon_{ca}(t, t_0)$ is the mean strain of sealed shrinkage specimens at time (*t*) = -54 x 10^{-6}
$\varepsilon_{bc}(t_0)$ is the mean initial strain of the loaded sealed specimens = 385 x 10^{-6}

Therefore, the basic creep at time (*t*) $\varepsilon_{bc}(t, t_0)$ = 278 x 10^{-6}

$$\varepsilon_{dc}(t, t_0) = \varepsilon_{cc}(t, t_0) - \varepsilon_{bc}(t, t_0)$$

Where:
$\varepsilon_{cc}(t, t_0)$ is the total creep at time (*t*) = 407 x 10^{-6}
$\varepsilon_{bc}(t, t_0)$ is the basic creep at time (*t*) = 278 x 10^{-6}

Therefore, the drying creep at time (*t*) $\varepsilon_{dc}(t, t_0)$ = 129 x 10^{-6}

The total creep coefficient at the end of one year of loading can be calculated using the following equation from Clause 8.2 of BS EN 12390-17:2019.

$$\varepsilon_{cc}(t, t_0) = \left[\frac{\sigma_c(t_0)}{E_c}\right] \varphi(t, t_0)$$

Where:
$\varepsilon_{cc}(t, t_0)$ is the total creep at time (*t*) = 407 x 10^{-6}
$\sigma_c(t_0)$ is the stress applied during testing = 15.1 MPa
E_c is the tangent modulus of elasticity = 48.4 GPa

Therefore, the total creep coefficient from this test regime is $\varphi(t, t_0)$ = 1.30

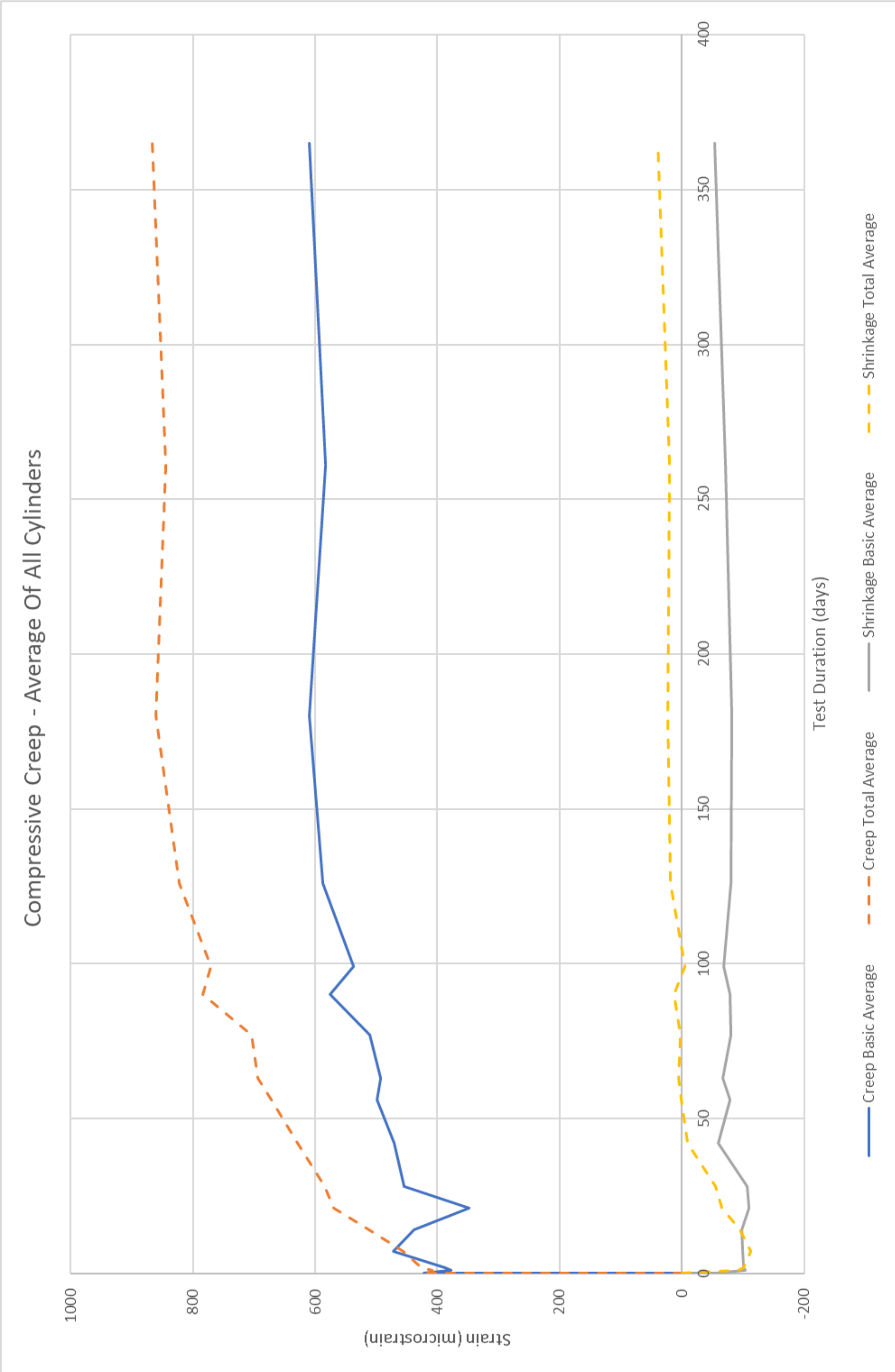

Figure 5 - Creep

9.7 Coefficient of thermal expansion (BS EN 1770 / AASHTO T336-11 [N3])

Mix 1 C40/50

The thermal expansion test was conducted on prismatic mortar samples to assess the dimensional response of the ACT concrete mix under controlled temperature variations. The test was performed in accordance with BS EN 1770:1998 at the Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab).

Moulded mortar samples with dimensions of 25 × 25 mm and a length of 300 mm were used. The concrete mix had a water-to-binder ratio of 0.35, a sand-to-binder ratio of 3.0, and included 1.6% ACT superplasticizer dosage (by binder weight).

Prior to testing, specimens were preconditioned for 7 days at 20°C with a relative humidity of approximately 65%. The thermal expansion behaviour was assessed over a temperature range from –20°C to 60°C.

Length changes were measured using a John Bull Demec strain gauge with a gauge length of 200 mm. K-type thermocouples were used to monitor temperature, and environmental conditions were controlled using a TAS environmental test chamber. The results of this test are reported in the table below.

Table 36 - Coefficient of thermal expansion

Test	Thermal Expansion Test
Standard followed	**BS EN 1770-1998**
Sample	Prismatic mortar samples (moulded)
Dimensions of sample	25x25mm
Length of sample	300mm
Casting performed by	Umer Jadoon
Concrete mix ref	ACT concrete
w/b and s/b ratio	0.35 and 3.0
ACT SP dosage (% bcw of binder)	1.6
Temperature range used for test	-20oC to 60oC
Preconditioning	7 days at 20oC and Relative humidity » 65%
Guage length of measuring instrument	200mm
Instrument used to measure changes in length	John Bull Demec Strain Guage
Type of thermocouple used	
Type of Environmental chamber used	
Test performed at	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by	Umer Jadoon

Table 37 - Test Results Coefficient of thermal expansion

Temperature	ACT sample 1 Demec reading (S1)	ACT sample 2 Demec reading (S2)	Average S1, S2	Average shrinkage/Expansion ΔL (inches)	(ΔL/L) *L = 200mm/7.87in*	α ((ΔL/L)/ΔT) (/°C)
18	686	867	776.5	0	0.00000	**11.2 x 10^{-6}**
23	687	873	780.0	0.00035	0.00004	
40	701	886	793.5	0.00170	0.00022	
60	719	904	811.5	0.00350	0.00044	
0	665	852	758.5	-0.00180	-0.00023	
-10	659	845	752.0	-0.00245	-0.00031	
-20	647	835	741.0	-0.00355	-0.00045	

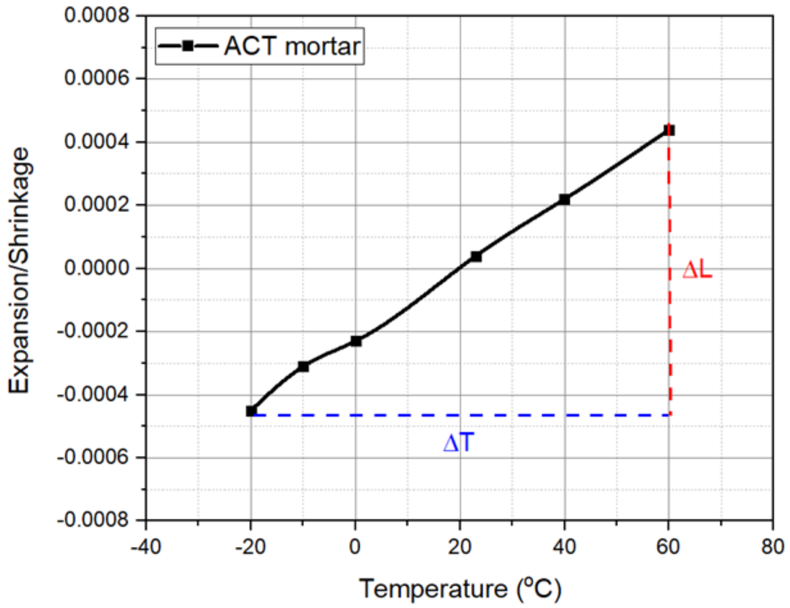

Figure 6 - Coefficient of thermal expansion

The thermal expansion test revealed that the ACT mortar samples exhibited a coefficient of thermal expansion of 11.2 × 10⁻6 /°C. The test was conducted using prismatic specimens placed in an environmental chamber set to various temperature levels. Thermocouples were embedded within the samples to enable continuous temperature monitoring. Measurements were recorded only after the sample temperature had stabilized, typically after at least one hour, and matched the chamber temperature. According to Flex 350, when the influence of thermal expansion is considered minor or moderate, a default coefficient of 10 × 10⁻6 /°C is recommended (Section 6.5).

9.8 Heat of reaction (EN 12390-14)

Mix 1 C40/50

This test was conducted on concrete samples to evaluate the heat of hydration over the early age period (0 to 72 hours). The test was carried out in a modified form of BS EN 12390-14 at the Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab).

Concrete samples were cast in 100 mm cubes, each surrounded by 50 mm insulation on all sides to monitor internal temperature rise due to cement hydration. The concrete used in this test, referred to as ACT concrete, had a water-to-cement ratio of 0.35 and included 1.6% ACT superplasticizer dosage.

The casting was performed at Loughborough University Lab on 19/09/2024. A total of three samples were prepared and tested continuously from 0 to 72 hours.

The binder and superplasticizer were supplied by ECOCEM, while aggregates were provided by Capital Concrete. Laboratory water from Loughborough University was used in the mix preparation. The results of this test are reported in the graphic below.

Table 38 - Heat of reaction Mix 1

Test	Heat of hydration test
Standard followed	**BS EN 12390-14 (in modified form)**
Sample	100mm^3 cube
Diameter of sample	100 mm
Length of sample	100 mm
Thickness of Insulation	50mm on all sides (see Figure 7)
Date of casting	19/09/2024
Casting performed by	Umer Jadoon
Concrete mix ref	ACT concrete
w/c ratio	0.35
ACT SP dosage (%)	1.6
Curing temperature	-
Test age	0 to 72 hours continuous
No. of samples used	3
Materials submitted by	Binder and Superplasticizer by ECOCEM Aggregates by Capital Concrete Water used from Loughborough University Laboratory
Test performed at	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by	Umer Jadoon

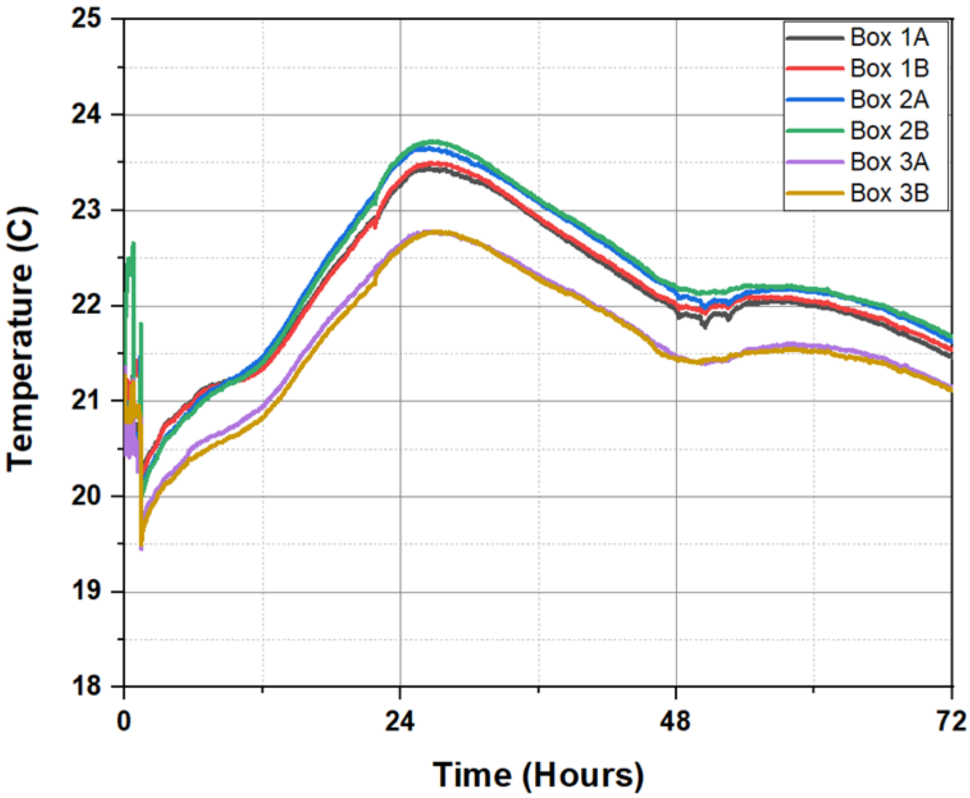

Figure 7 - Heat of reaction

The heat of hydration results indicated a very small temperature rise, with the maximum internal temperature of the insulated samples reaching only 23.7 °C, compared to an ambient temperature of approximately 20 °C throughout the experiment. This slight increase suggests that the ACT concrete exhibits low heat generation during hydration, and lower than typical equivalent CEM I mixes. As a result, it is unlikely to be vulnerable to thermal cracking caused by excessive internal temperature development which is a common concern in mass concrete applications.

Complementary testing to *EN 196-9 Methods of testing cement – Part 9: Heat of Hydration – Semi-adiabatic method* was carried out to assess the low heat characteristics of ACT cement according to BS EN 197-1:2011 Cement. For this method the assessment of joules/gram (J/g) is measured at 41 hours for a requirement of < 270 J/g.

Table 38 - Test results Heat of Hydration

Time	Temperature (°C)	Heat of Hydration (J/g)
12h	6.4	50
24h	10.0	98
41h	**8.9**	**130**
72h	5.5	160
120h	2.4	181
168h	1.4	195

ACT is classified as Low Heat (LH) as the heat of hydration at 41H was 130 J/g compared to the requirement of < 270 J/g.

ACT is also classified as a Very Low Heat according to BSI Flex 350, Table 1 Note A as the heat of hydration at 41H was 130 J/g compared to the requirement of < 220 J/g. This means that ACT could be classified as a Strength class 22.5 according to BS EN 197-1-1:2011.

Both test methods confirm that ACT has a very low heat profile and could offer excellent engineering benefits for large volume pours.

9.9 Maturity testing/early strength

Embedded maturity sensors from Converge were placed in elements throughout pouring. A "hot box", $1m^3$ of concrete placed in an insulated form that was poured during a ready-mix plant trial to calibrate the maturity function utilised as this was the first use of ACT concrete with Converge sensors.

Photo 1 - Hot box for maturity sensors

Sensors were tied to rebar and embedded in the raft foundation; the 1,400mm wall section and square column pours on the ground floor. Temperature and time were logged by the sensors and the Converge maturity system. The predicted the early age strength of concrete was then given based on the equivalent age principle taking temperature and time history and the information collected during the calibration pour.

The Converge sensors on the wall and column pours gave an equivalent age of about 3 MPa at 18 hours. No mechanical damage was observed after striking. The minimum recommended strength before formwork should be struck to withstand the mechanical forces of striking is 2 MPa. This verified the practice on site for striking time between 16- 18 hours in vertical applications.

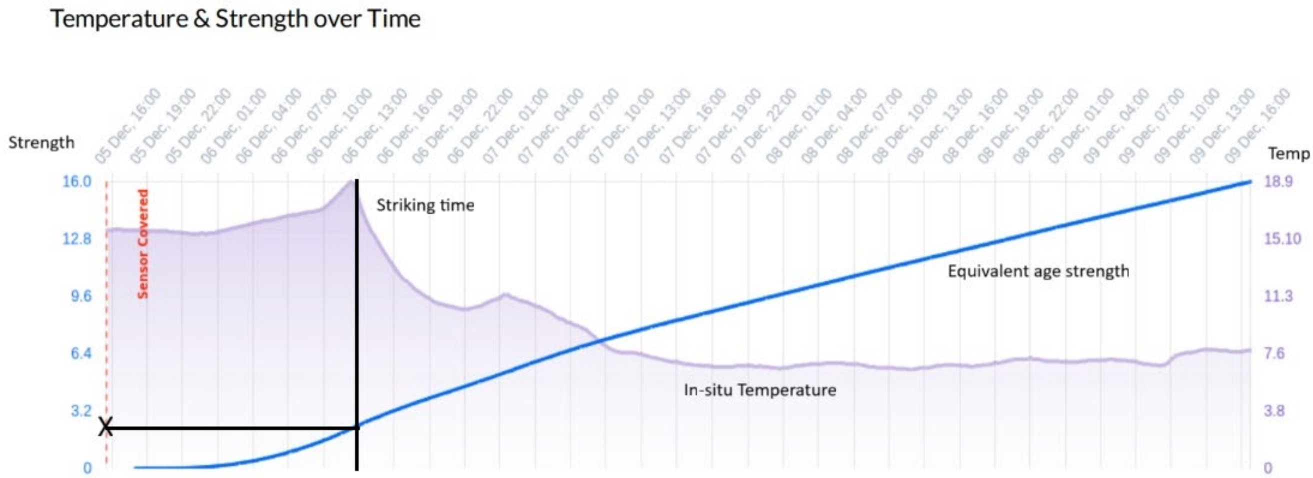

Figure 8- Converge sensor reading and strength prediction from wall pour

The raft foundation slab sensors pour predicted equivalent age strengths of ~15 MPa at 5 days. Standard cured cubes at 20°C measured over 30 MPa at 7 days but these can't be taken as an estimate of early age strength as their curing regime is different to the slab. Optimal post-tensioning scheduling requires accurate determination of in-situ strength so that sufficient strength is in the concrete slab to withstand the stresses to from post tensioning without issue. The Converge sensors predicted that 5 days curing was required before sufficient strength was in the slab for initial tensioning based on a 15 MPa requirement.

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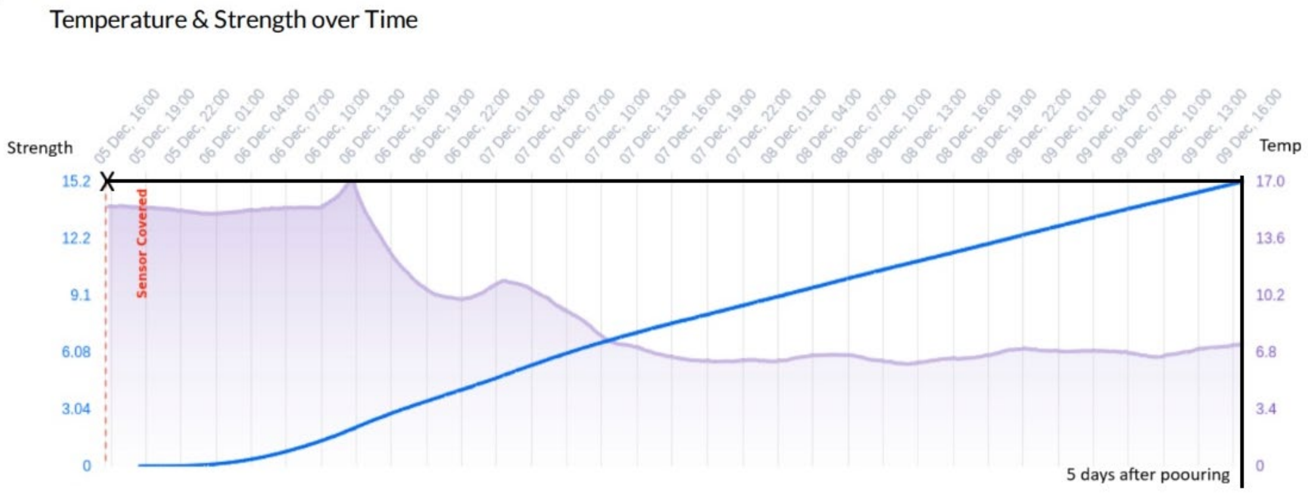

Figure 9 - Converge sensor reading and strength prediction from raft foundation pour.

This information was used to schedule the post tensioning on the second floor pour. In-situ temperatures never exceeded 20°C on any of the pours due to the low heat properties of ACT and also the low ambient temperatures on site over casting in November, December and January. This initial first use of Converge maturity sensors with ACT and it has been found to be useful and has provided relevant information for striking times and scheduling construction sequences. Only a limited number of sensors were used in this study, and further experiments and experience would be useful to further determine their accuracy with ACT concrete.

9.10 Large Scale Flexural Testing

Three reinforced ACT slabs were produced and sent to BRE for four-point bend testing. The slabs were 2.6 m long, 1 m wide and 150 mm deep, whilst the reinforcement was an A25 mesh with 50 mm of cover to the bottom face. The specimens were supported on rocker bearings 350 mm from each end and the load was applied vertically as two line loads 300 mm either side of the centre (600 mm from each support location). The three specimens achieved similar maximum loads before first load loss (36.8 kN, 33.1 kN, and 30.5 kN) which is usually the point at which the concrete on the underside first cracks in tension. They also achieved similar total maximum loads (70.9 kN, 66.2 kN, and 67.9 kN) which is the point at which the steel reinforcement is yielding (which can be seen on the load deflection diagrams). The specimens showed good repeatability of their results between the three tests, and all reached ductile failure of the steel as the ultimate failure method.

10.0 Assessment of test results – Durability properties

10.1 Carbonation – accelerated CO2 conditions (EN 12390-12)

Mix 1 C40/50

Specimens for accelerated carbonation testing were cast at BRE with concrete supplied by Capital Concrete in June 2025. The ACT concrete specimens, mix 1 C40/50 had achieved an average measurement of 8.0 mm of carbonation depth, equating to an average rate of accelerated carbonation of 1.01mm/√day. These values can be used in modelling to predict the service life of ACT in XC exposure environment. A reference concrete was cast at the same time and specimens showed no carbonation by 70 days in the accelerated carbonation chamber. This finding is reasoned to be as the reference mix, a CIIIA with 50% GGBS also had a low w/c ratio of 0.34. The finding is somewhat surprising as “conventional” concretes like CIIIA usually exhibit higher carbonation rates. Refer to photo 2.

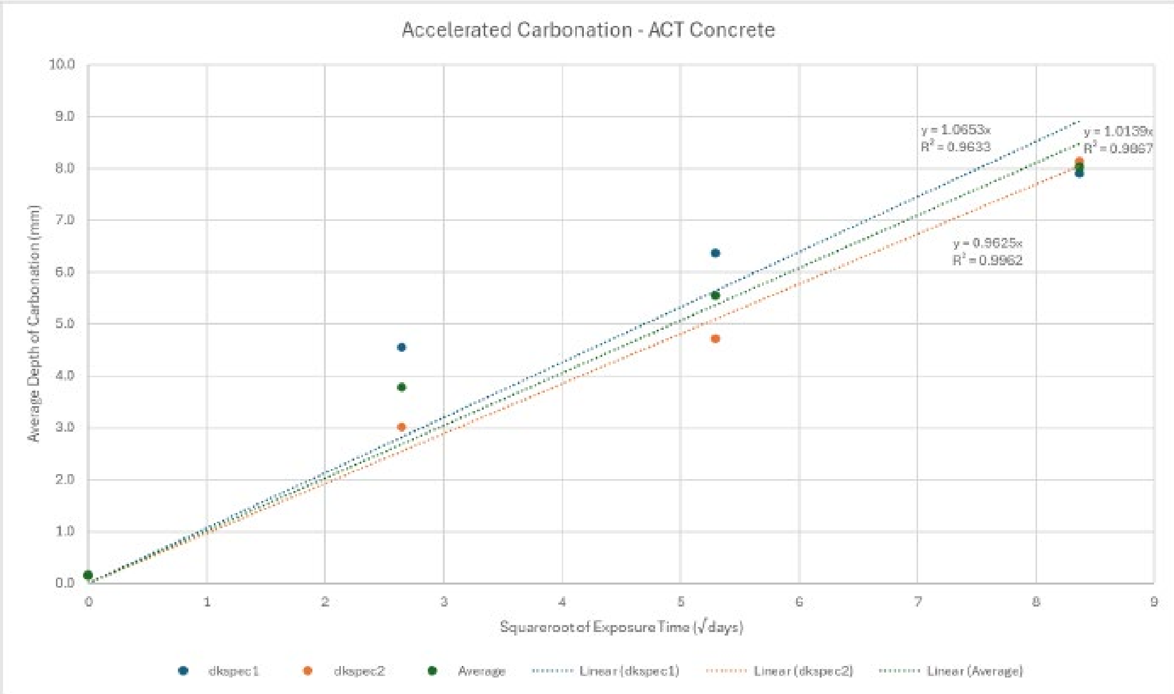

Figure 10 - Accelerated Carbonation

Photo 2 - Accelerated carbonation 70 days

10.2 Chloride migration (EN 12390-18 / Nordtest NT Build 492) – Mix 1 C40/50

Rapid Chloride Penetration Test (RCPT) was conducted to evaluate the resistance of the ACT concrete mix to chloride ion migration. The test was performed in accordance with NT Build 492 at the Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab).

The samples were cylindrical concrete specimens with an original diameter of 100 mm and length of 200 mm, collected from the demonstrator project at the Wembley site on 19/9/2024. The concrete mix used had a water-to-cement ratio of 0.35 and included 1.6% ACT superplasticizer dosage.

Following collection, the specimens were water cured at 20°C. Prior to testing, each cylinder was sawn into three discs measuring 50 mm in height and 100 mm in diameter using a Norton Clipper saw with wet grinding to ensure clean, precise cuts.

The test was performed at both 28 and 91 days, using standard reagents including calcium hydroxide ($Ca(OH)_2$), sodium chloride (NaCl), silver nitrate ($AgNO_3$), and sodium hydroxide (NaOH). The results of this test are reported in the table below.

Table 39 - Chloride migration at 28 days

Test	Rapid chloride penetration test
Standard followed	**NT Build 492**
Sample	Cylinders
Diameter of sample	100 mm
Length of sample	50 mm
Date of casting	19/09/2024
Casting performed by	Umer Jadoon
Concrete mix ref	ACT concrete C40/50
w/c ratio	0.35
ACT SP dosage (%)	1.6
Curing condition of samples	Water saturated
Curing temperature	20C
Test age	28 days
Reagents used	$Ca(OH)_2$, NaCl, $AgNO_3$, NaOH
Samples submitted by	John Sisk and Sons Ltd and ECOCEM
Test performed at	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by	Umer Jadoon

Table 40 - Test Results Chloride migration at 28 days

Mix reference	Penetration Depth (mm)								Mean X_d (mm)	SD (mm)	CoV (%)	D_{nssm} (x 10^{-12} m^2/s)
	X_{d1}	X_{d2}	X_{d3}	X_{d4}	X_{d5}	X_{d6}	X_{d7}	X_{d8}				
A1 – sample 1	11.1	11.9	10.5	10.7	13.4	10.2	10.2	10.3	**11.0**	1.01	9.43	4.54
A1 – sample 2	9.6	8.7	8.9	8.3	10.8	11.2	8.4	9.5	**9.43**	1.04	10.7	3.81

A2 – sample 1	17.1	15.5	14.3	14.5	15.7	15.3	13.3	12.7	**14.8**	1.32	8.89	6.23
A2 – sample 2	10.2	8.2	7.7	8.3	10.7	9.2	8.3	7.6	**8.78**	1.07	12.2	3.51
A3 – sample 1	9.2	8.5	8.6	7.2	10.6	9.6	8.1	7.5	**8.66**	1.05	12.1	3.47
A3 – sample 2	9.3	8.0	6.2	6.1	6.3	6.2	8.6	9.4	**7.52**	1.38	18.4	2.96
Average									**10.0**	**1.15**	**12.0**	**4.08**

Table 41 - Chloride migration at 91 days

Test	Rapid chloride penetration test
Standard followed	NT Build 492
Sample	Cylinders
Diameter of sample	100 mm
Length of sample	50 mm
Date of casting	19/09/2024
Casting performed by	Umer Jadoon
Concrete mix ref	ACT concrete C40/50
w/c ratio	0.35
ACT SP dosage (%)	1.6
Curing condition of samples	Water saturated
Curing temperature	20C
Test age	91 days
Reagents used	$Ca(OH)_2$, NaCl, $AgNO_3$, NaOH
Samples submitted by	John Sisk and Sons Ltd and ECOCEM
Test performed at	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by	Umer Jadoon

Table 42 - Chloride migration at 91 days

Mix reference	Penetration Depth (mm)								Mean x_d (mm)	SD (mm)	CoV (%)	D_{nssm} (x 10^{-12} m^2/s)
	x_{d1}	x_{d2}	x_{d3}	x_{d4}	x_{d5}	x_{d6}	x_{d7}	x_{d8}				
A1 – sample 1	7.0	7.2	10.5	11.3	10.2	9.9	10.2	8.0	**9.3**	1.54	16.5	3.71
A1 – sample 2	6.4	6.0	9.1	9.3	7.7	5.9	7.0	6.1	**7.24**	1.29	17.9	2.79
A2 – sample 1	8.3	9.1	7.8	9.9	9.4	9.2	10.9	9.2	**9.23**	0.88	9.54	3.67
A2 – sample 2	10.5	10.0	9.2	9.2	12.1	8.2	7.6	8.0	**9.35**	1.39	14.9	3.72
A3 – sample 1	8.9	11.8	12.4	12.7	9.4	8.6	10.5	10.2	**10.5**	1.48	14.0	4.27
A3 – sample 2	11.3	10.9	9.7	10.3	7.3	7.3	7.8	8.5	**9.14**	1.52	16.6	3.64
Average									**9.12**	**1.35**	**14.9**	**3.63**

The test results show that the non-steady-state migration coefficient (D_{nssm}) was 4.08 × 10^{-12} m^2/s at 28 days and 3.63 × 10^{-12} m^2/s at 91 days. The observed decrease in D_{nssm} over time is expected and indicates ongoing hydration, likely driven by the presence of supplementary cementitious materials (SCMs) in the ACT binder. At both testing ages, the migration coefficients fall within the category of "Very high" chloride penetration resistance, based on classifications commonly cited in the literature [1,2].

References:
[1] Pontes, J., Real, S. and Bogas, J.A., 2023. The rapid chloride migration test as a method to determine the chloride penetration resistance of concrete in marine environment. Construction and Building Materials, 404, p.133281.
https://doi.org/10.1016/j.conbuildmat.2023.133281
[2] Pontes, J., Bogas, J.A., Real, S. and Silva, A., 2021. The rapid chloride migration test in assessing the chloride penetration resistance of normal and lightweight concrete. Applied Sciences, 11(16), p.7251. https://doi.org/10.3390/app11167251

10.3 Freeze-thaw resistance without de-icing agents (PD CEN/TS 12390-9)

Mix 1 C40/50

The table below shows the results obtained from freeze-thaw scaling test with deionized water at BRE of cube specimens cast at Capital Concrete, Wembley on 4th September 2024.

Table 43 - Freeze-thaw resistance without de-icing agents

Specimen Number	S_7 kg/m^2	S_{14} kg/m^2	S_{28} kg/m^2	S_{42} kg/m^2	S_{56} kg/m^2
A24/068/10	0	0.0176	0.0252	0.0329	0.0960
A24/068/14	0	0.0036	0.0062	0.0147	0.0290
A24/068/16	0	0.0229	0.0288	0.0367	0.0452
A24/068/19	0	0.0175	0.0242	0.0423	0.0472
Mean	0	0.015	0.021	0.032	0.054

For reference, Clause 7.4 of BSI Flex 350 v1.0 does not cover PD CEN/TS 12390-9 testing without de-icing salts, however it notes that if a concrete was designed to resist de-icing salts and was tested in this way with a salt solution, a cumulative loss of scaled material at 28 days, S_{28}, should be below 1 kg/m^2, which is approximately 50 times the amount of scaled material from this test.

10.4 Freeze-thaw resistance with de-icing salts (PD CEN/TS 12390-9)

Mix 1 C40/50

The table below shows the results obtained from freeze-thaw scaling test with a 3% salt solution at BRE of cube specimens cast at Capital Concrete, Wembley on 4th September 2024. It should be noted that the Ecocem ACT concrete was not designed to resist freeze-thaw with de-icing salts.

Table 44 - Freeze-thaw resistance with de-icing salts

Specimen Number	S_7 kg/m²	S_{14} kg/m²	S_{28} kg/m²	S_{42} kg/m²	S_{56} kg/m²
A24/068/11	0	0.7467	1.4428	3.9937	6.6736
A24/068/13	0	0.8381	1.4810	3.3202	6.1464
A24/068/17a	0	0.7519	1.4314	3.3541	5.5715
A24/068/17b	0	0.7370	1.5155	4.1889	7.9980
Mean	0	0.768	1.468	3.714	6.597

For reference, Clause 7.4 of BSI Flex 350 v1.0 states that for a concrete designed to resist de-icing salt, a cumulative loss of scaled material at 28 days, S_{28}, should be below 1 kg/m^2, which this test has not achieved.

10.5 Sulfate resistance (BSI Flex 350 Class 2/Class 5 sulfate immersion)

Mix 1 C40/50

The table below shows the wear rating results of a sulfate resistance test where cubes were placed into Class 2 and Class 5 solutions which are refreshed every three months.

Table 45 - Sulfate resistance Mix 1

Days in Solution	Wear Ratings (mm)	
	Class 2	Class 5
0	0	0
91	0	0
182	1	0
365	1	-1

BSI Flex 350 v1 states to compare these results to a DC-4 concrete (see Table D2 of BRE Special Digest 1 for more details). Results of previous Class 5 sulfate resistance testing at BRE of concretes of DC-4 compliant concretes are shown in the table below.

Table 46 - Wear ratings Class 5

Days in Solution	Wear Ratings (mm)
	Class 5
0	0
91	0
182	1
365	3

The one results for the Ecocem ACT concrete show performance comparable with the results of previous DC-4 concrete testing.

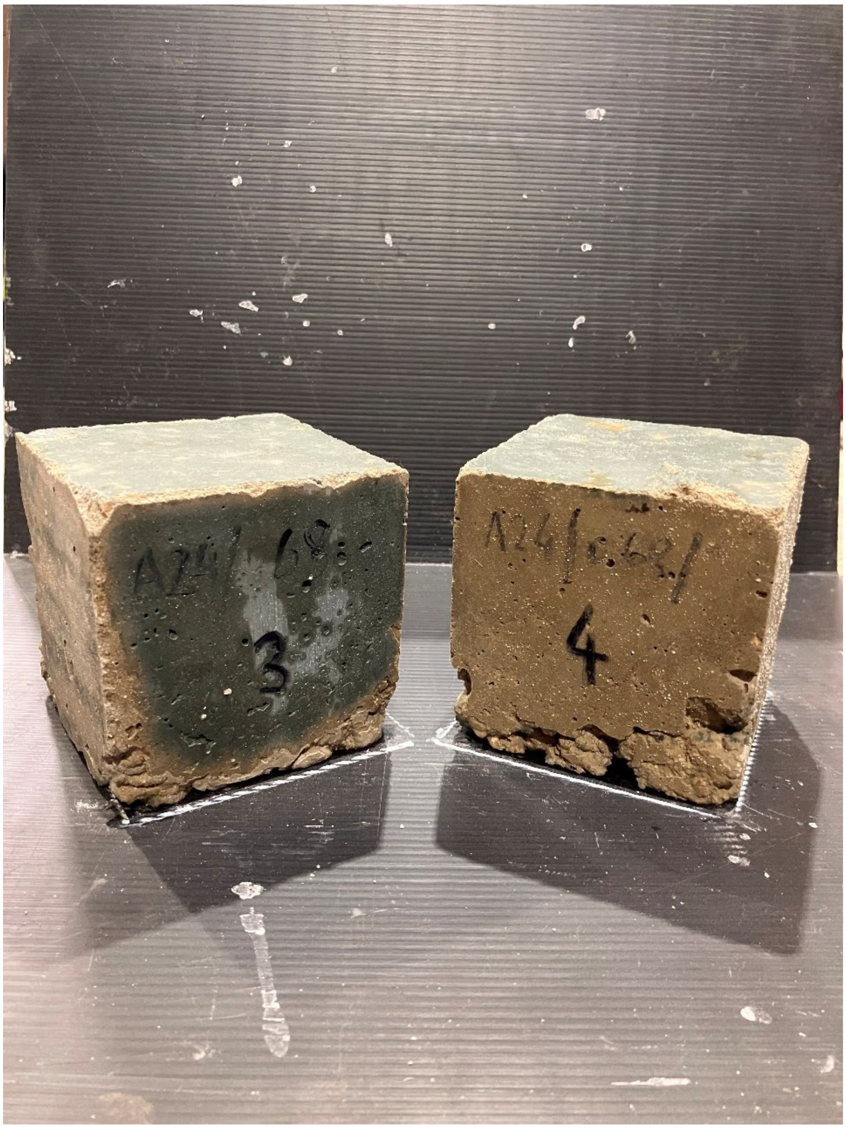

Photo 3 - Sulfate Class 2 - 0 day

Photo 4 - Sulfate Class 2 - 1 year

Photo 5 - Sulfate Class 5 - 0 day

Photo 6 - Sulfate Class 5 - 1 year

10.6 Acid resistance (BSI Flex 350 pH2.5 immersion) –

Mix 1 C40/50

The table below shows the mass change results of an acid resistance test where two cubes were placed into a citric acid solution which is refreshed every three months.

Table 47 - Acid Resistance Mix 1

Days in Solution	Mass Change (%) Citric Acid
0	0
91	4.6
182	5.0
365	4.9

BSI Flex 350 v1 states to compare these results to a DC-4z concrete (maximum w/c ratio of 0.45, minimum cement content of 360 kg/m^3 for a maximum 20 mm aggregate, using any cement combination listed in Table D2 of SD1). Previous acid resistance testing at BRE of concretes of w/c ratio of 0.45 and slightly lower cement content of 350 kg/m^3 showed mass changes as per the table below.

Table 48 - Mass Change

Days in Solution	Mass Change (%)		
	CEM I	CEM II/B-V	CEM III/A
0	0	0	0
91	4.4	4.3	2.7
182	12.4	13.1	9.8
365	26.6	32.7	25.7

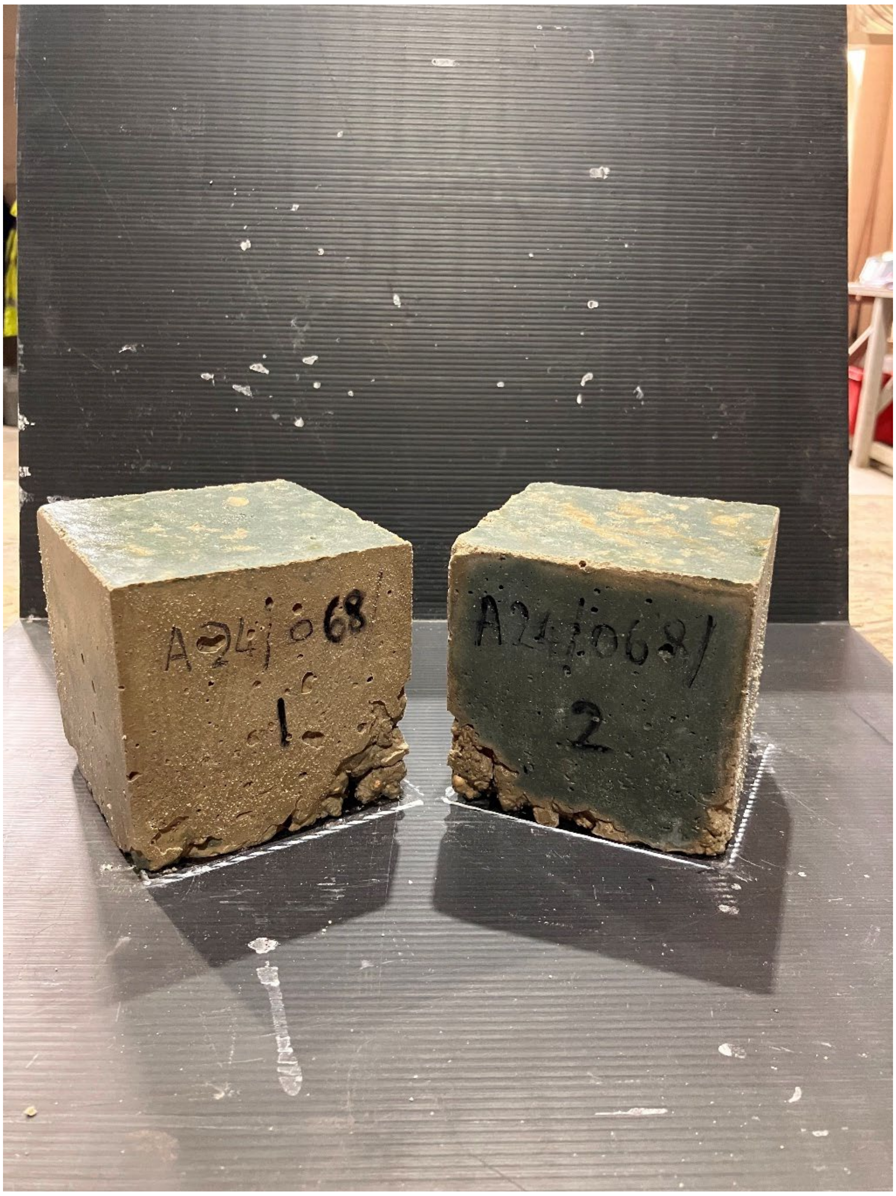

Photo 7 - Acid Test 0 day

Photo 8 - Acid Test 1 year

10.7 Fire resistance (BS 476)

Mix 1 C40/50

Specimens for fire resistance testing to an agreed specification broadly following the EFNARC guidelines noted in BSI Flex 350 v1.0 were cast at BRE with concrete supplied by Capital Concrete in June 2025. The test specification can be found in Appendix P. The test plan was to apply the fire curve for 2 hours. The heat measured tracked the target curve very closely. Around 20 minutes during testing of the reference concrete specimen, excessive spalling occurred that risked damaging the test furnace, so the decision was taken to stop the test just after the half hour mark.

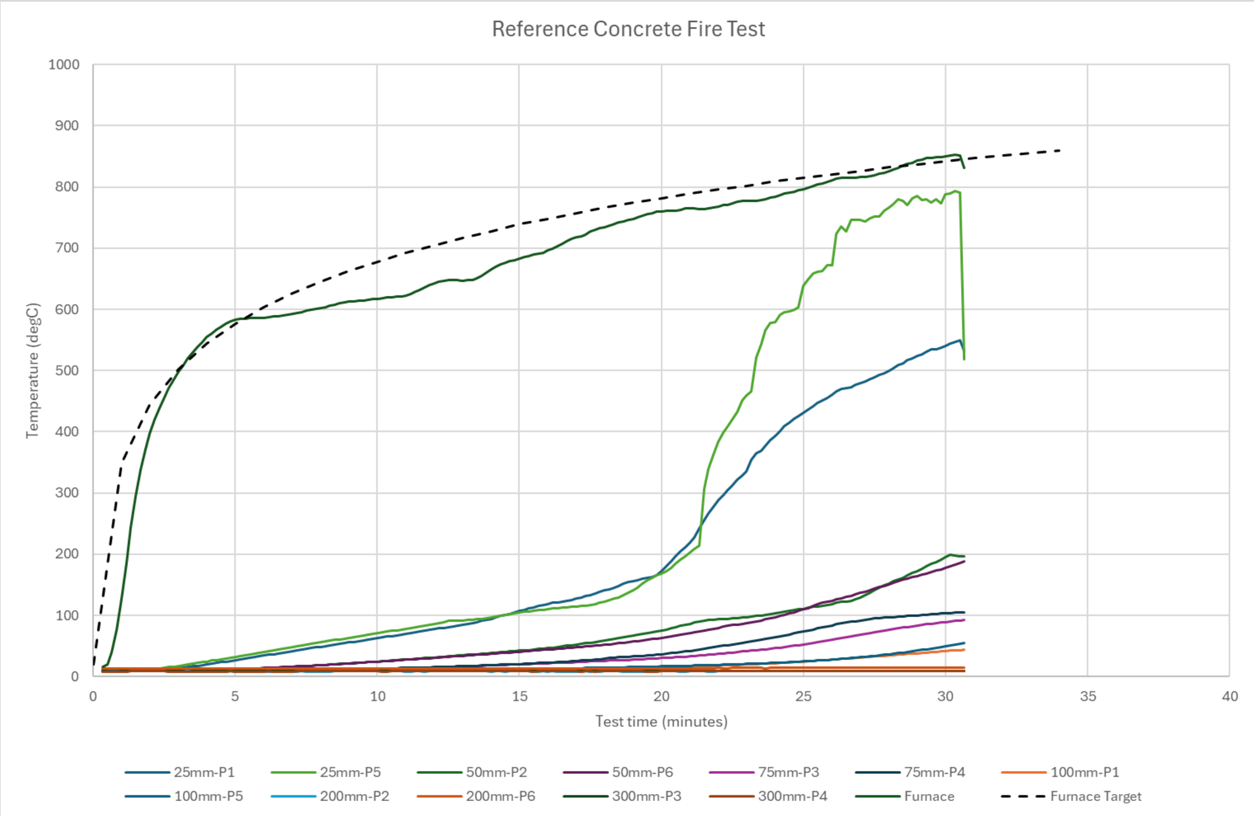

Figure 11 - Fire test Reference Concrete

Observations from the reference test are that spalling occurred very early in the test regime. The closest thermocouple to surface (25mm) spiked in temperature which was followed by the thermocouple at 50mm indicating spalling and heat transfer into the test specimen.

The ACT concrete specimen was then tested and also stopped at 30 minutes as spalling was occurring, although not to the extent noted in the first test. The applied heat exceeded the target temperature curve at early agers but then tracked the curve well. This means excessive heat was applied to this specimen. The graphs below show the temperatures recorded by the embedded thermocouples. The graph notation shows the thermocouple depth from the test face, followed by the position from the test specification (Appendix P). The effect of the spalling can be seen as previous, as the thermocouples closest to the test surface rise after approximately 18 minutes to approach the furnace temperature. However, the temperature does not spike, and the temperature of the next closest thermocouple is rising but at a lower temperature than the same thermocouple in the reference specimen. This indicates that there is less heat transfer occurring, which indicates that there is less spalling. This is evident from the post testing photos.

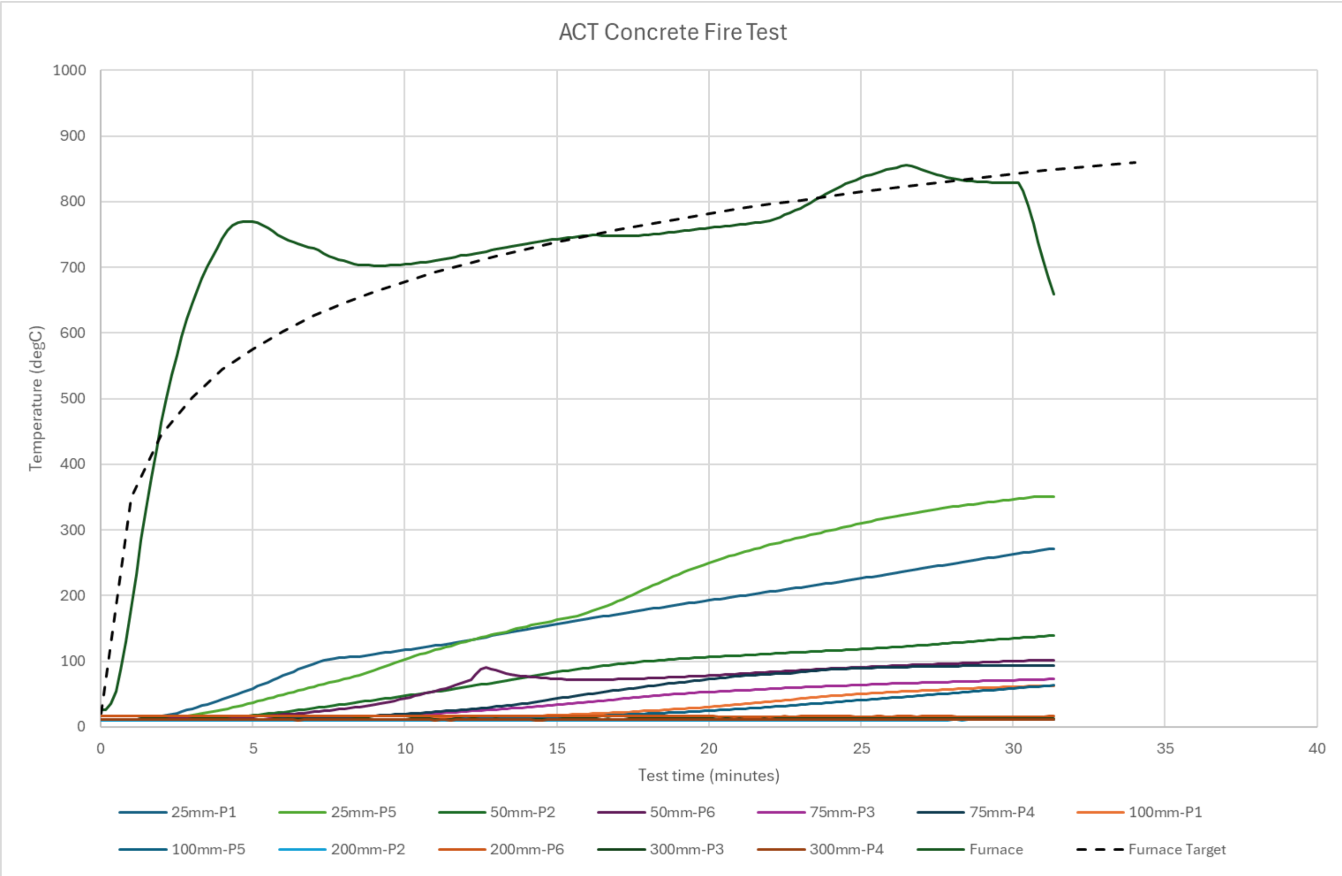

Figure 12 - Fire test ACT Concrete

Photo 9 - Fire Test Conventional

Photo 10 - Fire Test ACT

The companion cubes cast with the fire test specimens showed 28-day compressive cube strengths of 52.4 MPa and 73.0 MPa for the ACT and reference concretes respectively; and day of test (112 day) compressive cube strengths of 62.2 MPa and 80.1 MPa for the ACT and reference concretes respectively. The pre-test cores that were prepared for 1:1 height to diameter ratio cylinder compressive strength testing showed day of test strengths (112 day) of 44.6 MPa and 67.8 MPa for the ACT and reference concretes respectively. The pre-test cores that had their moisture content measured by oven drying showed moisture contents of 4.9 % and 4.4 % as a percentage of the wet weight for the ACT and reference concretes respectively.

The residual strength testing of cores post-test shows that the ACT specimens are performing better than the reference concrete. Full compressive strength profile of the post-test cores can be found in the fire test report. It was noted during coring that the reference concrete was difficult to obtain 60 mm cores from as the concrete had degraded to the point where it would disintegrate during coring.

Both specimens exhibited early age spalling with the ACT specimen performing better than the reference but the two hours of exposure was not achievable. This brings the test protocol into question as the reference concrete should not fail at such an early stage. The curing regime in the method could be altered to further reduce the moisture content of the test specimens. The moisture content was measured 4.5-49.9% and this is considered to be a factor to cause the early age spalling. A threshold value for moisture content could be provided in the test protocol. To achieve this a longer period of curing at RH 50% than the one-month post 3 month curing in humid conditions could be used. Alternatively, an elevated curing regime for the last month, perhaps at 40°C rather than 20°C could be considered.

10.8 Material Characterisation

X-ray diffraction (XRD) and scanning electron microscopy (SEM) was used to characterise and compare the microstructural features of ACT to CEM I. This work was carried out by Loughborough University at the Materials and Characterisation Centre (LMMC). The full report can be found in Appendix O. In CEM I pastes, strength development is primarily attributed to the formation of calcium silicate hydrate (C-S-H). In contrast, the ACT samples show a more complex mechanism, where the reduction in porosity and strength gain result from: (1) the filler effect of finely divided limestone (LS), which occupies voids between CEM I and GGBS grains; (2) the hydration products of CEM I and GGBS; and (3) the partial reaction of LS, which forms additional phases within the pore spaces. XRD analysis confirms the formation of carboaluminates due to LS reactivity. Furthermore, ACT samples exhibit higher ettringite peak intensities compared to CEM I, contributing to enhanced particle binding and strength development.

10.9 XRD Findings

Higher levels of Ettringite (AFt) were identified in the ACT samples after 1 day compared to the CEM I samples as shown in Figure 13. This can have a positive effect on early ager strength development and shrinkage reduction as formation of ettringite is expansive.

Further findings show the presence of carboaluminates in the form of Calcium hemicarboaluminates (Hc) and Calcium monocarboaluminates (Mc) in ACT samples. These are not visible after 1 day of hydration as shown in Figure 13. However, their peaks become more prominent at 7 days and later. By 28 days, a well-defined Hc peak appears, indicating limestone hydration. This suggests that limestone initially acts primarily as a filler and does not participate significantly in early hydration. After 28 days, it shows signs of hydration through the formation of carboaluminate phases. Additionally, the hydrotalcite peak (Ht), a product of GGBS hydration, becomes evident at 28 days, indicating slag particle hydration at later ages.

Acting as a filler, LS enhances the packing density of the system, thereby increasing the amount of free water available for the hydration of CEM I and GGBS. This increase in effective water facilitates early hydration reactions, particularly of CEM I, resulting in a more rapid formation of AFt phases and consequently higher AFt content compared to the CEM I-only mix.

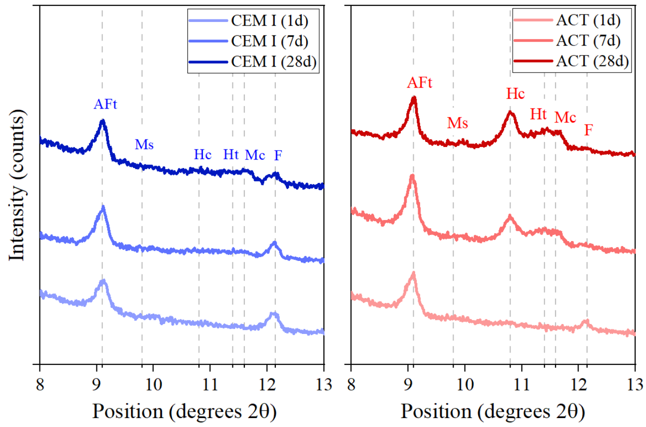

Figure 13 - XRD diffractogram showing peaks of key phases formed at different ages in the 8 to 13° 2Θ region for CEM I and ACT paste samples.

In Figure 14, the calcite peaks for ACT paste samples are shown. ACT samples exhibit significantly higher calcite peaks than CEM I due to the addition of 50% limestone. The intensity of the calcite peak decreases over time as a result of the hydration process. This consumption of calcite in ACT mixes leads to the formation of Hc and Mc phases, as previously shown in Figure 13.

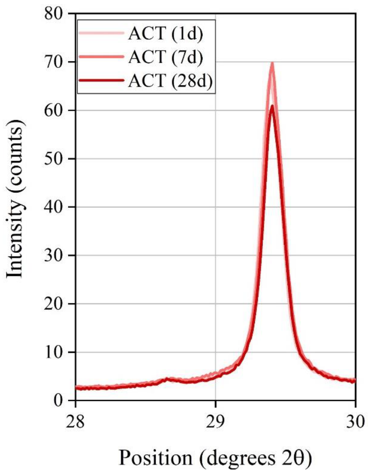

Figure 14 – Detailed view of calcite consumption in ACT paste during hydration over time

The formation of key phases such as Alite (C_3S/AL), Belite (C_2S/BL), Tricalcium Aluminate (C_3A/CA), and Portlandite (CH), are shown in Figure 15. After 1 day of hydration, the AL, BL, and CA peaks are more intense in CEM I paste samples, reflecting the presence of clinker-related minerals. In contrast, ACT paste samples show higher calcite content rather than AL, BL, or CA peaks.

In ACT paste, only 20% of CEM I is available for this reaction, resulting in a less intense CH peak at early age. Over time, BL begins to hydrate, producing additional C–S–H and CH. This leads to an increase in the CH peak in CEM I samples as expected, which corresponds with a decrease in AL and BL peak intensity from 1 to 28 days. However, in ACT samples, the increase in CH peak intensity over time is less pronounced due to: (i) the limited availability of CEM I, and (ii) the consumption of CH in GGBS reactions, which are known to be enhanced in the presence of limestone. Additionally, the complete reduction of AL and BL peaks in ACT samples may also be attributed to accelerated alite hydration promoted by the presence of GGBS. No potentially deleterious materials were observed in the analysis and hydration products found are consistent with known cement chemistry with some subtle differences.

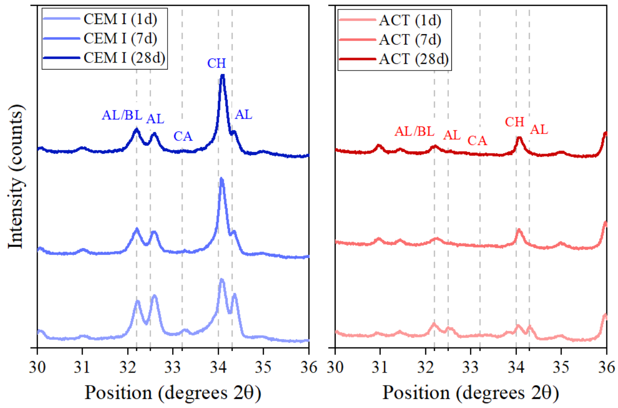

Figure 15 – XRD Diffractogram showing key phases formed in the 30-36° 2 ϴ range in CEM I and ACT samples at 1, 7 and 28 days.

The filling effect of limestones fines has reduced porosity and positively influenced water efficiency. The limestone was also found to hydrate to form carboaluminate phases. A reduction of Portlandite, early formation of ettringite where also observed compared to CEM I pastes.

10.10 SEM Findings

Scanning electron microscopic images of ACT samples reveal grains of varying sizes, corresponding to GGBS, limestone, and CEM I. This variation in particle size contributes to dense particle packing, as evident from the images where different-sized grains are closely packed in a compact matrix. However, unlike the CEM I samples, the individual hydration activity around these grains appears less pronounced. This is likely due to the high limestone content (50%) in ACT, as limestone does not hydrate substantially. Consequently, a comparatively less dense hydration product is observed around or on top of these limestone grains. Ettringite needles are embedded within the hydration products, as shown in Figure 16. This observation correlates with the XRD results, which show higher AFt peaks in comparison to the CEM I paste samples. It suggests the limestone filler is offering nucleation points for hydration to take place. No potentially deleterious materials were observed.

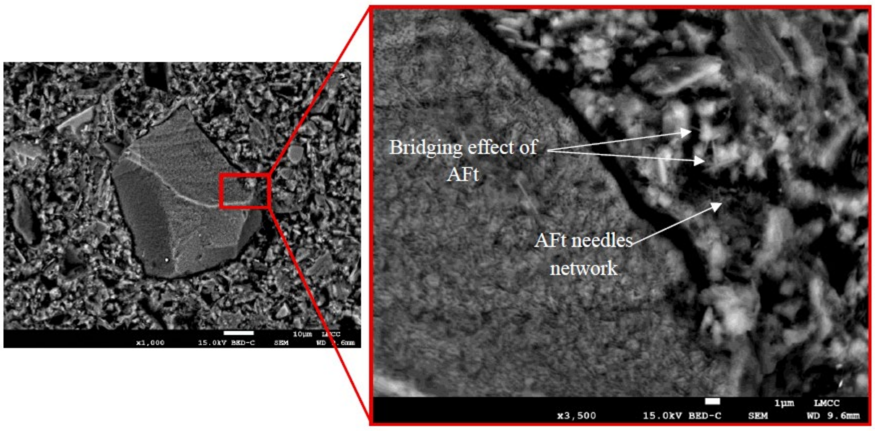

Figure 16 – SEM image displaying Ettringite needles embedded within the hydration products and their bridging effect

These findings offer considerations to the performance of ACT concrete in terms of fresh and hardened properties both relating to engineering and durability performance.

10.11 Water Penetration (BS EN 12390-8:2019)

Water penetration testing was undertaken on concrete cubes cast at Capital Concrete Cricklewood and subsequently take to BRE. The cubes were tested at 28 days to BS EN 12390-8:2019. The depth of penetration noted in the three ACT cubes at the end of testing was 16 mm, 9 mm, and 17 mm.

11.0 Life Cycle Analysis

11.1 Life Cycle Assessment

A comparison of ‘as built’ design and baseline equivalent for the same geometry with ‘business as usual’ materials was carried out to determine the sustainability credentials of ACT. All calculations scoped for ‘Cradle to Gate’ carbon emissions (lifecycle modules A1-A3), accounting for raw material extraction, transportation to manufacturing plant and manufacturing processes.

11.2 Baseline Design

For the Baseline Design, the carbon factors (CF) for the different concrete mixes were the ‘UK Average’ for each mix, extracted from the Low Carbon Concrete Group (LCCG) Market Benchmark database, figure 17. This database summarises the distribution of the embodied carbon of normal wight concrete recently produced in the UK and is annually updated. For C32/40, UK Average CF is 264 $kgCO_2e/m^3$; for C40/50 it is 271 $kgCO_2e/m^3$, and for C50/60 the UK Average CF is 308 $kgCO_2e/m^3$.
For rebar, the UK Average value specified by the Institution of Structural Engineers (IStructE) database was used, which is 0.76 $kgCO_2e/kg$.
Based on these carbon factors, and the material quantities of the built geometry, the total ‘Baseline’ structure resulted in 20.85 tCO_2e.

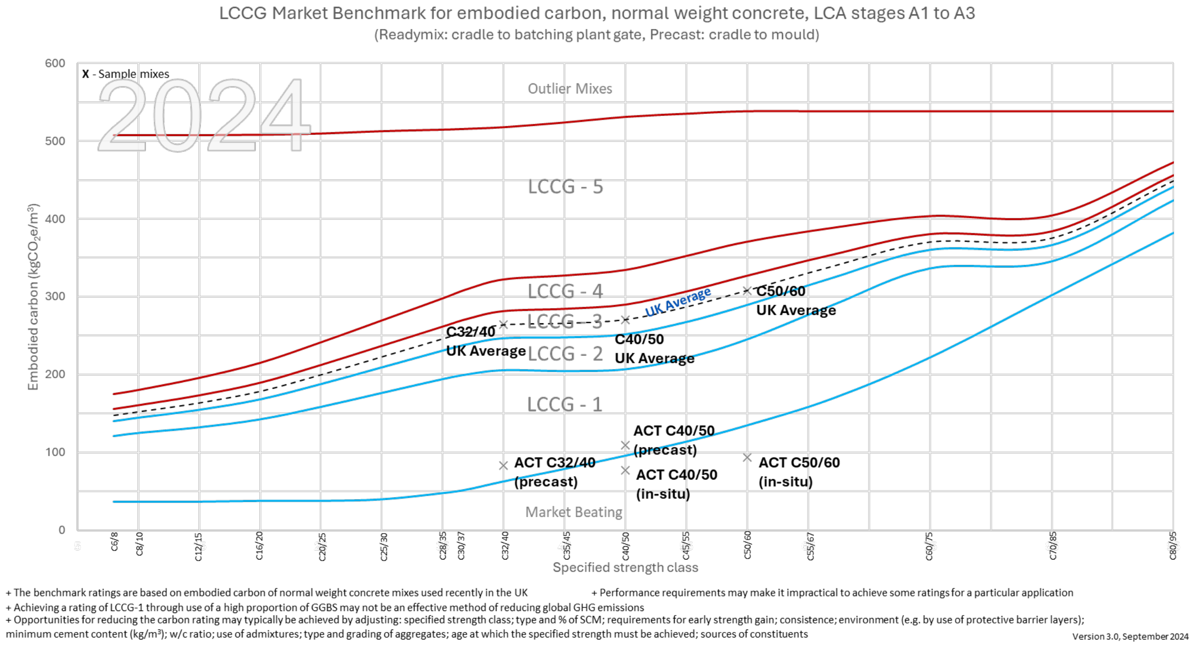

Figure 17 - LCCG Market Benchmark for Embodied Carbon, normal weight concrete

11.3 As Built Design and Comparison

For the 'As Built' design, the Carbon Factors used were calculated based on the elemental composition of each cement and concrete mix, established by the cement and concrete manufacturers See Table 49 below for the summary and references to the detailed calculations for each mix in the report.

Table 49 – Embodied carbon of concrete mixes

Mix number	Producer	Mix Design	Report reference	EC **($kgCO_2e/m^3$)**
1	Capital	C40/50 S4	Table 12	77.55
2	Capital	C50/60 S4	Table 14	93.34
3	Creagh	C32/40 S3	Table 16	83.38
4	Creagh	C40/50 SCC	Table 18	108.98

For rebar in situ, we opted for a low-carbon steel option, RIVA Steel. This manufacturer provides an environmental product declaration (EPD), which was used as the source for its carbon factor, which is 0.21 $kgCO_2e/kg$. For the precast elements, the rebar was unknown, so the IStructE UK Average CF was used instead.
Based on these carbon factors, and the material quantities of the built geometry, the total 'As Built' structure resulted in 6.24 tCO_2e. This value represents a 70.1% reduction in the total embodied carbon of the structure against the 'Baseline'.

If only concrete elements are accounted, the total carbon reduction for concrete elements against their 'Baseline' equivalent for this structure is 71% reduction. See Figure 18 and Table 50 for more details.

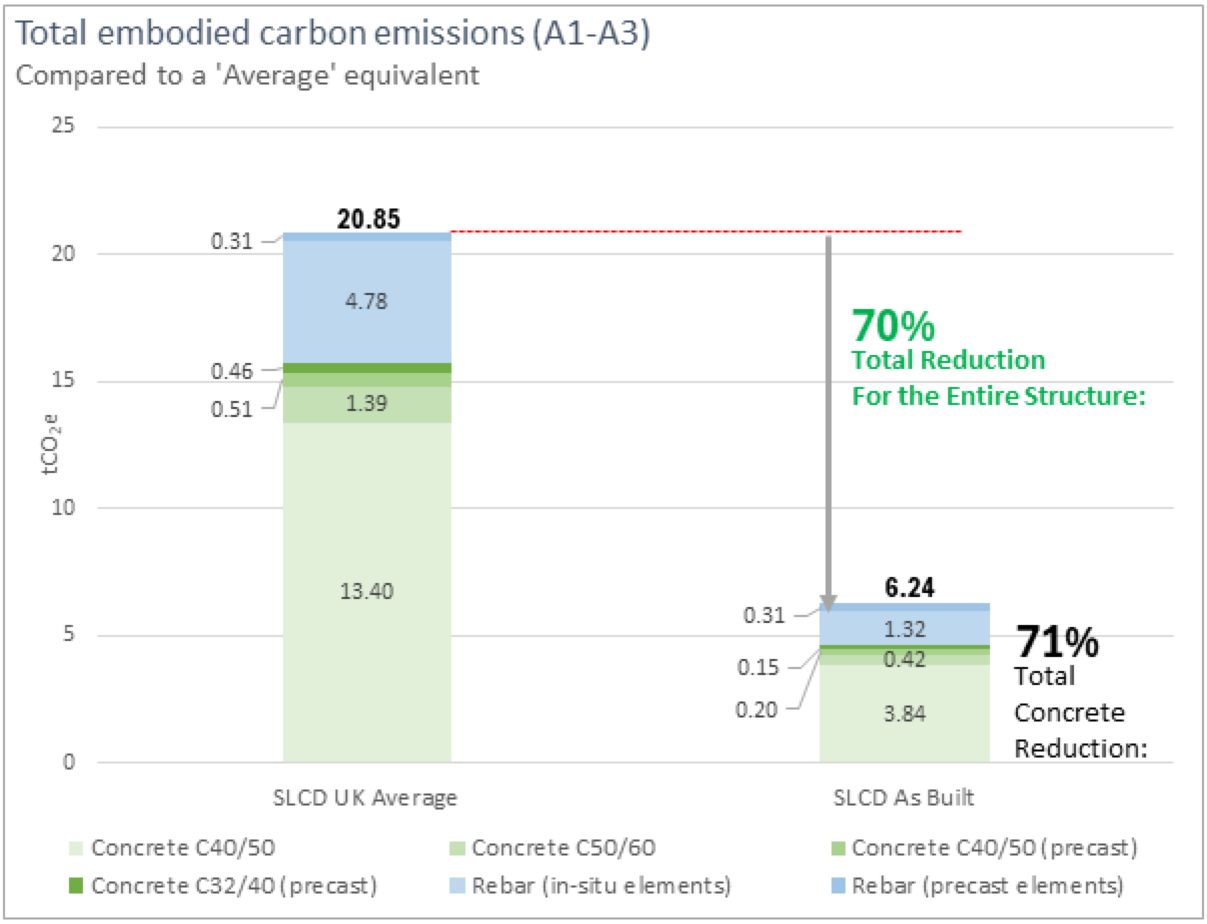

Figure 18- Embodied Carbon Emissions (A1 - A3) for the 'Baseline' design (SLCD UK Average) against the 'As Built' design

Table 50 - Life Cycle Analysis of In-situ and precast elements

	Material	Location	Qty	Baseline Carbon Factor Selection	Carbon Factor	EC (tCO_2e)	As-Built Carbon Factor Selection	Carbon Factor	EC (tCO_2e)	% Reduction
In situ elements	Concrete C40/50	Slabs	49.50 m^3	C40/50 LCCG-3.3 (UK Average)*	270.7 $kgCO_2e/m^3$	13.40	Ecocem ACT C40/50	77.55 $kgCO_2e/m^3$	3.84	71.4%
In situ elements	Concrete C50/60	GF Columns	4.50 m^3	C50/60 LCCG-3.3 (UK Average)*	308.1 $kgCO_2e/m^3$	1.39	Ecocem ACT C50/60	93.34 $kgCO_2e/m^3$	0.42	69.7%
In situ elements	Rebar Steel	Slabs & GF Columns	6,292 kg	Rebar UK average (IStructE)	0.76 $kgCO_2e/kg$	4.78	RIVA steel	0.21 $kgCO_2e/kg$	1.32	72.4%
Precast elements	Concrete C40/50**	L1 Columns	1.87 m^3	C40/50 LCCG-3.3 (UK Average)*	270.7 $kgCO_2e/m^3$	0.51	Ecocem ACT C40/50	108.95 $kgCO_2e/m^3$	0.20	59.8%
Precast elements	Concrete C32/40**	Stairs	1.76 m^3	C32/40 LCCG-3.3 (UK Average)*	264.0 $kgCO_2e/m^3$	0.46	Ecocem ACT C32/40	83.15 $kgCO_2e/m^3$	0.15	68.5%
Precast elements	Rebar Steel**	L1 Columns & Stairs	410 kg	Rebar UK average (IStructE)	0.76 $kgCO_2e/kg$	0.31	Rebar UK average (IStructE)	0.76 $kgCO_2e/kg$	0.31	0.0%
					Total	**20.85**		**Total**	**6.24**	**70.1%**

*Values from: Low Carbon Concrete Group (LCCG) Market Benchmark 2024, based on data from the MPA covering around 56% of the ready-mixed concrete produced in the UK in 2023 and supplemented by data from contractors and independent concrete suppliers. The data was based on a common carbon methodology - gross carbon emission data to EN 15804.
**Subject to confirmation of the mix and specifications used.

The carbon factors associated with the concrete mix designs have been benchmarked using the Low Carbon Concrete Group (LCCG) Market Benchmark 2024. For the **C40/50 mix**, the UK average carbon factor is **270.7 $kgCO_2e/m^3$**, while the Ecocem ACT mix achieves a significantly lower value of **77.55 $kgCO_2e/m^3$**, representing a **reduction of approximately 71.4%**. For the **C50/60 mix**, the UK average carbon factor stands at 308.1 $kgCO_2e/m^3$, with the Ecocem ACT alternative delivering a reduced figure of **93.34 $kgCO_2e/m^3$**, equating to a **69.7% reduction in embodied carbon**.

These calculations support the claim of 70% reduction of embodied carbon using Ecocem ACT which offer significant and realisable carbon reductions in the industry.

12.0 Other performance observations

12.1 Structural Designers perspective

RAMBOLL BUILDINGS

Ramboll undertook structural design of the Ecocem ACT demonstrator structure. Lab and plant trials demonstrated compressive strengths of up to C50/60, in line with conventional mix designs. As such we designed each element using strengths typical to real world projects:

- Precast stairs = C32/40
- Slabs (including PT) and precast columns = C40/50
- Insitu columns = C50/60

N.B. these strengths were higher than required for this small structure, however were used to demonstrate the performance envelope for Ecocem ACT. Typical concrete strengths and element sizes were coordinated with SISK to provide representative examples of how concretes using this technology could be implemented on future projects.

We aimed to demonstrate suitability for as many construction methodologies as possible, with insitu (red), PT (yellow) and precast (blue) elements chosen as shown in Figure 1. To achieve this, we produced design intent and closely coordinated with Creagh (precast supplier) and Interspan (PT subcontractor). Otherwise, we designed this structure as a conventional RC structure to EC2, and the as-built structure has performed as such, with no excessive cracking or deflections beyond what would be expected for a conventional, BS 8500 compliant mix. This is particularly reassuring given this is a suspended structure, as opposed to bearing, and should give confidence to engineers who specify Ecocem ACT in the future.

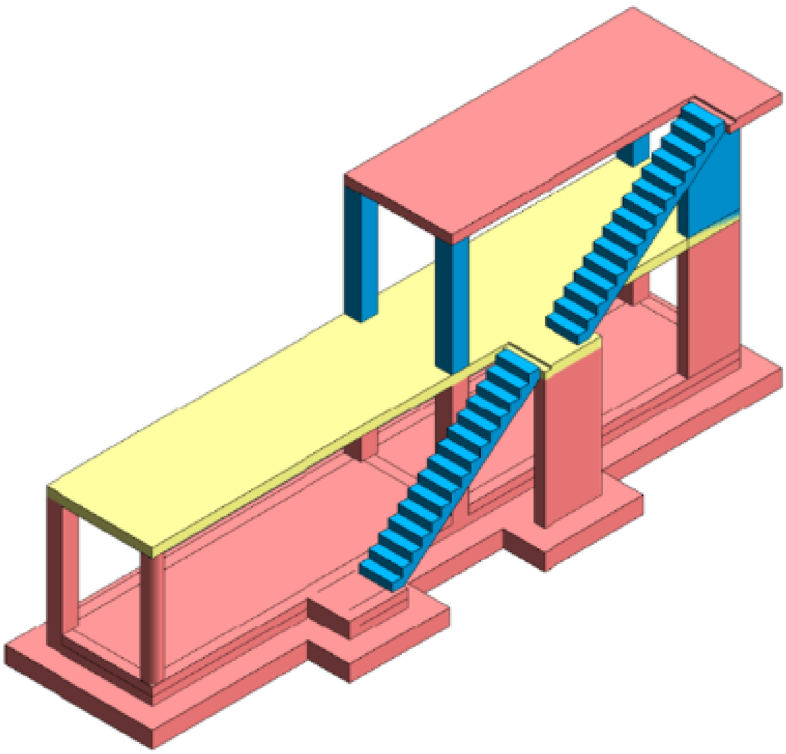

Figure 1 3D Isometric View

1/2 Doc ID / Version

Confidential

In addition to the demonstrator structure, we supported in specification of testing Ecocem ACT to the BSI Flex350. As demonstrated elsewhere in this report, the test results demonstrate equivalent or superior performance to conventional concrete mixes across all aspects tested. Of particular interest to structural engineers are:

- **Compressive Strength Development**: 28-day strength has been achieved specified strength in all cases, a per typical requirements for loading RC structures.
- **Durability**: ACT has demonstrated complaint performance in all durability tests required by the Flex350. In addition to these requirements, Ramboll requested water penetration testing, as high limestone replacement often experience increased penetration, reducing durability. The max penetration of 17mm from the tests undertaken by BRE, are well within the typical 10-30mm range for CEM I concrete containing limestone filler.
- **Fire Performance**: Fire testing has been undertaken with comparable performance between the ACT and reference samples.
- **Creep and Shrinkage**: The results of the creep and shrinkage testing are within reference limits compared to CEMI concrete and advantageous compared to other lower carbon concretes, offering improved deflection and cracking performance.

In both the demonstrator structure and testing regime to BSI Flex350, Ecocem ACT has consistently demonstrated comparable performance to conventional CEM I based concretes, while delivering a massive, embodied carbon saving. This technology presents an exciting opportunity to significantly reduce the contribution of the construction industry to global carbon emissions, with the cement and concrete production currently accounting for around 7% of global CO_2 emissions. To improve confidence in using this material, further demonstration opportunities should be sought, in both permanent and temporary works.

12.2 Ready-mix concrete perspective

Findings Report – Use of EcocemACT from a readymixed supplier's perspective.

Positives.

- Initial Plant trials positive, once water demand and open life determined in respect to initial Laboratory work.
- Product easy to batch like normal binders currently in use.
- Repeatability of producing concrete between batches good.
- Works with normal plasticisers.
- Open life of concrete good, more than 2 hours.
- Characteristic strength compliant at @ 28 days and there is a gain from 28 to 56 days.

Negatives.

- Does not comply with current standard's and cementitious types (BS8500).
- Silo required to store product.
- Early age strength in lower temperatures slow development.

Jack Sindhu.
16.06.25

12.3 Precast concrete producers' perspective

CREAGH
INNOVATION IN CONCRETE

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Findings Report – Use of Ecocem ACT in pre-cast concrete manufacturing.

Creagh Concrete Products Ltd. provided three pre-cast concrete mix designs for the Ecocem technical team to carry out lab trials with the ACT binder. After review and minor adjustments to the concrete mixes we carried out plant trials. Successfully manufacturing pre-cast stairs, columns, and wall panels for the Sisk demonstration building in London.

Positives.

- ACT was easily incorporated into all three concrete mixes.
- Concrete was easy to produce using standard methods.
- Repeatability and consistency of concrete batches was good.
- Workability was comparable to our standard OPC mixes.
- Open time was comparable to our standard OPC mixes allowing for concrete placement.
- Quality of finish was consistent and met our quality standards.
- Early age concrete strength development was sufficient for striking/stripping of the pre-cast elements.
- Characteristic strength was compliant for all three mixes.

Negatives.

- ACT does not currently comply with current standards for cement types.
- An extra silo is required to store product.
- SCC concrete mixes were more susceptible to drying shrinkage cracks.

Sean Toal

Quality Manager

12.4 Main contractors' perspective

12.4.1 Sisk Observations

SISK Contractor Observations Report
Scalable Low Carbon Demonstrator Project
Date: October 2025

Summary

The ACT Scalable Low Carbon Demonstrator project marks the first structural deployment of Ecocem's ACT cement technology on a live construction site. As the main contractor, Sisk has overseen the integration of ACT into both precast and in situ concrete elements, with full compliance to BSI Flex 350 V1 standard.

ACT concrete was successfully batched, delivered, and placed within the scheduled programme. No delays were recorded due to material performance. The consistency of supply and placement characteristics met expectations, with every truck tested for slump and setting time. Early age strength monitoring confirmed the development of maturity aligned with construction sequencing. Compressive strength results across all mixes exceeded target values at 7, 28, and 56 days. Testing by AMTEST, Capital Concrete, and Harringtons confirmed ACT's structural reliability. Strength development classes were achieved, validating ACT's suitability for structural applications. Curing performance was consistent with conventional concrete. No anomalies were observed in surface finish or compaction. Recommendations include standard curing protocols, with no need for extended durations or special treatments. This supports ACT's compatibility with our existing site practices.

Observations

-Placement and compaction of concrete: ACT behaved predictably during placement, with good flow and minimal bleed.

-Surface finishing: Achieved high quality finishes with standard tools and techniques.

-Environmental Impact: ACT achieved a 71% reduction in embodied carbon compared to reference concrete, supporting Sisk's sustainability roadmap.

-Concrete Pumping: As part of this project, a concrete pump was used to test the standard methodology typically employed for high-rise construction. The use of ACT concrete presented no differences in pumping ability or cleaning down procedures when compared to standard concrete mixes. The material flowed predictably through the pump, and all cleaning operations were completed without issue.

Conclusion

ACT has proven to be a viable low-carbon alternative to traditional cement, with no compromise on performance or programme delivery. SISK supports its standardisation for broader industry use.

Maria Estrada

Aidan King

Ross Cullen

12.4.2 Harringtons Observations

Harringtons concrete subcontractor. Refer to Appendix K – Harringtons Findings report

12.4.2.1 Placement and Compaction Performance and Recommendations

The placement of the low carbon concrete mix generally went well, though the team noted its sticky nature, which is attributed to the admixtures and is also sometimes seen in CEM1 mixes. During the raft slab pour, the pump operator needed to use more pressure, but this did not cause issues due to the short pumping distance. The concrete slump was consistent with the S4 range, but when there was a 30-minute gap between loads, the mix became noticeably stiffer. For column pours, the mix tended to fill the trunk of the skip before discharging, which prolonged the process but did not affect the finish. The team found that more effort was needed to level the concrete with spazzles, as the mix would stick and make it heavier to drag. Overall, the placement and compaction were successful, but attention should be paid to the stickiness and timing between loads.

12.4.2.2 Surface Finishing Performance and Recommendations

Surface finishing with this mix was mostly positive. The power float performed very well, as the mix tended to close itself during tamping and levelling, resulting in fewer ridges and a faster process to achieve a flat surface. No polished finish was attempted; a slight texture was left, and tight tolerances were easily achieved. The brush finish was more challenging because the mix closed itself, but it might be easier to achieve in warmer conditions with more curing time. The easy float worked best when a small amount of water was applied, allowing it to glide smoothly and achieve a finish possibly better than with a CEM1 mix. The hand trowel tended to stick to the mix, causing some tolerance issues, but this is also common with CEM1 mixes. There was little to no bleeding of water, which helps prevent ponding. The team recommends adjusting techniques and timing, especially for brush finishes, and using water with floats and trowels as needed.

12.4.2.3 Curing Performance and Recommendations

The team noted that the time required for the concrete to set enough for power floating was generally 2-3 hours longer than with a normal CEM1 mix. This extended setting time should be considered when planning finishing operations. For brush finishes, it is recommended to allow more curing time, especially in warmer conditions, to prevent the mix from closing the brush lines. Overall, the curing process requires careful timing adjustments compared to standard mixes, and the team looks forward to further collaboration and refinement of techniques with this mix.

13.0 Conclusions and recommendations

13.1 Conclusions

This project has proven Ecocem ACT low-carbon concrete Technology's technical readiness level as TRL-7. The testing and evaluation of ACT demonstrate that it is a technically viable and environmentally superior alternative to conventional cement-based concretes. When assessed across fresh, engineering, and durability assessments, ACT consistently met or exceeded performance expectations.

Fresh property trials confirmed excellent workability across both ready-mix and precast applications, with stable consistence retention, minimal bleeding, and controlled setting times that align with standard construction schedules.

Engineering property testing showed that compressive, flexural, and tensile strengths achieved or surpassed design requirements for C32/40, C40/50, and C50/60 mixes. Compressive strength was tested in different labs showing good repeatability and reproducibility of performance. Modulus of elasticity, shrinkage, creep, and thermal expansion results fell within ranges observed for conventional concretes, confirming ACT's structural reliability for reinforced and prestressed elements. The low heat of characteristics measured against BSI Flex 350 requirements further highlights ACT's suitability for mass pours and reducing the risk of thermal cracking. This could be factored into planning for deep pour where some crack reducing steel could be removed from the design which could have an economic and LCA benefit. Converge maturity sensors were found to be useful and provided relevant information for striking times and scheduling construction sequences. However, only a limited amount of sensors were used in this study, and further experiments and experience would be useful to further determine their accuracy with ACT concrete. Three reinforced ACT slabs were produced for four-points bend testing. The specimens showed good repeatability of their results between the three tests, and all reached ductile failure of the steel as the ultimate failure method.

Durability performance was equally robust. ACT exhibited very high resistance to chloride ingress at 28 days which was further enhanced when tested at 91 days. Accelerated testing gave a rate of carbonation of 1.01mm/√day which is for consideration in design specifications relating to cover depth. The freeze-thaw resistance with di-ionised water was good, however resistance with di-icing salts was above the acceptable limit. The concrete mix designs were not optimised for freeze-thaw resistance to de-icing salts and further work is recommended to establish optimal concrete mix designs with ACT for freeze-thaw resistance where de-icing salts are likely to be used. ACT also showed good sulfate and acid resistance at year of test data and has shown DC-4 equivalent performance. Fire test results for both ACT and reference concrete displayed spalling in less than 30 minutes. The ACT specimen performed better than the reference, but the fire testing regime could be adapted as the reference concrete which is standardised and used showed poor performance using the method. Material characterisation confirmed no deleterious phases, supporting confidence in ACT's long-term service life while giving an insight into the hydration products.

Most importantly, life cycle analysis validated ACT's transformative environmental impact. Across all mixes, ACT achieved around a 70% reduction in embodied carbon compared to UK benchmark concretes. For the demonstrator structure, embodied carbon fell by nearly two-thirds, from 20.85 tCO_2e (baseline) to 6.24 tCO_2e (as built).

One key purpose of this project is to demonstrate ACT at scale on a construction site. ACT was batched using commercial ready mixed and precast concrete plants and delivered to site as per normal. It was placed and finished using the usual everyday construction techniques with observations and findings from industry practitioners noted, with all parties satisfied with the usability of ACT.

Taken together, these findings establish ACT as a **scalable, reliable, and high-performance low-carbon concrete technology**. It provides the structural and durability credentials necessary for mainstream adoption while delivering substantial carbon reductions that directly support net zero ambitions.

13.2 Recommendations

Further demonstration projects are highly desirable to assess the repeatability and reproducibility of Ecocem ACT on construction sites.

A range of different applications and concrete mix designs could be considered if future works such as concrete mix design's specifically for resistance to de-icing salts for exposure to XF2 and XF4 EN206 exposure classes but also a range of strength and consistence classes.

Measures to accelerate the early-age strength development of ACT could be investigated for more optimal practices that are usual with post-tensioning and prestressed precast operations.

The fire testing protocol used in this study and as proposed by BSI Flex 350 gave surprising results with the reference concrete exhibiting early age spalling during the test. The fire test protocol could be reviewed given this finding.

Durability testing to BSI Flex 350 calls for comparison testing against a reference concrete. This could be replaced by performance limits for durability that could be determined by national studies. This could remove duplication of reference concrete testing in material assessments.

Carbon assessments of concrete products are recommended to calculate the life cycle analysis of construction projects.

The SCM proportion of Ecocem ACT used in this project is GGBS, other SCM sources such as calcined clay, fly-ash, natural pozzolans or other sources could be assessed for suitability with the performance criteria of Ecocem ACT.

The findings of this project and study could be used by concrete standard committees for the inclusion of ACT like cement formulations in the harmonised cement standard, EN 197-1 and for concrete formulations based on ACT to be approved for use in National Annexes to EN 206.

The use of performance-based specification based on BSI Flex 350 offers a system to assess low carbon concrete technology and offers industry a route to rapid decarbonisation of concrete as evidenced by the 70% reduction of embodied CO_2 on this project. BSI Flex 350 lack a formal accreditation process and incorporating BSI Flex 350 a part of BS 8500 is a key recommendation to the widespread adoption of low carbon technologies.

ACT could be deployed on permanent works in low-risk applications to give more reference sites and for data collection using BSI Flex 350 as the specification tool.

Training and education of all stakeholders in the industry of low carbon concrete technologies such as Ecocem ACT is critical to their adoption and success in decarbonising concrete.

14.0 COSHH (Control of Substances Hazardous to Health) and waste processing

Please refer to Appendix Q - ACT Safety data sheet MSDS

Appendix A – Capital Concrete Lab Trials

ecocem	R&I Trials results - Sisk	Version 1 Page - 1 - of 3

General Project Information

Tests conducted by	Patrick Azar
Date	25/06/2024
Client name	Sisk
Concrete supplier	Capital concrete

Confidential according to NDA signed between Capital Concrete Ltd and ECOCEM with effective date of 23/02/2024

Mix designs

The different mix designs tested for the Sisk project are detailed in Table 1 below.

Table 1: Mix designs tested in Ecocem Laboratory for the Sisk project.

			Mix design 1	Mix design 2	Mix design 3	Mix design 4
Mix design (kg/m³)	Sand Cliffe 0-4		849.0	810	810	806.5
	Aggregate 4-20		1103.0	1053	1053	1048
	G/S		**1.3**	**1.3**	**1.3**	**1.3**
	ACT		350	350	400	400
	Limestone filler			50		50
	Optima 100 (%)		1.6%	1.5%	1.5%	1%
	Effective water		122.5	139.3	139.3	141.3
	W/C		**0.35**	**0.35**	**0.35**	**0.31**
Fresh state results	Fresh Density (kg/m³)		2428	2389	2379	2413
	Air (%)		2.7%	3.0%	3.5%	2.8%
	Slump T_0 (mm)		215	235	235	240
	Slump T_{30} (mm)		220	230	230	230
	Slump T_{60} (mm)		220	230	230	220
	Slump T_{90} (mm)		195	220	220	200
	Slump T_{120} (mm)		190	220	220	185
	Inverted cone T_0 (s)		3.0	2.0	3.0	3.0
	Inverted cone T_{30} (s)		3.8	3.0	2.0	3.0
	Inverted cone T_{60} (s)		5.0	2.5	2.2	4.0
	Inverted cone T_{90} (s)		4.0	4.4	4.2	4.0
	Inverted cone T_{120} (s)		5.0	3.5	3.0	4.0
Conservation	24h	T (°C)	20	20	20	20
		RH (%)	100	100	100	100
	After 24h	T (°C)	20	20	20	20
		RH (%)	100	100	100	100
Hardened state	*fc* (24h) 10x10 cube		6.3	5.9	6.0	5.9
	fc (7d) 10x10 cube		39.5	37.3	40.5	36.4
	fc (28d) 10x10 cube		53.5	50.4	55.7	49.9
	Porosity 28d		-	-	-	-
	Porosity 90d		-	-	-	-
	Resistivity 28d		-	-	-	-
	Resistivity 90d		-	-	-	-
	Acc carbonation 28d		-	-	-	-
	Acc carbonation 90d		-	-	-	-

We tested different formulations using the aggregates provided by Capital Concrete, evaluating varying binder contents of 350 and 450 kg/m³, with and without the addition of limestone filler. The results were all promising in terms of rheology, with the concrete maintaining an S4 consistency class for up to two hours of open time. Compressive strength at 1 day was similar across all formulations, with values around 6 MPa. At 28 days, some differences were observed, but the results remained comparable, ranging between 50 and 55 MPa.

Total Shrinkage results

The total shrinkage was measured on concrete prisms (7x7x28 cm) taken from the mix design N°1 kept in 50% RH and 20°C conditions with and without curing agent. The results of the total shrinkage and mass loss are presented in Figure 1 (a) and (b), respectively.

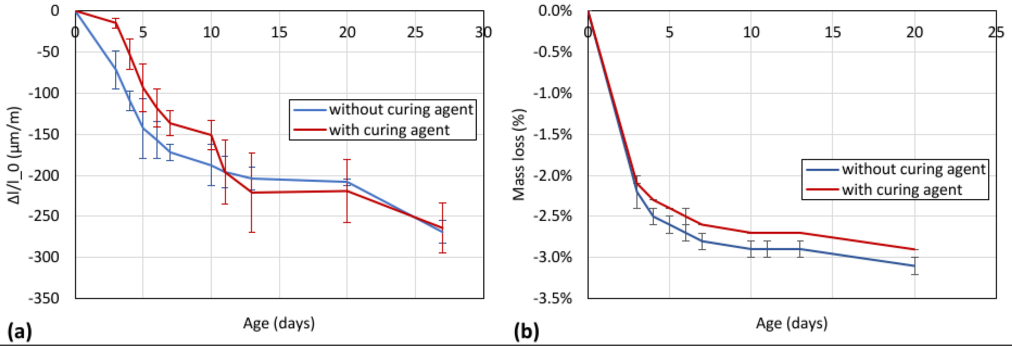


Figure 1: (a) total shrinkage and (b) mass loss of concrete 7x7x28 cm prisms kept in 50% RH at 20°C.

The results indicate that the use of a curing agent led to a slight reduction in the total shrinkage of the concrete, though without any significant impact. It is worth noting that the total shrinkage of this material remains relatively low or comparable to that of conventional concrete.

L

Appendix B – Creagh Concrete Lab Trials

ecocem	R&I Trials results - Sisk	Version 1 Page - 1 - of 3

General Project Information

Tests conducted by	Kiiashko Artur
Date	26/02/2025
Client name	Sisk
Concrete supplier	Creagh Concrete

Confidential according to NDA signed between Creagh Concrete Production Limited and ECOCEM with effective date of 28/02/2024

Mix designs

Two different mix designs tested for the Sisk project are detailed in Table 1 (self-compacting concrete) and Table 2 (S3 type ordinary concrete) below.

Table 1: Mix designs tested in Ecocem Laboratory for self-compacting

		Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density
	0/2 Creagh concrete	5.25%	1.75%	2.63	6.50%	1.75%	2.63	3.70%	1.75%	2.63	2,55%	1.75%	2.63	2,55%	1.75%	2.63
	0/4	5.26%	1.70%	2.64	5.10%	1.70%	2.64	4.00%	1.70%	2.64	2,6%	1.70%	2.64	2,6%	1.70%	2.64
	6/14	1.78%	1.60%	2.7	0.37%	1.60%	2.7	0.90%	1.60%	2.7	1,55%	1.60%	2.7	1,55%	1.60%	2.7
		C 40-50 GUK-1			C 40-50 GUK-3			C 40-50 GUK-9			C 40-50 GUK-13			C 40-50 GUK-14		
Composition (kg/m3)		0/2 Creagh concrete		310	0/2 Creagh concrete		305	2.63		300	2.63		300	2.63		300
		0/4		590	0/4		580	2.64		580	2.64		580	2.64		580
		6/14		770	6/14		770	2.7		770	2.7		770	2.7		770
		ACT		420	ACT		520	ACT		520	ACT		520	ACT		520
		Omya HP-VF		140	Omya HP-VF		40	Omya HP-VF		40	Omya HP-VF		40	Omya HP-VF		40
		PCE reference	1.50%	8.40	PCE reference	1.40%	7.84	PCE reference	1.40%	7.84	PCE reference	1.40%	7.84	C-paste	1.30%	7.28
		Water eff	0.31	173.00	Water eff	0.31	173.00	Water eff	0.31	176.00	Water eff	0.31	174.00	Water eff	0.31	174.00
		Water total	0.36	200.8	Water total	0.36	200.5	Water total	0.36	203.4	Water total	0.36	201.4	Water total	0.36	201.4
Fresh state		Spread	V-Funel	L-box	Spread	V-Funel	L-box	Spread	V-Funel	L-box	Spread	V-Funel	L-box	Spread	V-Funel	L-box
	T0	630	9		780	8		780	8		790	11		770	23	
	T30	580	9	0.9	720	11	0.9	700	10	0.95	730	10		480	>30	
	T60	540	13		710	14		670	12		710	9		0	-	
	Mv (kg/m3)/ Ao	2360 / 2,8%			2390 / 1,8%			2390 / 1,7%			2390 / 2,2%			2390 / 2,2%		
	Comments	10x10 cubes			10x10 cubes			10x10 cubes			10x10 cubes			10x10 cubes		
Hardened state		at 20°C	at 30°C for 24h	at 40°C for 24h	at 20°C	at 30°C for 24h	at 40°C for 24h	at 20°C	at 30°C for 24h		at 20°C	at 30°C for 24h		at 20°C	at 30°C for 24h	
	Rc24h (MPa)	4.0	6.8	11.4	6.2	10.8	18.4	7.3	10.5		8,9	12,7		8,9	15,3	
	Rc2j (MPa)	8.2	10.5	16.5	12.7	17	24.8	16.1	20.5							
	Rc7j (MPa)							41.7	43		39,7	38,5		43,8	36,1	
	Rc28j (MPa)	50	45.8	47.9	56.1	55.8	53	61,2	59,4		66,7	58,3		65,4	60,1	
	Rc90j (MPa)	64,0	60,7	59,8	72,5	67,6	64,4	68,7	74,0		72,3	73,2		69,9	59,5	
	Comments	Fail			Pass			Pass			Pass			Fail		

Table 2: Mix designs tested in Ecocem Laboratory for S3 type ordinary concrete

	Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density	Humidity	Absorption	Density
0/2	5.25%	1.75%	2.63	7.00%	1.76%	2.63	7.00%	1.76%	2.63	3.70%	1.76%	2.63	3.70%	1.76%	2.63	3.70%	1.76%	2.63	3.70%	1.76%	2.63	2,55%	1.76%	2.63	2,55%	1.76%	2.63
0/4	5.26%	1.70%	2.64	6.40%	1.70%	2.64	6.40%	1.70%	2.64	3.70%	1.70%	2.64	3.70%	1.70%	2.64	3.70%	1.70%	2.64	3.70%	1.70%	2.64	2,6%	1.70%	2.64	2,6%	1.70%	2.64
6/14	1.78%	1.60%	2.7	2.15%	1.60%	2.7	2.15%	1.60%	2.7	0.70%	1.60%	2.7	0.70%	1.60%	2.7	0.70%	1.60%	2.7	0.70%	1.60%	2.7	1,55%	1.60%	2.7	1,55%	1.60%	2.7

		C 32-40 GUK-2	C 32-40 GUK-4	C 32-40 GUK-5	C 32-40 GUK-6	C 32-40 GUK-7	C 32-40 GUK-8	C 32-40 GUK-10	C 32-40 GUK-11	C 32-40 GUK-12
Composition (kg/m3)	0/2	365	350	350	350	350	362	360	350	350
	0/4	465	450	450	450	460	465	460	450	450
	6/14	1020	1020	1050	1025	1030	1036	1020	1020	1020
	ACT	390	390	390	390	390	390	390	390	390
	Acc. Powder mix					27				
	PCE reference	2.00% 7.80	1.65% 6.44	1.40% 5.46	1.65% 6.44	1.65% 6.88	1.65% 6.44	1.50% 5.85	1.50% 5.85	0.90% 3.51
	C paste									0,5% 1,95
	Water eff	0.39 152.10	0.40 156.00	0.38 148.20	0.39 150.15	0.36 140.40	0.36 140.40	0.37 144.30	0.39 152.10	0.39 152.10
	Water total	0.47 182.7	0.48 186.1	0.46 178.8	0.46 180.4	0.41 170.9	0.44 171.3	0.45 174.8	0.47 182.2	0.47 182.2

	C 32-40 GUK-2		C 32-40 GUK-4		C 32-40 GUK-5		C 32-40 GUK-6		C 32-40 GUK-7		C 32-40 GUK-8		C 32-40 GUK-10		C 32-40 GUK-11		C 32-40 GUK-12	
Fresh state	Slump (mm)	Inverted cone (s)	Slump (mm)	Inverted cone (s)	Slump (mm)	Inverted cone (s)	Slump (mm)	Inverted cone (s)	Slump (mm)	Inverted cone (s)	Slump (mm)	Inverted cone (s)	Slump (mm)	Inverted cone (s)	Slump (mm)	Inverted cone (s)	Slump (mm)	Inverted cone (s)
T0	220	5.4	240	5	180		240	5	220	6	220	9	150	20	230	5	220	5
T30	200	3	225	6	60		220	4	0	-	130	-	45	-	220	4	210	10
T60	220	-	210	6			210	4							220	5	195	10
Mv (kg/m3)/ Ao	2410 / 2%		2410 / 2%		_		-		-		-		-		1.8%/ 2440 kg/m3		0.8%/ 2490 kg/m3	
Comments	10x10, addition of SP and water little by little		10x10		10x10		10x10		10x10		10x10		10x10		10x10		10x10	

	C 32-40 GUK-2			C 32-40 GUK-4			C 32-40 GUK-5			C 32-40 GUK-6			C 32-40 GUK-7			C 32-40 GUK-8			C 32-40 GUK-10			C 32-40 GUK-11			C 32-40 GUK-12		
Hardened state	at 20°C	at 30°C for 24h	at 40°C for 24h	at 20°C			at 20°C	at 30°C for 24h		at 20°C	at 30°C		at 20°C	at 30°C		at 20°C	at 30°C		at 20°C	at 30°C		at 20°C	at 30°C		at 20°C	at 30°C	
Rc24h (MPa)	6.0	8.2	14.0	5.5			6.5	11.0		5.8	8.9		10.0	12.3		6.6	11.3		6.6	9.7		6,2	10,5		6,9	11,2	
Rc2j (MPa)	9	12.7	16.8	11			12.3	16.6		11.8	15.5		16.8			13.9			12.1	15.1							
Rc7j (MPa)										32.3			35.7			35.8			31.9	32.1		34	32,5		36,7	36,6	
Rc28j (MPa)	49	45.6	46.5	53.7			58	53.5		52,7	47,3		57,6	54,3		57,4	52,7		54,3	47,8		56,9	49,7		60	54	
Rc90j (MPa)	63,0	60,3	53,3	64,5			64,8			56,4	59,0								54,1	56,1		58,2	58,2		69,4	63,7	
Comments	Pass			Pass			Fail			Pass			Fail			Fail			Fail			Pass			Pass		

In both cases, the target was achieved. It was recommended to use the formulation GUK-13 for the self-compacting concrete application and GUK-11 for S3 type concrete.

L

Appendix C – Capital Concrete Mix Designs

PROPOSED CONCRETE MIX COMPOSITION

Date : November 11, 2024

Our Ref:

Rev:

Capital Concrete

Brett House
St Michael's Close
Aylesford
Kent
ME20 7XE

Tel: 0203 974 0520

For the attention of:

Delivery Address:

Supplying Plant: Cricklewood

All mixes in accordance with BS 8500-2 (except proprietary mixes) unless otherwise agreed. Batch weights of materials calculated on a SSD basis for 1.0m3 of fresh compacted concrete. Mixes are quality controlled and actual mix proportions may vary in response to control systems.

CONCRETE SPECIFICATION			
C40/50 ECOCEM ACT	Mix no:	DC Class:	CL Class: 0.4
Cement Type:	Max Agg: 20mm	Min. Cement:	W/C Ratio:
Slump: S4	Total Embodied CO_2 kg per m3 77.55		

SSD MIX DESIGN PER CUBIC METRE

Material	Source / Supplier	Quantity	Units	CO_2 (kg)	CO_2 kg/m3
4/10mm Gravel	Cliffe Brett	303	kg	3.43	1.04
10/20mm Gravel	Cliffe Brett	707	kg	3.43	2.43
Sand 0/4	Cliffe Brett	910	kg	3.43	3.12
Water	Water	123	li		
EcocemACT	EcocemACT	350	kg	200.00	70.00
Optima100	OPTIMA100	5,600	ml	.16	.90

W/C Ratio: 0.36	Alk Kg: 2.08	Cl% 0.29	SO4%: 2.06

Total Material CO_2	77.55
Plant CO_2	
Total CO_2 From Production	**77.55**
CO_2 for Delivery to Site	.00
Total CO_2	**77.55**

Distance	3.00	Average CO_2 per distance	

Notes:

The Company reserves the right to vary the mix design details given above subject to production demands and quality control requirements. No variation will be made below specified minimum cement contents or above specified maximum free w/c ratios. Aggregates are a natural product and therefore may contain natural defects such as lignite and pyrities.

Jack Sindhu
Technical Manager

11 November 2024 14:56
Page 1 of 1

THE QUALITY SCHEME FOR READY MIXED CONCRETE — ISO 9001 — UKAS PRODUCT CERTIFICATION 009

PROPOSED CONCRETE MIX COMPOSITION

Date : February 13, 2025

Our Ref: 115239

Rev: 000

Cash Sale - Wembley CC

Capital Concrete

Brett House
St Michael's Close
Aylesford
Kent
ME20 7XE

Tel: 0203 974 0520

For the attention of:

Delivery Address: John Sisk, Fulton Road, Wembley, HA9 0NU

Supplying Plant: Cricklewood

All mixes in accordance with BS 8500-2 (except proprietary mixes) unless otherwise agreed. Batch weights of materials calculated on a SSD basis for 1.0m3 of fresh compacted concrete. Mixes are quality controlled and actual mix proportions may vary in response to control systems.

CONCRETE SPECIFICATION			
C50/60 ECOCEM	Mix no:	DC Class:	CL Class: 0.4
Cement Type: ECOACT	Max Agg: 20LSmm	Min. Cement:	W/C Ratio:
Slump: S4	Total Embodied CO2 kg per m3 93.34		

SSD MIX DESIGN PER CUBIC METRE					
Material	Source / Supplier	Quantity	Units	CO2 (kg)	CO2 kg/m3
4/20mm Limestone	4/10mm Limestone Torr	990	kg	3.43	3.40
Sand 0/4	Cliffe Brett	840	kg	3.43	2.88
Water	Water	151	li		
EcocemACT	EcocemACT	430	kg	200.00	86.00
Optima100	OPTIMA100	6,000	ml	.16	.96

W/C Ratio: 0.35	Alk Kg: 2.27	Cl% 0.20	SO4%: 2.04

Total Material CO2	93.34
Plant CO2	
Total CO2 From Production	**93.34**
CO2 for Delivery to Site	.00
Total CO2	**93.34**

Distance	3.00	Average CO2 per distance	

Notes:

The Company reserves the right to vary the mix design details given above subject to production demands and quality control requirements. No variation will be made below specified minimum cement contents or above specified maximum free w/c ratios. Aggregates are a natural product and therefore may contain natural defects such as lignite and pyrities.

Jack Sindhu
Technical Manager

13 February 2025 08:30
Page 1 of 1

THE QUALITY SCHEME FOR READY MIXED CONCRETE

UKAS PRODUCT CERTIFICATION 009

Appendix D – Creagh Concrete Mix Designs

Embodied carbon calculation

Job name:	Sisk - ACT	Date:	

C32/40 - Stairs

Materials	Source	Amount (kg/m3)	kgCO2e/T	kgCO2e/kg
6/14mm aggregate	Creagh	1036	3.43	3.55
0/4 sand	Creagh	465	3.43	1.59
0/2 sand	Creagh	362	3.43	1.24
Limestone filler	Omya	-	8	0.00
Superplasticiser	Chryso	6.44	0.16	0.00
Cement	Ecocem ACT	390	200	78.00
Water	Bore hole/rain catchment	171		
Total kgCO2e/m^3				**83.38**

C40/50 - SCC - Walls and Columns

Materials	Source	Amount (kg/m3)	kgCO2e/T	kgCO2e/kg
6/14mm aggregate	Creagh	770	3.43	2.64
0/4 sand	Creagh	580	3.43	1.99
0/2 sand	Creagh	300	3.43	1.03
Limestone filler	Omya	40	8	0.32
Superplasticiser	Chryso	7.84	0.16	0.00
Cement	Ecocem ACT	520	200	104.00
Water	Bore hole/rain catchment	176		
Total kgCO2e/m^3				**109.98**

Appendix E – Concrete Pour Log

Business Function	Document Owner	Document Type
Quality	Director - HSSQ	FORM

FM-QA-1500-09 Concrete Pour Log

Project Particulars

The particulars relating to the project are as follows:

Project Name	Scalable Low Carbon Demonstrator Project	Project Number	N/A
Engineer in Charge	Tom Foley		

Pour Information

Location	Various	Design Mixes	C40/50, C50/60

Delivery Record

Pour Date/Reference	Location	Ticket No.	Truck Reg No.	Quantity (M³)	Batch/Shelf Time	Arrival to Site Time	Discharge Time		Air Temperature (If required)	Slump Test		Cubes Taken			Comments
							Start	Finish		(mm)	Degree of Workability	Yes	No	Ref	
25/11/2024 – ITR F385749.4	Raft Slab	34025863	GN20YHL	7.00	10:07	10:55	10:58	11:27		187	S4	☒	☐		Design Mix – C40/50 Total Concrete Volume – 25.50m3
25/11/2024	Raft Slab	34025866	GK19FPN	7.00	10:43	11:20	11:35	11:54		205	S4	☒	☐		
25/11/2024	Raft Slab	34025872	GM19VMW	7.00	11:36	12:13	12:22	12:40		212	S4	☒	☐		
25/11/2024	Raft Slab	34025877	GF21JYH	4.50	12:04	12:57	13:00	13:29		195	S4	☒	☐		
02/12/2024 – ITR F357096.463	GF Slab	34026199	GK70EEH	7.00	8:16	9:16	9:22	9:52		195	S4	☒	☐		Design Mix – C40/50 Total Concrete Volume – 10m3
02/12/2024	GF Slab	34026205	GF21JYH	3.00	9:50	10:28	10:32	10:58		192	S4	☒	☐		
05/12/2024 – ITR F1.4140047	GF Columns	34026382	GK19FPN	4.50	13:20	14:01	14:04	15:54		228	S4	☒	☐		Design Mix – C50/60 Total Concrete Volume – 4.50m3
12/12/2024 – ITR F432134.109	L1 PT Slab	34026748	GC19XDJ	5.00	13:11	14:17	14:20	15:01		175	S4	☒	☐		Design Mix – C40/50 Total Concrete Volume – 9m3
12/12/2024	L1 PT Slab	34026755	GK72EOW	4.00	14:31	15:19	15:27	15:41		170	S4	☒	☐		
14/01/2025 – ITR F357096.465	L2 Slab	34027459	GM19VMZ	5.00	7:43	8:43	8:35	9:13		160	S4	☒	☐		Design Mix – C40/50 Total Concrete Volume – 5m3
												☐	☐		

John Sisk & Son (Holdings) Ltd.
Management System

FM-QA-1500-09 Concrete Pour Log
FM-QA-1500-09
Last Updated: July-2021

Rev 00

Page 1 of 2

Business Function	Document Owner	Document Type
Quality	Director - HSSQ	FORM

FM-QA-1500-09 Concrete Pour Log

Pour Date/Reference	Location	Ticket No.	Truck Reg No.	Quantity (M^3)	Batch/Shelf Time	Arrival to Site Time	Discharge Time		Air Temperature (If required)	Slump Test		Cubes Taken			Comments
							Start	Finish		(mm)	Degree of Workability	Yes	No	Ref	
												☐	☐		
												☐	☐		

Appendix F – AMTEST Trial Cube Results

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000772 Certificate date: 05/09/2024

Testing machine: COMPRESSION MACHINE

Client: ECO

Reference: AT002468

Specimen type: CUBE Cement quantity [kg/m³]: .

Cement type: . Preparation date: 04/09/2024

Sample conditions:

Condition when received: GOOD Condition at test time: SATISFACTORY

Sampling location: CRICKLEWOOD Sampling date: 04/09/2024

Preparation method: BY HAND

Specimen ID: CUBE 1 C40.50 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00

Area [mm2]: 10000.0 Mass [kg]: 2.358 Density [Kg/m3]: 2358.0

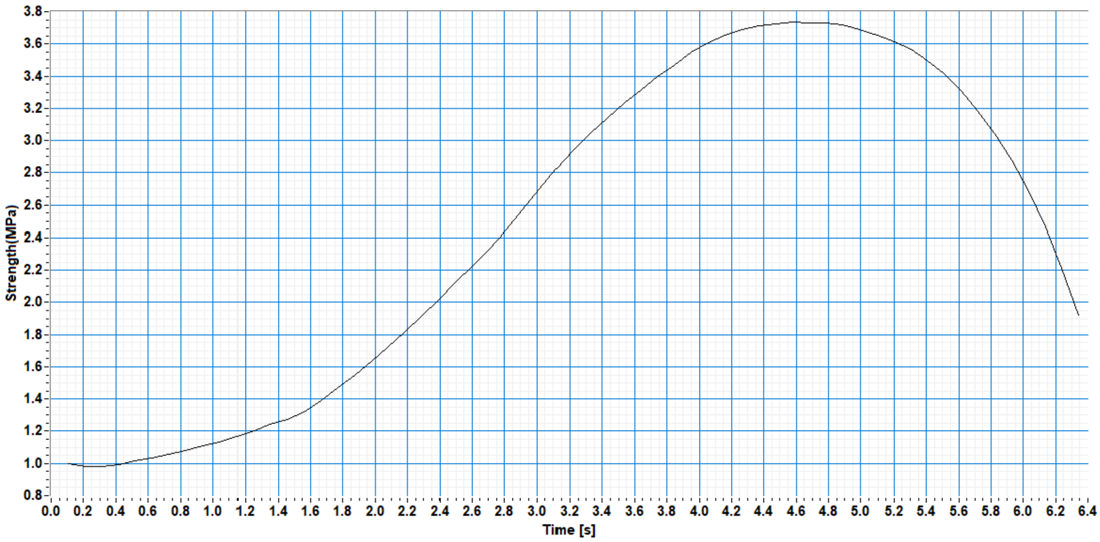
Specimen age [dd]: 24 HOURS

Load Rate [MPa/s]: 0.800 Test date: 05/09/2024

Max Load [kN]: 37.30 **Strength [MPa]: 3.73**

Failure type: Satisfactory

Notes: TRIAL



Operator:
LIAM

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number:	AMT-CRS-000771 - ID 9377	Certificate date:	11/09/2024
Testing machine:	COMPRESSION MACHINE		
Client:	ECO		
Reference:	AT002467.7		
Specimen type:	CUBE	Cement quantity [kg/m³]:	.
Cement type:	.	Preparation date:	04/09/2024

Sample conditions:

Condition when received:	GOOD	Condition at test time:	SATISFACTORY
Sampling location:	CRICKLEWOOD	Sampling date:	04/09/2024
Preparation method:	BY HAND		
Specimen ID:	CUBE 8 C50.60 04.09.24		

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00

Area [mm2]: 10000.0 Mass [kg]: 2.459 Density [Kg/m3]: 2459.0

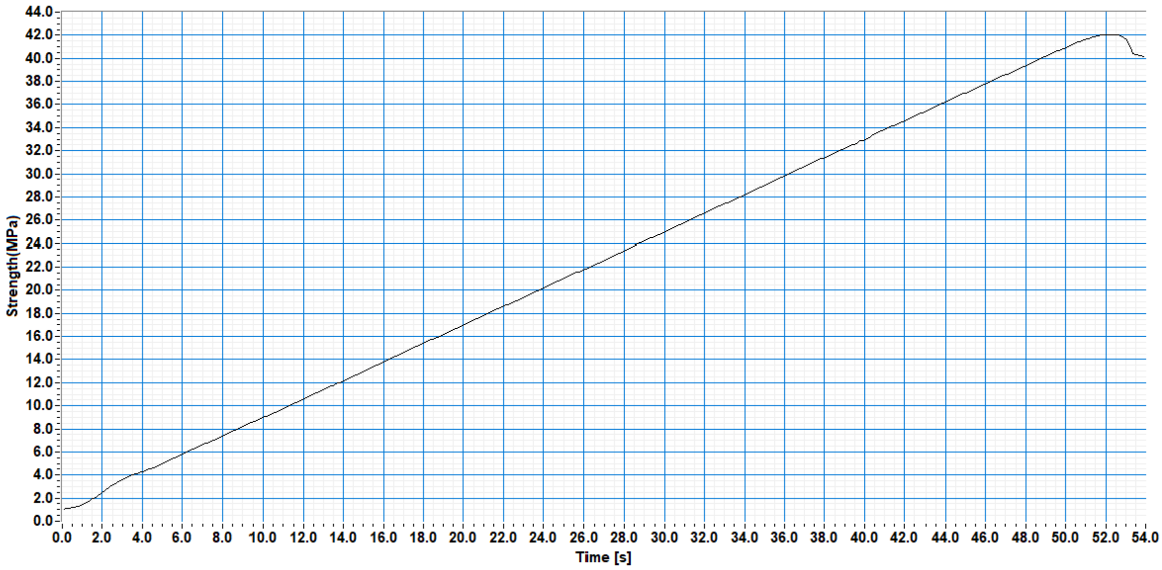
Specimen age [dd]: 7 DAYS

Load Rate [MPa/s]: 0.800 Test date: 11/09/2024

Max Load [kN]: 420.70 **Strength [MPa]: 42.07**

Failure type: Satisfactory

Notes: CUBE TRIAL (TIME TESTED 15:14)



Operator:
EDVARDS

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000771 ID 9377 Certificate date: 11/09/2024

Testing machine: COMPRESSION MACHINE

Client: ECO

Reference: AT002467.6

Specimen type: CUBE Cement quantity [kg/m³]: .

Cement type: . Preparation date: 04/09/2024

Sample conditions:

Condition when received: GOOD Condition at test time: SATISFACTORY

Sampling location: CRICKLEWOOD Sampling date: 04/09/2024

Preparation method: BY HAND

Specimen ID: CUBE 7 C50.60 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00

Area [mm2]: 10000.0 Mass [kg]: 2.443 Density [Kg/m3]: 2443.0

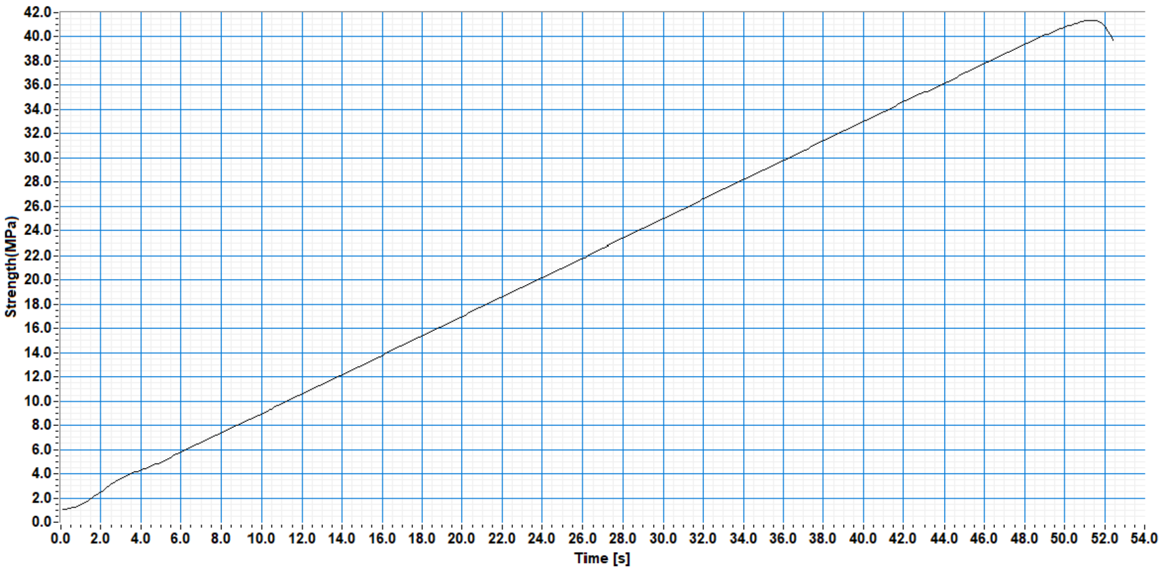
Specimen age [dd]: 7 DAYS

Load Rate [MPa/s]: 0.800 Test date: 11/09/2024

Max Load [kN]: 413.60 **Strength [MPa]: 41.36**

Failure type: Satisfactory

Notes: CUBE TRIAL (TIME TESTED 15:09)



Operator:
EDVARDS

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000771 - ID 9377
Certificate date: 09/09/2024
Testing machine: COMPRESSION MACHINE
Client: ECO
Reference: AT002467.5
Specimen type: CUBE
Cement quantity [kg/m³]: .
Cement type: .
Preparation date: 04/09/2024

Sample conditions:

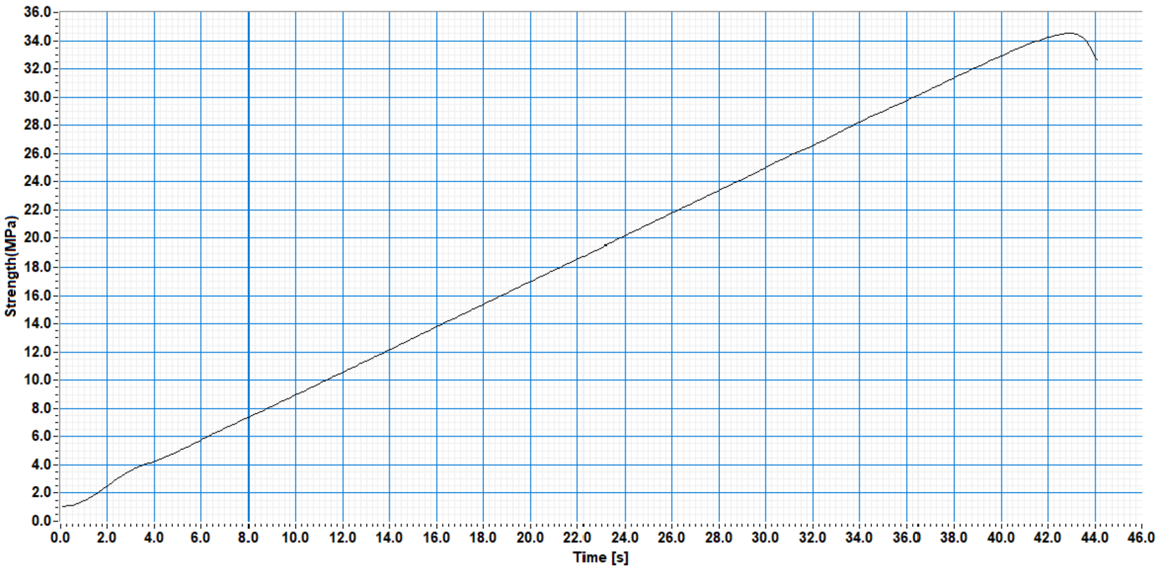
Condition when received: GOOD
Condition at test time: SATISFACTORY
Sampling location: CRICKLEWOOD
Sampling date: 04/09/2024
Preparation method: BY HAND
Specimen ID: CUBE 6 C50.60 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00
Area [mm2]: 10000.0 Mass [kg]: 2.448 Density [Kg/m3]: 2448.0
Specimen age [dd]: 5 DAYS
Load Rate [MPa/s]: 0.800 Test date: 09/09/2024

Max Load [kN]: 345.30 **Strength [MPa]: 34.53**

Failure type: Satisfactory

Notes: CUBE TRIAL (TIME TESTED - 14:03)



Operator:
EDVARDS

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000771 - ID 9377
Certificate date: 09/09/2024
Testing machine: COMPRESSION MACHINE
Client: ECO
Reference: AT002467.4
Specimen type: CUBE
Cement quantity [kg/m³]: .
Cement type: .
Preparation date: 04/09/2024

Sample conditions:

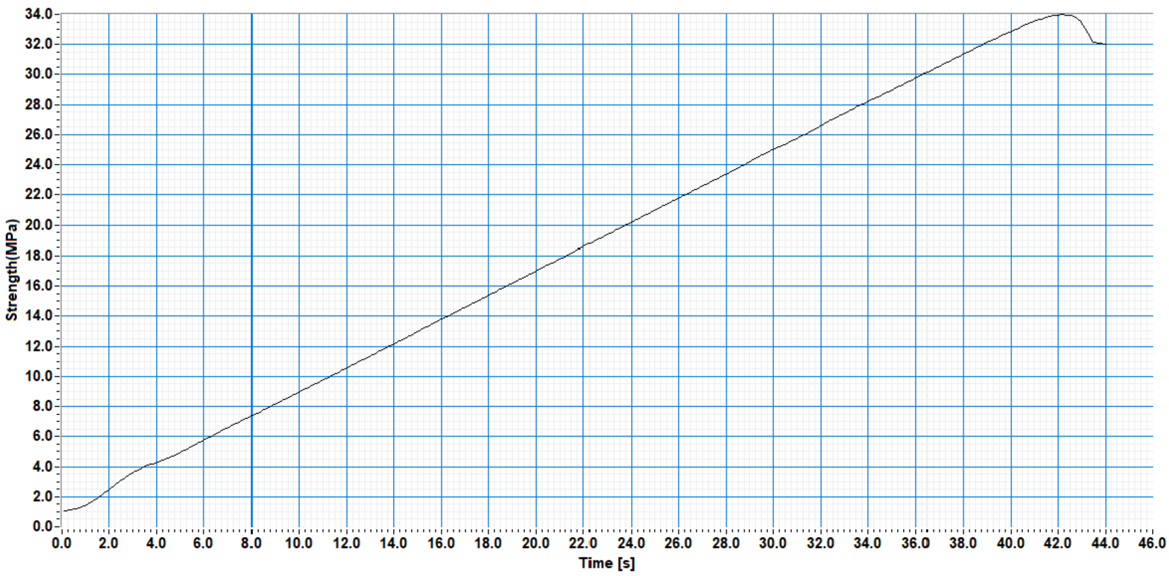
Condition when received: GOOD
Condition at test time: SATISFACTORY
Sampling location: CRICKLEWOOD
Sampling date: 04/09/2024
Preparation method: BY HAND
Specimen ID: CUBE 5 C50.60 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00
Area [mm2]: 10000.0 Mass [kg]: 2.427 Density [Kg/m3]: 2427.0
Specimen age [dd]: 5 DAYS
Load Rate [MPa/s]: 0.800
Test date: 09/09/2024

Max Load [kN]: 339.80 **Strength [MPa]: 33.98**

Failure type: Satisfactory

Notes: CUBE TRIAL (TIME TESTED - 14:00)



Operator:
EDVARDS

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000771
Certificate date: 07/09/2024
Testing machine: COMPRESSION MACHINE
Client: ECO
Reference: AT002467.3
Specimen type: CUBE
Cement quantity [kg/m³]: .
Cement type: .
Preparation date: 04/09/2024

Sample conditions:

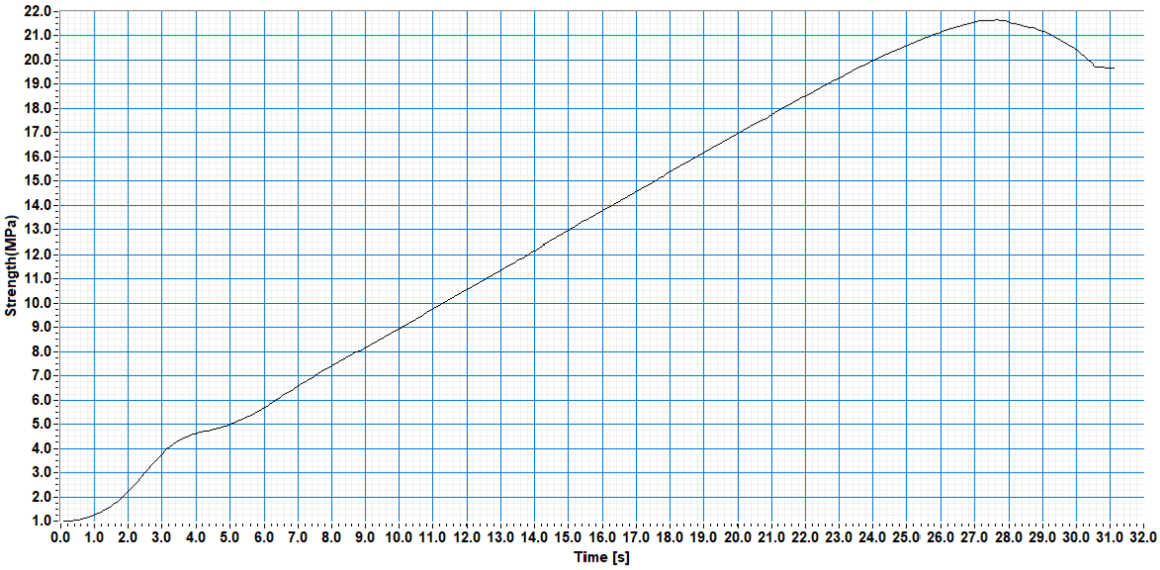
Condition when received: GOOD
Condition at test time: SATISFACTORY
Sampling location: CRICKLEWOOD
Sampling date: 04/09/2006
Preparation method: BY HAND
Specimen ID: CUBE 4 C50.60 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00
Area [mm2]: 10000.0
Mass [kg]: 2.362
Density [Kg/m3]: 2362.0
Specimen age [dd]: 3 DAYS
Load Rate [MPa/s]: 0.800
Test date: 07/09/2024

Max Load [kN]: 216.60
Strength [MPa]: 21.66

Failure type: Satisfactory

Notes: CAPITAL CONCRETE TRIAL



Operator:
LIAM

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000771
Certificate date: 07/09/2024
Testing machine: COMPRESSION MACHINE
Client: ECO
Reference: AT002467.2
Specimen type: CUBE
Cement quantity [kg/m³]: .
Cement type: .
Preparation date: 04/09/2024

Sample conditions:

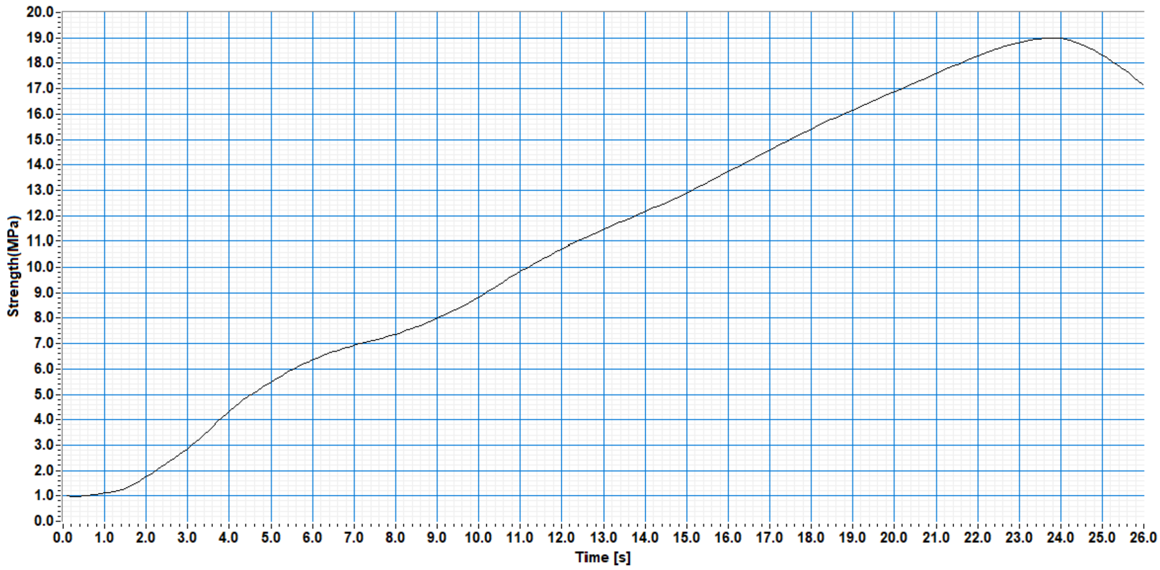
Condition when received: GOOD
Condition at test time: SATISFACTORY
Sampling location: CRICKLEWOOD
Sampling date: 04/09/2006
Preparation method: BY HAND
Specimen ID: CUBE 3 C50.60 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00
Area [mm2]: 10000.0
Mass [kg]: 2.357
Density [Kg/m3]: 2357.0
Specimen age [dd]: 3 DAYS
Load Rate [MPa/s]: 0.800
Test date: 07/09/2024

Max Load [kN]: 190.10
Strength [MPa]: 19.01

Failure type: Satisfactory

Notes: CAPITAL CONCRETE TRIAL



Operator:
LIAM

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000771
Certificate date: 05/09/2024
Testing machine: COMPRESSION MACHINE
Client: ECO
Reference: AT002467
Specimen type: CUBE
Cement quantity [kg/m³]: .
Cement type: .
Preparation date: 04/09/2024

Sample conditions:

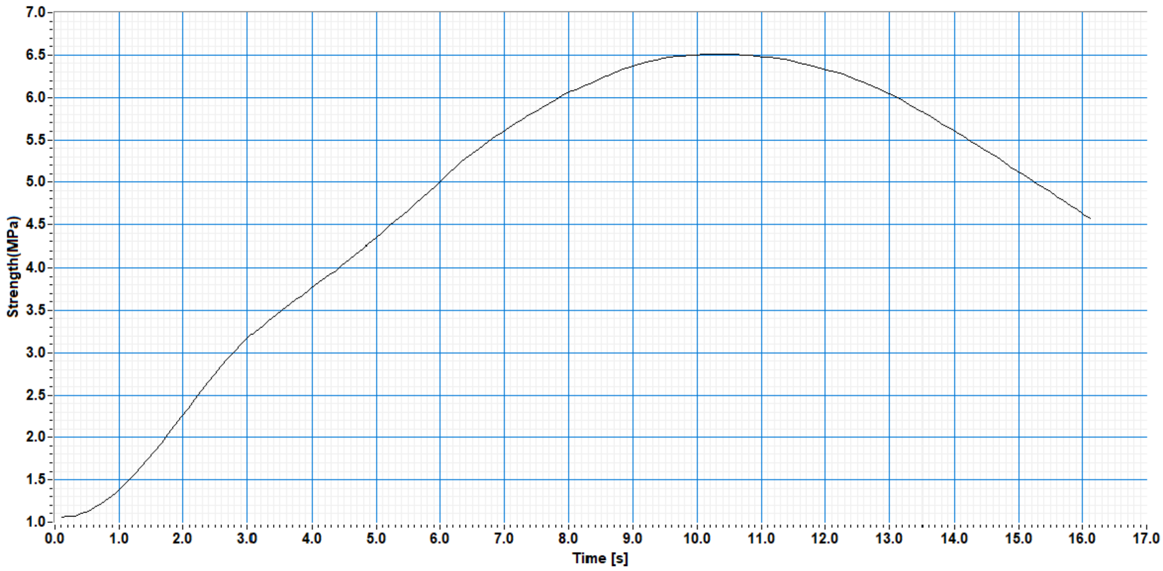
Condition when received: GOOD
Condition at test time: SATISFACTORY
Sampling location: CRICKLEWOOD
Sampling date: 04/09/2024
Preparation method: BY HAND
Specimen ID: CUBE 1 C50.60 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00
Area [mm2]: 10000.0 Mass [kg]: 2.348 Density [Kg/m3]: 2348.0
Specimen age [dd]: 24 HOURS
Load Rate [MPa/s]: 0.800 Test date: 05/09/2024

Max Load [kN]: 65.10 **Strength [MPa]: 6.51**

Failure type: Satisfactory

Notes: TRIAL



Operator:
LIAM

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number:	AMT-CRS-000771	Certificate date:	05/09/2024
Testing machine:	COMPRESSION MACHINE		
Client:	ECO		
Reference:	AT002467.1		
Specimen type:	CUBE	Cement quantity [kg/m³]:	.
Cement type:	.	Preparation date:	04/09/2024

Sample conditions:

Condition when received:	GOOD	Condition at test time:	SATISFACTORY
Sampling location:	CRICKLEWOOD	Sampling date:	04/09/2024
Preparation method:	BY HAND		
Specimen ID:	CUBE 2 C50.60 04.09.24		

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00

Area [mm2]: 10000.0 Mass [kg]: 2.354 Density [Kg/m3]: 2354.0

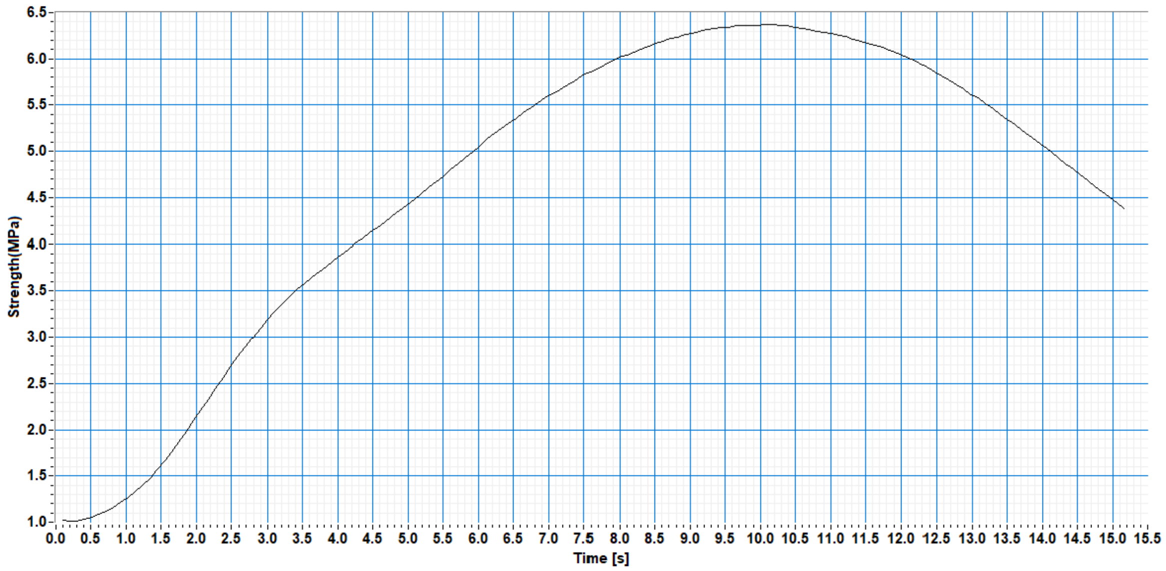
Specimen age [dd]: 24 HOURS

Load Rate [MPa/s]: 0.800 Test date: 05/09/2024

Max Load [kN]: 63.70 **Strength [MPa]: 6.37**

Failure type: Satisfactory

Notes: TRIAL



Operator:
LIAM

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000772 - ID 9369
Certificate date: 11/09/2024

Testing machine: COMPRESSION MACHINE

Client: ECO

Reference: AT002468.6

Specimen type: CUBE
Cement quantity [kg/m³]: .

Cement type: .
Preparation date: 04/09/2024

Sample conditions:

Condition when received: GOOD
Condition at test time: SATISFACTORY

Sampling location: CRICKLEWOOD
Sampling date: 04/09/2024

Preparation method: BY HAND

Specimen ID: CUBE 7 C40.50 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00

Area [mm2]: 10000.0 Mass [kg]: 2.367 Density [Kg/m3]: 2367.0

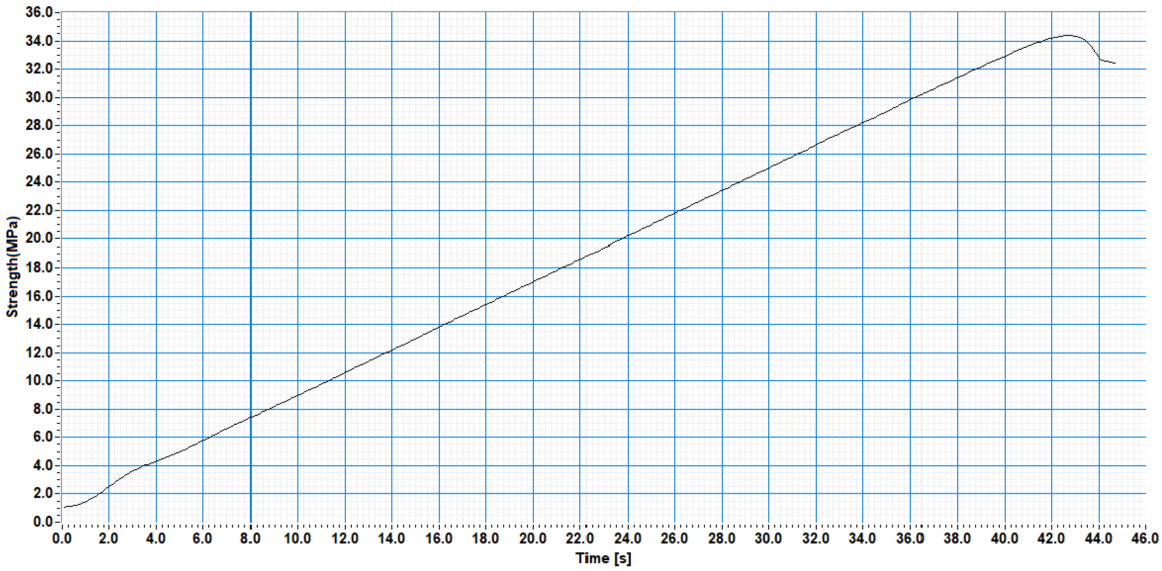
Specimen age [dd]: 7 DAYS

Load Rate [MPa/s]: 0.800
Test date: 11/09/2024

Max Load [kN]: 343.90 **Strength [MPa]: 34.39**

Failure type: Satisfactory

Notes: CUBE TRIAL (TIME TESTED 15:17)



Operator:
EDVARDS

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000772 - ID 9369

Certificate date: 11/09/2024

Testing machine: COMPRESSION MACHINE

Client: ECO

Reference: AT002468.7

Specimen type: CUBE

Cement quantity [kg/m³]: .

Cement type: .

Preparation date: 04/09/2024

Sample conditions:

Condition when received: GOOD

Condition at test time: SATISFACTORY

Sampling location: CRICKLEWOOD

Sampling date: 04/09/2024

Preparation method: BY HAND

Specimen ID: CUBE 8 C40.50 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00

Area [mm2]: 10000.0 Mass [kg]: 2.375 Density [Kg/m3]: 2375.0

Specimen age [dd]: 7 DAYS

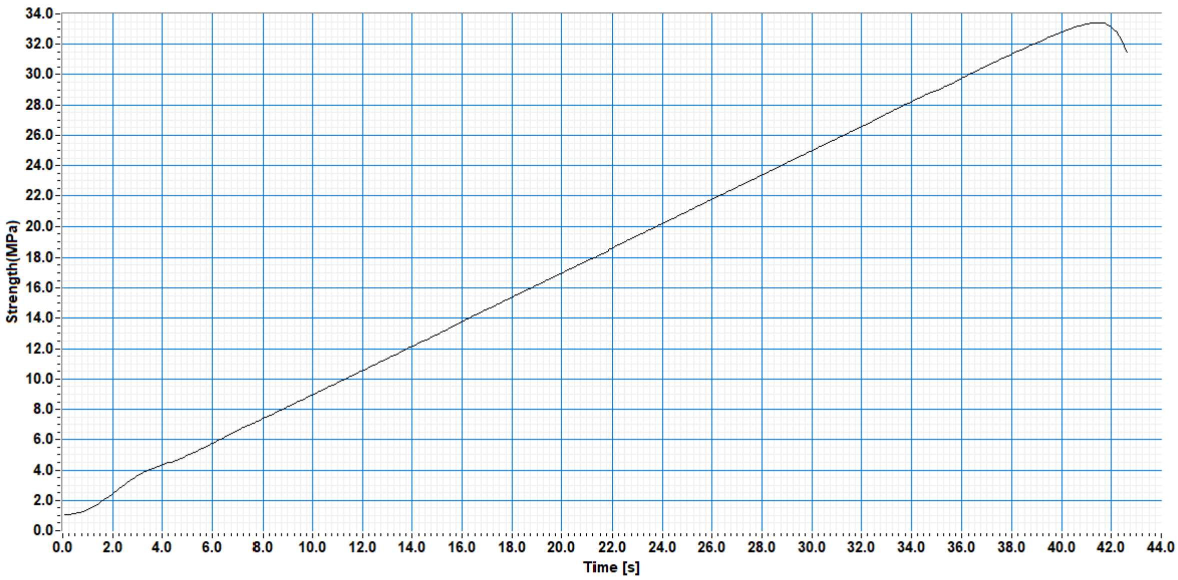
Load Rate [MPa/s]: 0.800

Test date: 11/09/2024

Max Load [kN]: 334.30 **Strength [MPa]: 33.43**

Failure type: Satisfactory

Notes: CUBE TRIAL (TIME TESTED 15:21)



Operator:
EDVARDS

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number:	AMT-CRS-000772 - ID 9369	Certificate date:	09/09/2024
Testing machine:	COMPRESSION MACHINE		
Client:	ECO		
Reference:	AT002468.4		
Specimen type:	CUBE	Cement quantity [kg/m³]:	.
Cement type:	.	Preparation date:	04/09/2024

Sample conditions:

Condition when received:	GOOD	Condition at test time:	SATISFACTORY
Sampling location:	CRICKLEWOOD	Sampling date:	04/09/2024
Preparation method:	BY HAND		
Specimen ID:	CUBE 5 C40.50 04.09.24		

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00

Area [mm2]: 10000.0 Mass [kg]: 2.375 Density [Kg/m3]: 2375.0

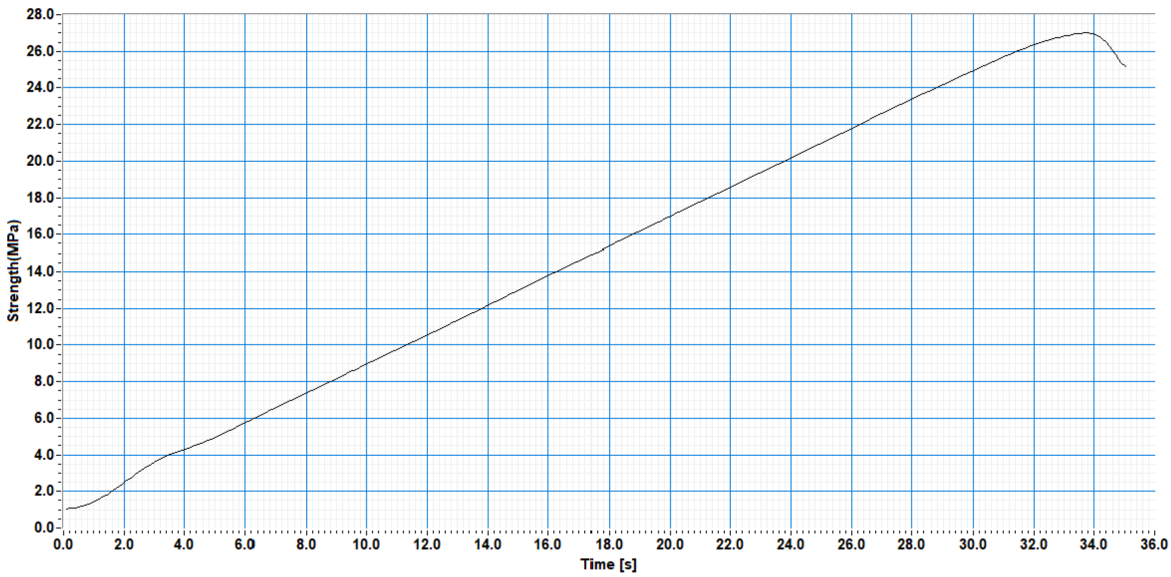
Specimen age [dd]: 5 DAYS

Load Rate [MPa/s]: 0.800 Test date: 09/09/2024

Max Load [kN]: 270.00 **Strength [MPa]: 27.00**

Failure type: Satisfactory

Notes: CUBE TRIAL (TIME TESTED - 12:00)



Operator:
EDVARDS

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number:	AMT-CRS-000772	Certificate date:	07/09/2024
Testing machine:	COMPRESSION MACHINE		
Client:	ECO		
Reference:	AT002468.2		
Specimen type:	CUBE	Cement quantity [kg/m³]:	.
Cement type:	.	Preparation date:	04/09/2024

Sample conditions:

Condition when received:	GOOD	Condition at test time:	SATISFACTORY
Sampling location:	CRICKLEWOOD	Sampling date:	04/09/2006
Preparation method:	BY HAND		
Specimen ID:	CUBE 3 C40.50 04.09.24		

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00

Area [mm2]: 10000.0 Mass [kg]: 2.361 Density [Kg/m3]: 2361.0

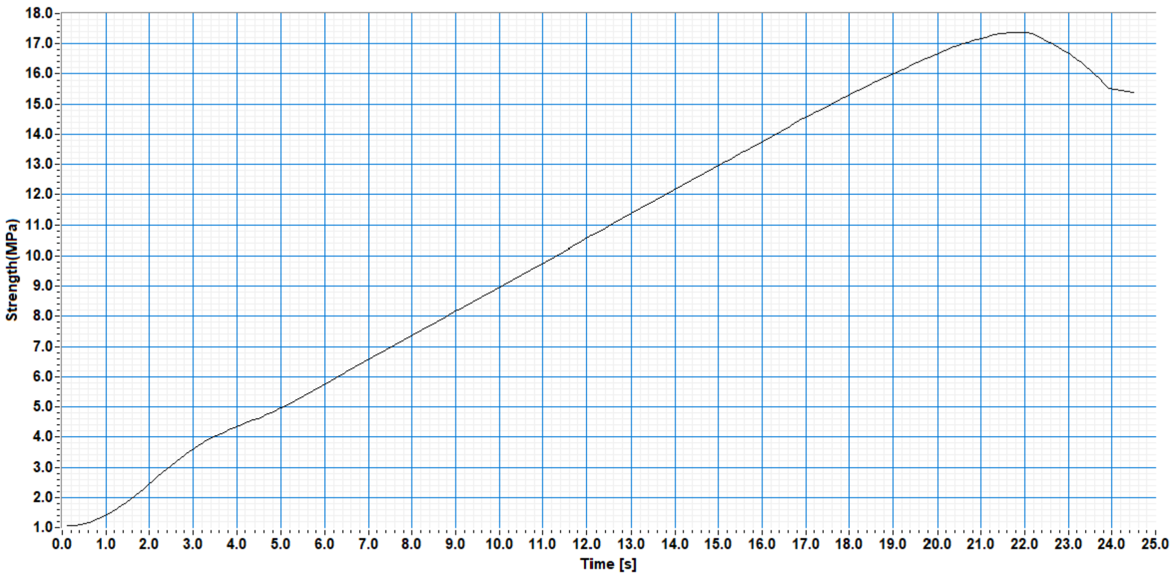
Specimen age [dd]: 3 DAYS

Load Rate [MPa/s]: 0.800 Test date: 07/09/2024

Max Load [kN]: 173.70 **Strength [MPa]: 17.37**

Failure type: Satisfactory

Notes: CAPITAL CONCRETE



Operator:
LIAM

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000772
Certificate date: 07/09/2024
Testing machine: COMPRESSION MACHINE
Client: ECO
Reference: AT002468.3
Specimen type: CUBE
Cement quantity [kg/m³]: .
Cement type: .
Preparation date: 04/09/2024

Sample conditions:

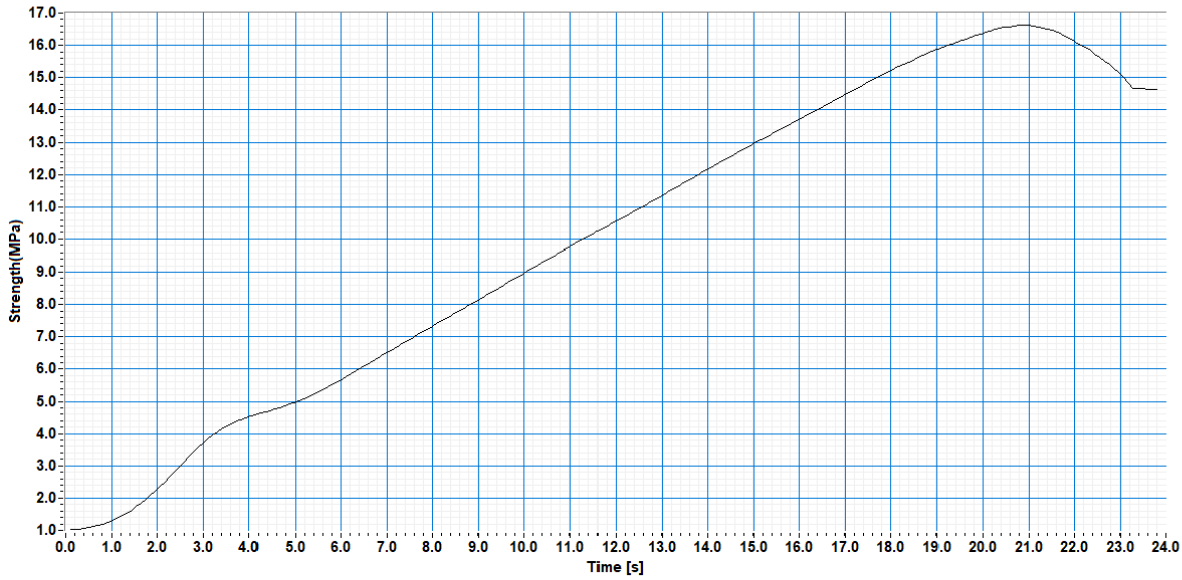
Condition when received: GOOD
Condition at test time: SATISFACTORY
Sampling location: CRICKLEWOOD
Sampling date: 04/09/2006
Preparation method: BY HAND
Specimen ID: CUBE 4 C40.50 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00
Area [mm2]: 10000.0
Mass [kg]: 2.365
Density [Kg/m3]: 2365.0
Specimen age [dd]: 3 DAYS
Load Rate [MPa/s]: 0.800
Test date: 07/09/2024

Max Load [kN]: 166.20
Strength [MPa]: 16.62

Failure type: Satisfactory

Notes: CAPITAL CONCRETE



Operator:
LIAM

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000772 Certificate date: 05/09/2024

Testing machine: COMPRESSION MACHINE

Client: ECO

Reference: AT002468.1

Specimen type: CUBE Cement quantity [kg/m³]: .

Cement type: . Preparation date: 04/09/2024

Sample conditions:

Condition when received: GOOD Condition at test time: SATISFACTORY

Sampling location: CRICKLEWOOD Sampling date: 04/09/2024

Preparation method: BY HAND

Specimen ID: CUBE 2 C40.50 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00

Area [mm2]: 10000.0 Mass [kg]: 2.361 Density [Kg/m3]: 2361.0

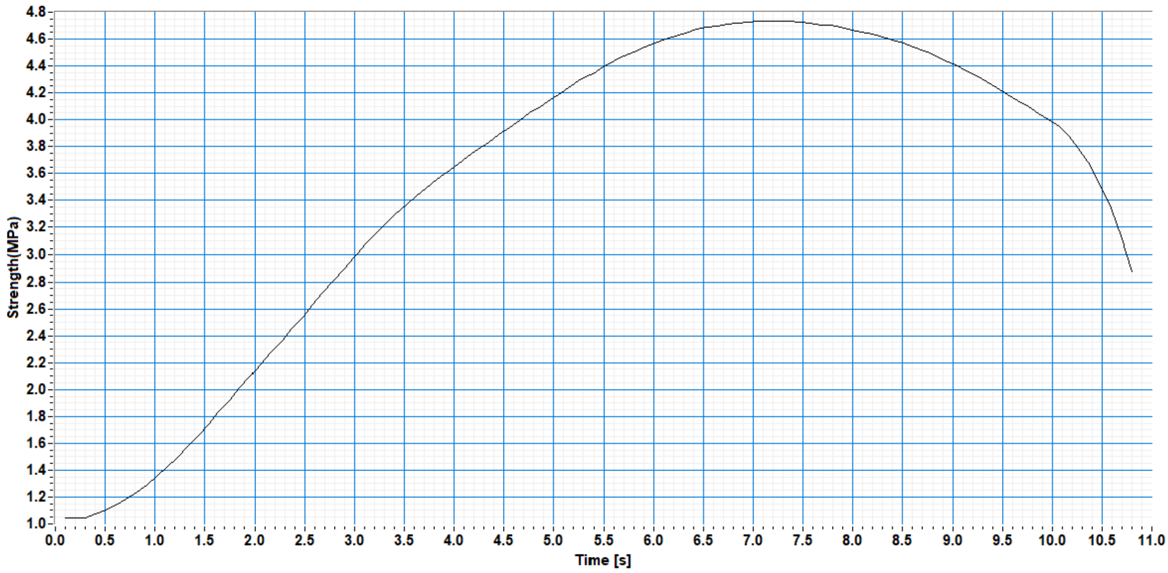
Specimen age [dd]: 24 HOURS

Load Rate [MPa/s]: 0.800 Test date: 05/09/2024

Max Load [kN]: 47.40 **Strength [MPa]: 4.74**

Failure type: Satisfactory

Notes: TRIAL



Operator:
LIAM

AMTEST LAB

Compression test on concrete: EN 12390-3

Certificate number: AMT-CRS-000772 - ID 9369
Certificate date: 09/09/2024
Testing machine: COMPRESSION MACHINE
Client: ECO
Reference: AT002468.5
Specimen type: CUBE
Cement quantity [kg/m³]: .
Cement type: .
Preparation date: 04/09/2024

Sample conditions:

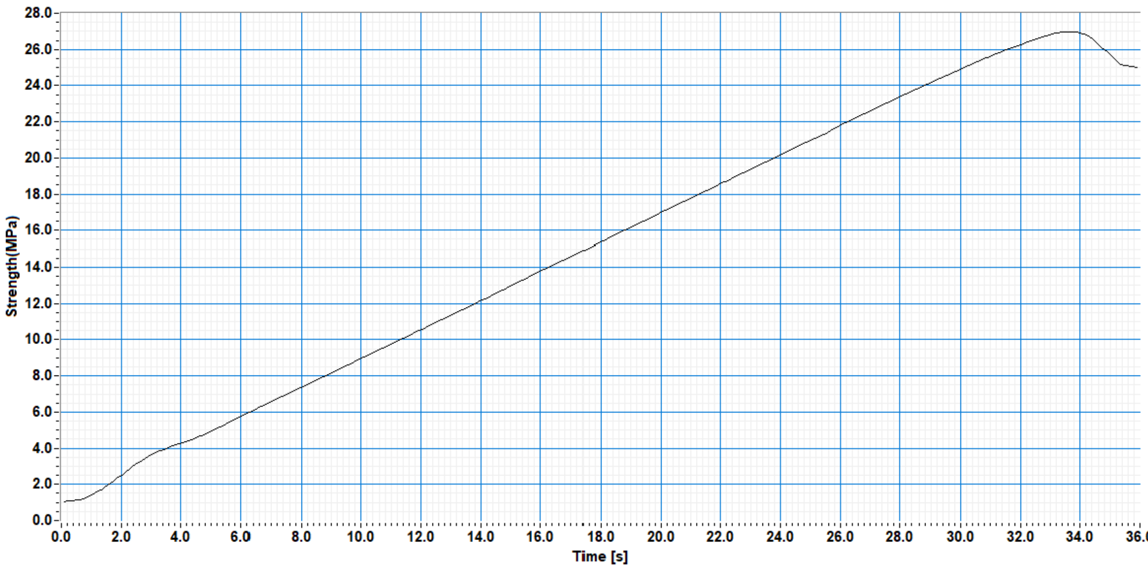
Condition when received: GOOD
Condition at test time: SATISFACTORY
Sampling location: CRICKLEWOOD
Sampling date: 04/09/2024
Preparation method: BY HAND
Specimen ID: CUBE 6 C40.50 04.09.24

Dimensions: a(mm) 100.00 b(mm) 100.00 c(mm) 100.00
Area [mm2]: 10000.0
Mass [kg]: 2.383
Density [Kg/m3]: 2383.0
Specimen age [dd]: 5 DAYS
Load Rate [MPa/s]: 0.800
Test date: 09/09/2024

Max Load [kN]: 269.80
Strength [MPa]: 26.98

Failure type: Satisfactory

Notes: CUBE TRIAL (TIME TESTED - 12:04)



Operator:
EDVARDS

Appendix G – Capital Concrete Cube Results

Cube Results Summary

Capital Concrete Ltd
Capital Concrete Ltd
Brett House
St Michaels Close
Aylesford, Kent
ME20 7EX
Tel. 0203 974 0520

18.03.25
www.capitalconcrete.co.uk

Customer	John Sisk.
Site	EcocemACT Mock Up Fulton Road. Wembley.

Ticket No	Sampled	Mix Details	Cementitious	Age	Density	N/mm2	Age	Density	N/mm2	Age	Density	N/mm2
34025863	25/11/2024	C40/50	ECOCEMACT	7	2349	34.5	28	2348	57.0	56	2358	67.1
34025866	25/11/2024	C40/50	ECOCEMACT	7	2356	31.9	28	2343	55.6	56	2353	60.5
34026199	02/12/2024	C40/50	ECOCEMACT	7	2365	34.8	28	2370	62.3	56	2372	65.1
34026382	05/12/2024	C50/60	ECOCEMACT	7	2408	47.8	28	2447	74.6	56	2445	85.9
34026748	12/12/2024	C40/50	ECOCEMACT	7	2345	31.8	28	2375	58.5	56	2395	65.0
34027459	14/01/2025	C40/50	ECOCEMACT	7	2343	32.1	28	2380	53.1	56	2382	60.2

Issue Date:03.02.2025 | N.B. these samples form part of Capital Concrete conformity testing regime

Jack Sindhu.
PGDip Advanced Concrete Technology,MCS, MICT
Technical Director.

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Appendix H – Harringtons Cube Results

CTSL CONCRETE TESTING SOLUTIONS LIMITED

PRELIMINARY CUBE TEST DATA

(BS EN 12390-1: 2021, 2: 2019, 3: 2019, 7: 2019)

12 Boughton Road
Thamesmead
London
SE28 0AG
Tel: 02036590524

UKAS TESTING 9436

Client: Harringtons Builders Plc
Harrington House
Middlesex HA90LH

Scheme: Fulton Road

Contract no: C12667

Request Sheet No.	Lab Ref.	Client Ref.	Date Made	Time Made	Date Received	Date Tested	Age Days	Weight kg	Sample Location	Density kg/m3	Load kN	Cube Strength Mpa	Spec Strgth at 28 days Mpa
FP1	572893	1A	25/11/2024		03/12/2024	04/12/2024	9	8.105	MOCK UP RAFT SLAB	2400	772.3	34.3	C50
FP1	577328	1B	25/11/2024		03/12/2024	16/12/2024	21	8.205	MOCK UP RAFT SLAB	2430	1058.8	47.1	C50
FP1	579814	1C	25/11/2024		03/12/2024	23/12/2024	28	8.148	MOCK UP RAFT SLAB	2410	1297.3	57.7	C50
FP1	584632	1D	25/11/2024		03/12/2024	20/01/2025	56	8.014	MOCK UP RAFT SLAB	2380	1424.5	63.3	C50
110391	572186	25.11.A	25/11/2024	12:00	25/11/2024	02/12/2024	7	2.372	RAFT SLAB , SCELABLE LOW CARBON	2370	373.6	37.4	C50
110391	575328	25.11.B	25/11/2024	12:00	25/11/2024	09/12/2024	14	2.345	RAFT SLAB , SCELABLE LOW CARBON	2350	452.3	45.2	C50
110391	580111	25.11.C	25/11/2024	12:00	25/11/2024	23/12/2024	28	2.398	RAFT SLAB , SCELABLE LOW CARBON	2400	543.1	54.3	C50
110391	584633	25.11.D	25/11/2024	12:00	25/11/2024	20/01/2025	56	2.339	RAFT SLAB , SCELABLE LOW CARBON	2340	624.8	62.5	C50

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CTSL Concrete Testing Solutions Limited

PRELIMINARY CUBE TEST DATA

(BS EN 12390-1: 2021, 2: 2019, 3: 2019, 7: 2019)

UKAS Testing 9436

12 Boughton Road
Thamesmead
London
SE28 0AG
Tel: 02036590524

Client: Harringtons Builders Plc
Harrington House
Middlesex HA90LH

Scheme: Fulton Road

Contract no: C12667

Request Sheet No.	Lab Ref.	Client Ref.	Date Made	Time Made	Date Received	Date Tested	Age Days	Weight kg	Sample Location	Density kg/m3	Load kN	Cube Strength Mpa	Spec Strgth at 28 days Mpa
110391A	572187	25.11.E	25/11/2024	12:00	25/11/2024	02/12/2024	7	2.396	RAFT SLAB , SCELABLE LOW CARBON	2400	377.5	37.8	C50
110391A	575347	25.11.F	25/11/2024	12:00	25/11/2024	09/12/2024	14	2.385	RAFT SLAB , SCELABLE LOW CARBON	2390	462.7	46.3	C50
110391A	580112	25.11.G	25/11/2024	12:00	25/11/2024	23/12/2024	28	2.481	RAFT SLAB , SCELABLE LOW CARBON	2480	521.3	52.1	C50
110391A	584634	25.11.H	25/11/2024	12:00	25/11/2024	20/01/2025	56	2.427	RAFT SLAB , SCELABLE LOW CARBON	2430	609.9	61.0	C50
FP2	574539	2A	02/12/2024		03/12/2024	09/12/2024	7	8.139	MOCK UP GF SLAB	2410	771.9	34.3	C50
FP2	581456	2B	02/12/2024		03/12/2024	23/12/2024	21	7.854	MOCK UP GF SLAB	2330	1116.3	49.6	C50
FP2	581722	2C	02/12/2024		03/12/2024	30/12/2024	28	8.077	MOCK UP GF SLAB	2390	1226.8	54.5	C50
FP2	586036	2D	02/12/2024		03/12/2024	27/01/2025	56	7.894	MOCK UP GF SLAB	2340	1417.9	63.0	C50

PRELIMINARY CUBE TEST DATA

(BS EN 12390-1: 2021, 2: 2019, 3: 2019, 7: 2019)

CTSL Concrete Testing Solutions Limited

12 Boughton Road
Thamesmead
London
SE28 0AG
Tel: 02036590524

UKAS TESTING 9436

Client: Harringtons Builders Plc
Harrington House
Middlesex HA90LH

Scheme: Fulton Road

Contract no: C12667

Request Sheet No.	Lab Ref.	Client Ref.	Date Made	Time Made	Date Received	Date Tested	Age Days	Weight kg	Sample Location	Density kg/m3	Load kN	Cube Strength Mpa	Spec Strgth at 28 days Mpa
109521	574386	05.12.A	05/12/2024		05/12/2024	07/12/2024	2	2.530	LOW CARBON COLUMNS + FLOORS, GF-1ST FLOOR	2530	290.7	29.1	C60
109521	574387	05.12.B	05/12/2024		05/12/2024	08/12/2024	3	2.418	LOW CARBON COLUMNS + FLOORS, GF-1ST FLOOR	2420	331.5	33.2	C60
109521	576079	05.12.C	05/12/2024		05/12/2024	12/12/2024	7	2.526	LOW CARBON COLUMNS + FLOORS, GF-1ST FLOOR	2530	456.2	45.6	C60
109521	578683	05.12.D	05/12/2024		05/12/2024	19/12/2024	14	2.491	LOW CARBON COLUMNS + FLOORS, GF-1ST FLOOR	2490	509.3	50.9	C60
109521	581994	05.12.E	05/12/2024		05/12/2024	02/01/2025	28	2.478	LOW CARBON COLUMNS + FLOORS, GF-1ST FLOOR	2480	634.8	63.5	C60
109521	586527	05.12.F	05/12/2024		05/12/2024	30/01/2025	56	2.408	LOW CARBON COLUMNS + FLOORS, GF-1ST FLOOR	2410	687.9	68.8	C60
FR/3	576828	3A	05/12/2024		13/12/2024	13/12/2024	8	8.413	MOCK UP COLUMNS WALLS	2490	840.3	37.3	C60
FR/3	578776	3B	05/12/2024		13/12/2024	19/12/2024	14	8.378	MOCK UP COLUMNS WALLS	2480	1219.8	54.2	C60

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CTSL Concrete Testing Solutions Limited

PRELIMINARY CUBE TEST DATA

(BS EN 12390-1: 2021, 2: 2019, 3: 2019, 7: 2019)

UKAS Testing 9436

12 Boughton Road
Thamesmead
London
SE28 0AG
Tel: 02036590524

Client: Harringtons Builders Plc
Harrington House
Middlesex HA90LH

Scheme: Fulton Road

Contract no: C12667

Request Sheet No.	Lab Ref.	Client Ref.	Date Made	Time Made	Date Received	Date Tested	Age Days	Weight kg	Sample Location	Density kg/m3	Load kN	Cube Strength Mpa	Spec Strgth at 28 days Mpa
FR/3	581143	3C	05/12/2024		13/12/2024	02/01/2025	28	8.319	MOCK UP COLUMNS WALLS	2470	1464.2	65.1	C60
FR/3	586528	3D	05/12/2024		13/12/2024	30/01/2025	56	8.204	MOCK UP COLUMNS WALLS	2430	1604.5	71.3	C60
FR/1	579099	1A	12/12/2024		13/12/2024	19/12/2024	7	7.954	MOCK UP 1ST FLOOR SLAB PT CABLE	2360	532.6	23.7	C50
FR/1	581429	1B	12/12/2024		13/12/2024	27/12/2024	15	8.008	MOCK UP 1ST FLOOR SLAB PT CABLE	2370	843.8	37.5	C50
FR/1	582212	1C	12/12/2024		13/12/2024	09/01/2025	28	8.117	MOCK UP 1ST FLOOR SLAB PT CABLE	2410	1126.2	50.1	C50
FR/1	588431	1D	12/12/2024		13/12/2024	06/02/2025	56	7.893	MOCK UP 1ST FLOOR SLAB PT CABLE	2340	1287.5	57.2	C50
FR/2	576827	2A	12/12/2024		13/12/2024	13/12/2024	1	8.185	MOCK UP 1ST FLOOR SLAB PT CABLE	2430	80.7	3.6	C50
FR/2	577408	2B	12/12/2024		13/12/2024	16/12/2024	4	7.854	MOCK UP 1ST FLOOR SLAB PT CABLE	2330	251.3	11.2	C50

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CONCRETE TESTING SOLUTIONS LIMITED

PRELIMINARY CUBE TEST DATA

(BS EN 12390-1: 2021, 2: 2019, 3: 2019, 7: 2019)

12 Boughton Road
Thamesmead
London
SE28 0AG
Tel: 02036590524

9436

Client: Harringtons Builders Plc
Harrington House
Middlesex HA90LH

Scheme: Fulton Road

Contract no: C12667

Request Sheet No.	Lab Ref.	Client Ref.	Date Made	Time Made	Date Received	Date Tested	Age Days	Weight kg	Sample Location	Density kg/m3	Load kN	Cube Strength Mpa	Spec Strgth at 28 days Mpa
FR/2	578567	2C	12/12/2024		13/12/2024	18/12/2024	6	8.132	MOCK UP 1ST FLOOR SLAB PT CABLE	2410	419.5	18.6	C50
FR/2	579097	2D	12/12/2024		13/12/2024	19/12/2024	7	8.025	MOCK UP 1ST FLOOR SLAB PT CABLE	2380	451.3	20.1	C50
C667/14.01	584958	./14.01.A	14/01/2025	08:30	21/01/2025	22/01/2025	8	8.021	MOCK-UP 2ND FLOOR SLAB	2380	730.3	32.5	C50
C667/14.01	590486	./14.01.B	14/01/2025	08:30	21/01/2025	11/02/2025	28	8.016	MOCK-UP 2ND FLOOR SLAB	2380	1202.3	53.4	C50
C667/14.01	590485	./14.01.C	14/01/2025	08:30	21/01/2025	11/02/2025	28	7.856	MOCK-UP 2ND FLOOR SLAB	2330	1256.3	55.8	C50
C667/14.01	600954	./14.01.D	14/01/2025	08:30	21/01/2025	11/03/2025	56	7.896	MOCK-UP 2ND FLOOR SLAB	2340	1357.8	60.3	C50
FR/1A	584735	14.01.A	14/01/2025		16/01/2025	21/01/2025	7	8.059	MOCK UP SECOND FLOOR SLAB	2390	676.1	30.0	C50
FR/1A	589803	14.01.B	14/01/2025		16/01/2025	11/02/2025	28	7.949	MOCK UP SECOND FLOOR SLAB	2360	1168.9	52.0	C50

NB: this data summary does not replace the final laboratory report and is issued on the strict understanding that it is subject to verification and laboratory approval. Data must not be extracted or republished without prior written approval.

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CTSL Concrete Testing Solutions Limited

PRELIMINARY CUBE TEST DATA

(BS EN 12390-1: 2021, 2: 2019, 3: 2019, 7: 2019)

UKAS Testing 9436

12 Boughton Road
Thamesmead
London
SE28 0AG
Tel: 02036590524

Client: Harringtons Builders Plc
Harrington House
Middlesex HA90LH

Scheme: Fulton Road

Contract no: C12667

Request Sheet No.	Lab Ref.	Client Ref.	Date Made	Time Made	Date Received	Date Tested	Age Days	Weight kg	Sample Location	Density kg/m3	Load kN	Cube Strength Mpa	Spec Strgth at 28 days Mpa
FR/1A	589804	14.01.C	14/01/2025		16/01/2025	11/02/2025	28	7.875	MOCK UP SECOND FLOOR SLAB	2330	1128.9	50.2	C50
FR/1A	600955	14.01.D	14/01/2025		16/01/2025	11/03/2025	56	7.905	MOCK UP SECOND FLOOR SLAB	2340	1324.6	58.9	C50

NB: this data summary does not replace the final laboratory report and is issued on the strict understanding that it is subject to verification and laboratory approval. Data must not be extracted or republished without prior written approval.

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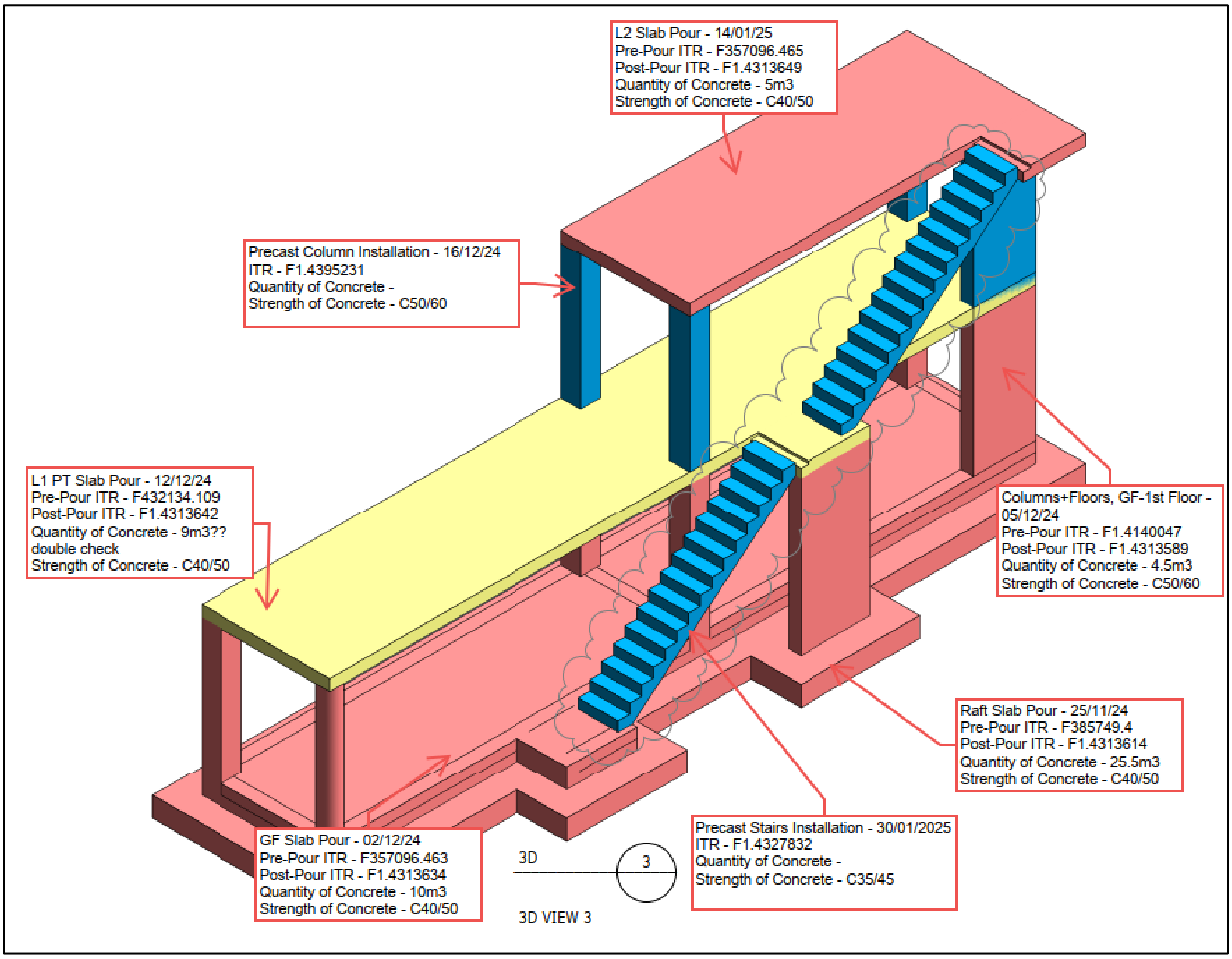
Appendix I - Fieldview Forms – Pre-Pours, Post-Pours, Precast Installation

The table and diagram below show the quality forms for the different pours of the SLCD project. Reports are available on request.

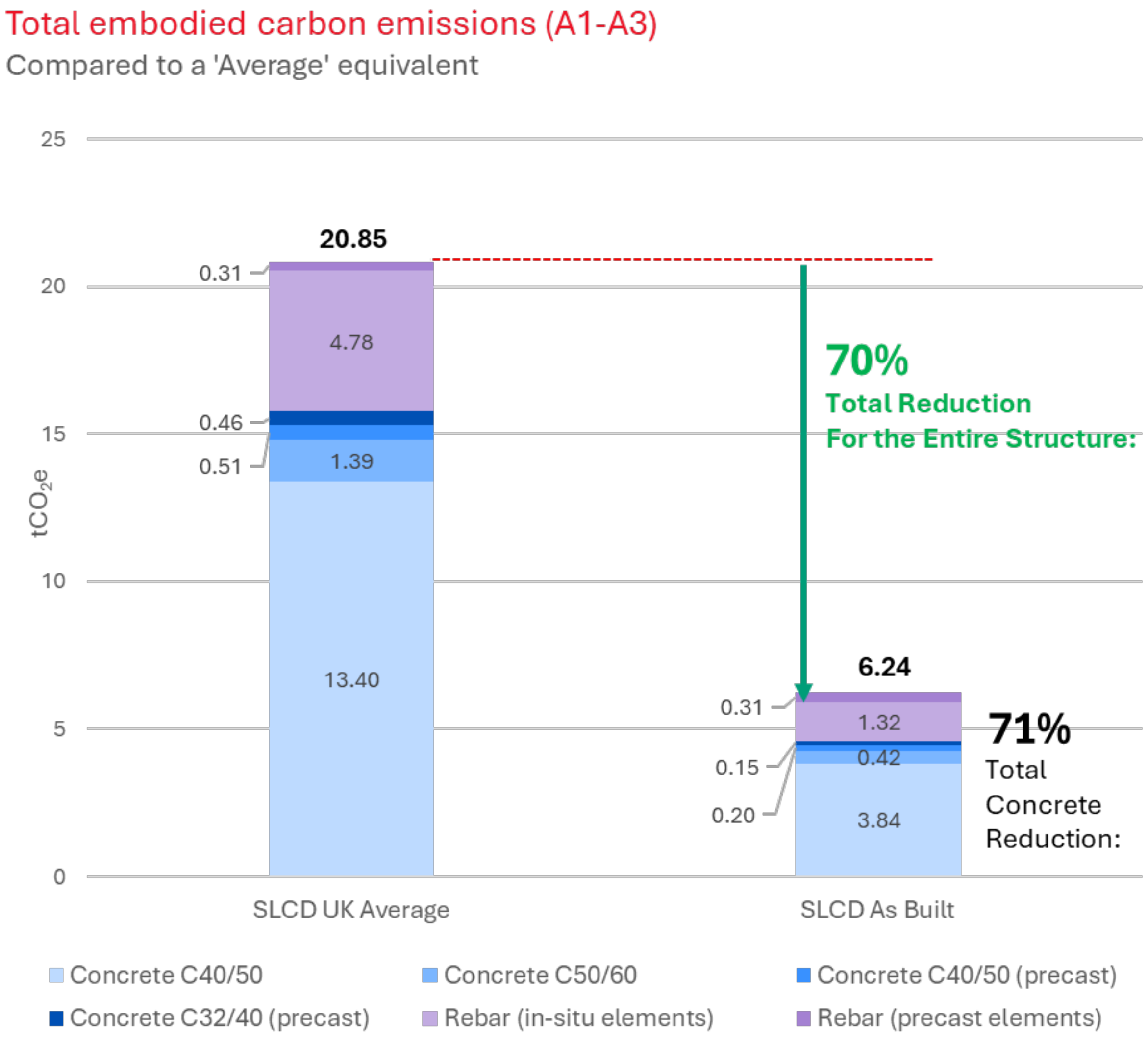
Pre-Pour ITR Number	Date Created	Post-Pour ITR Number	Date Created	Location
F385749.4	25/11/2024	F1.4313614	29/01/2025	Raft Slab
F357096.463	02/11/2024	F1.4313634	29/01/2025	GF Slab
F1.4140047	05/11/2024	F1.4313589	29/01/2025	GF Columns
F432134.109	12/12/2024	F1.4313642	29/01/2025	L1 PT Slab
F357096.465	13/01/2025	F1.4313649	29/01/2025	L2 Slab

ITR Number	Date Created	Location
F1.439523.1	14/02/2024	Precast Column Installation
F1.4327832	31/01/2024	Precast Stairs Installation



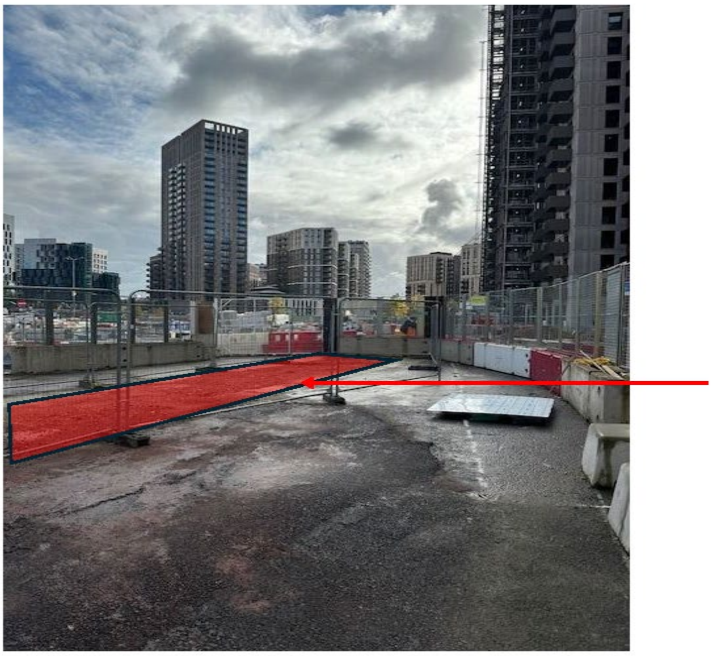
Appendix J – Embodied Carbon Reductions

An Embodied Carbon analysis was conducted for the materials installed in Scalable Low Carbon Demonstrator structure and compared to a UK average alternative scenario. The concrete mixes used represent over 70% reduction compared to UK average.



Appendix K – Harringtons Finding Report

LOW CARBON DEMONSTRATOR PROJECT



Location of Low Carbon Demonstrator Project

Key Pour Dates :

Works commenced on 18-11-24

Foundation slab poured on 25-11-24 using a 20-metre concrete pump- Total C40/50 concrete volume 22m3

Ground Floor slab poured on 02-12-24 using a 20-metre concrete pump- Total C40/50concrete volume 10m3

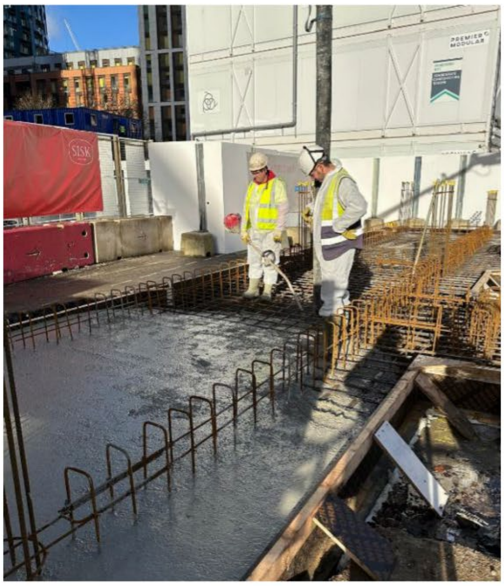
Verts from GF to Level 1 poured on 05-12-24 using concrete skip- Total C50/60 concrete volume 4.5m3

First Floor slab poured on 12-12-24 using a 24-metre concrete pump- Total C40/50 concrete volume 9m3

Roof slab poured on 14-01-25 using a 24-metre concrete pump- Total C40/50 concrete volume 4.3m3

Pumping the mix

On the Raft slab pour, the concrete pump operator stipulated that he needed to use more pressure to pump the mix through the line. This did not affect us on our pour as we were only pouring a short distance. Concrete slump was consistent with S4 range however when a gap of 30 minutes between loads was experienced, the concrete was noticeably stiffer.



Applying concrete finishes.

Power float

The power float performed very well with this mix as the mix seems to close itself during the tamping and leveling process. This means the power float has less ridges to deal with and speeds up the process of achieving a universal flat surface.

Please note, we did not attempt a polished finish with the power float and left a slight texture to it.

We do not envisage any difficulty in achieving tight tolerances with this mix.

Applying concrete finishes.

Brush finish

This finish was a little more difficult to achieve due to the mix closing itself. However, it should be noted that it may be possible to achieve if the mix had cured more before applying the brush.

We would recommend trying this again in possibly warmer conditions when more time could be given to cure and possibly prevent the concrete closing the lines that the brush applys.

Applying concrete finishes.

Easy float

When applying the easy float, our concrete finishers said that by applying a small amount of water, it allowed the easy float to glide more smoothly across the mix and not stick to the mix. When the easy float was applied without water, it tended to pull the mix with it causing the level of the concrete to drop which can lead to tolerance issues and ridges forming.

It should be noted that this is can also occur with normal CEM1 mixes.

When the float was applied with a small amount of water when the concrete was starting to tighten, a very good finish was achieved, possibly better than what is usually achieved with a CEM1 Mix.

Applying concrete finishes.

Hand trowel

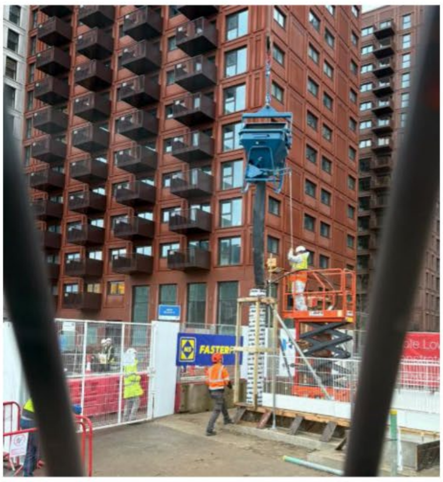
When applying the hand trowel, our concrete finishers said that the trowel sticks to the mix. This then pulls the mix with it causing the level of the concrete to drop which can lead to tolerance issues and ridges forming. Some water helps here however as the trowel has a smaller surface area than the easy float, it tends to not achieve as good a finish as the easy float.

It should be noted that this is can also occur with normal CEM1 mixes.

One good thing to note with this mix is that there appears to be little to no bleeding of water from the mix itself. This is very beneficial when trying to eliminate ponding.

Insitu- Concrete column pouring.

During the pouring of the columns, it should be noted that the mix tended to fill the trunk of the skip first before discharging into the column box. This could be due to the stick nature of the mix. This did not appear to have an adverse affect on the finish, it just prolonged the time taken to fill the column box.



SISK ESTD. 1859

HARRINGTONS BUILDERS PLC

Insitu- Concrete column finishes.

In general, the concrete finish achieved on the In-situ columns was on par with what is usually achieved with a CEM1 mix with a lot of plasticizer in it. For the columns we used the 3 different types of ply below and they rated in the order they are listed

Canadian Pour form 107-Performed best
Tulsa- Good quality
Chinese film faced- Adequate

Unfortunately, the finish to the Radius column did not meet our expectations and we are attempting another mock pour using a smaller form on the ground floor. This could be due to the quality of the mould used or pokering.

SISK ESTD. 1859

HARRINGTONS BUILDERS PLC

General thoughts and observations

Overall, our team have mainly positive feedback for this mix. One main observation that was consistently raised was its sticky nature. This will generally be down to the use of admixtures and can also be common of other CEM1 mixes. The concrete finishers found that it was generally took more effort to level the concrete using the spazzles . The concrete would stick to the spazzle and make it heavier to drag the concrete across the slab to level it off.

With the power floating, the time it takes for this concrete to go off enough to start finishing is generally 2-3 hours more than with a normal CEM1 mix.

We look forward to working with this mix more frequently on future projects and would welcome further collaboration with both Sisk & Ecocem.

Appendix L – Coverage Report

Concrete Report

converge

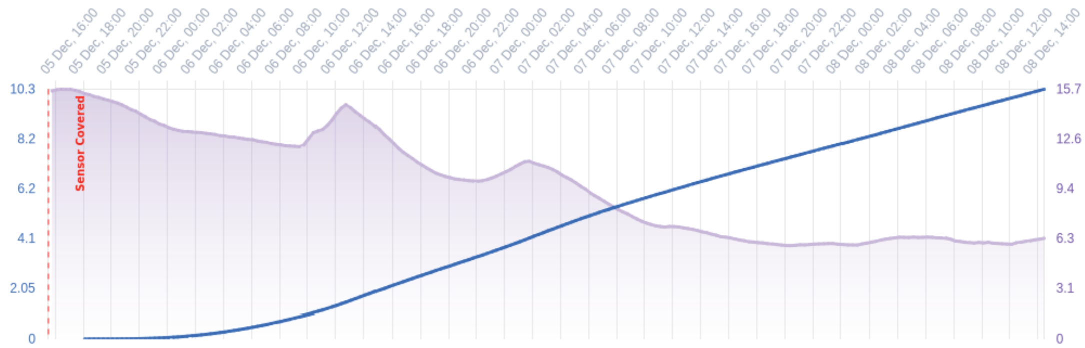
Wembley Park

Wall 1400mm / Signal 1 Signal 1

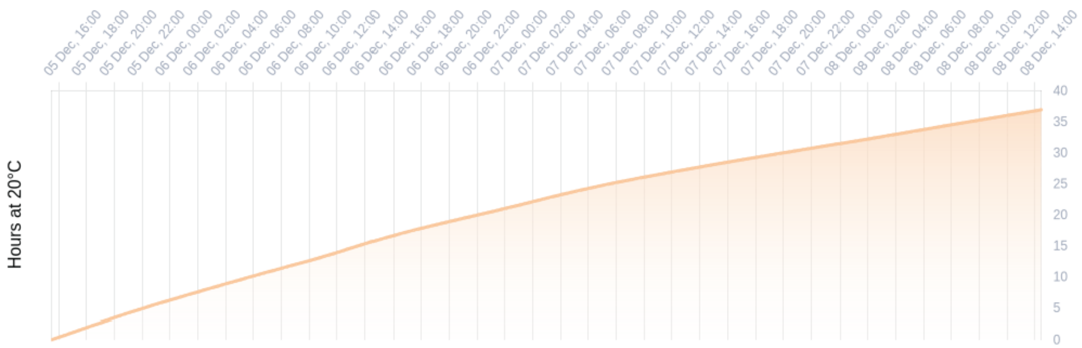
Report generated on Oct 20th, 2025 by Aled Roberts

10.3 MPa	6.3 °C	15.7 °C	5.8 °C
Compressive Strength	Temperature	Highest Temperature	Lowest Temperature
Dec 8th, 2024, 14:27	Dec 8th, 2024, 14:27	Dec 5th, 2024, 16:25	Dec 7th, 2024, 20:26

Temperature & Strength over Time



Equivalent age



Concrete Report

Wembley Park

Wall 1400mm / Signal 1 Signal 1

Report generated on Oct 20th, 2025 by Aled Roberts

Activity History

Sensor Registered	Dec 4th, 2024, 12:42 by Flavius
Sensor Covered	Dec 5th, 2024, 15:27
Finished Monitoring	Dec 8th, 2024, 14:37

Compressive Strength History

10.3MPa	Dec 8th, 2024, 14:27 (last recorded strength)

Concrete Mix Details

Mix Name:	C50/60
Calibrated:	Nov 21st, 2024, 10:24
Consistence:	

Concrete Report

converge

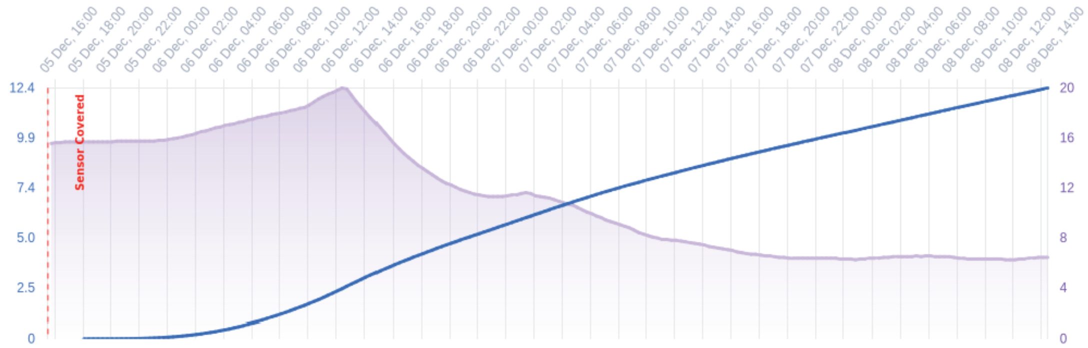
Wembley Park

Wall 1400mm / Signal 1 Signal 1 / Probe 1

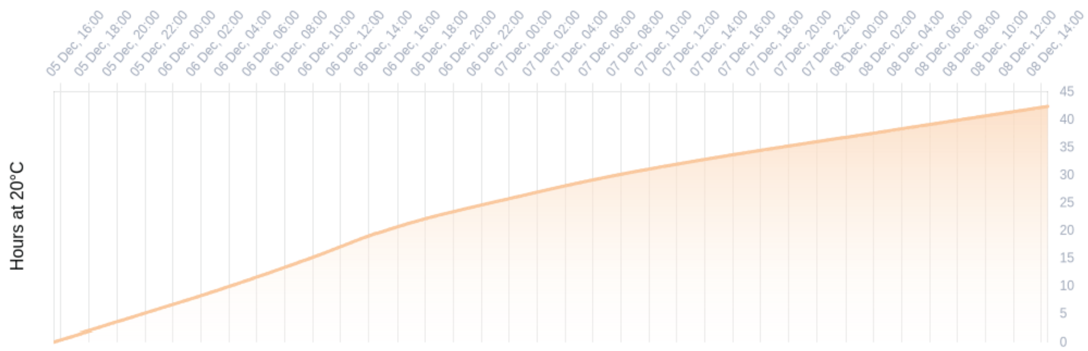
Report generated on Oct 20th, 2025 by Aled Roberts

12.4 MPa Compressive Strength Dec 8th, 2024, 14:27	**6.4** °C Temperature Dec 8th, 2024, 14:27	**20.0** °C Highest Temperature Dec 6th, 2024, 12:25	**6.3** °C Lowest Temperature Dec 8th, 2024, 00:46

Temperature & Strength over Time



Equivalent age



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Concrete Report

converge

Wembley Park

Wall 1400mm / Signal 1 Signal 1 / Probe 1

Report generated on Oct 20th, 2025 by Aled Roberts

Activity History

Sensor Registered	Dec 4th, 2024, 12:42 by Flavius
Sensor Covered	Dec 5th, 2024, 15:28
Finished Monitoring	Dec 8th, 2024, 14:37

Compressive Strength History

12.4MPa	Dec 8th, 2024, 14:27 (last recorded strength)

Concrete Mix Details

Mix Name:	C50/60
Calibrated:	Nov 21st, 2024, 10:24
Consistence:	

Concrete Report

converge

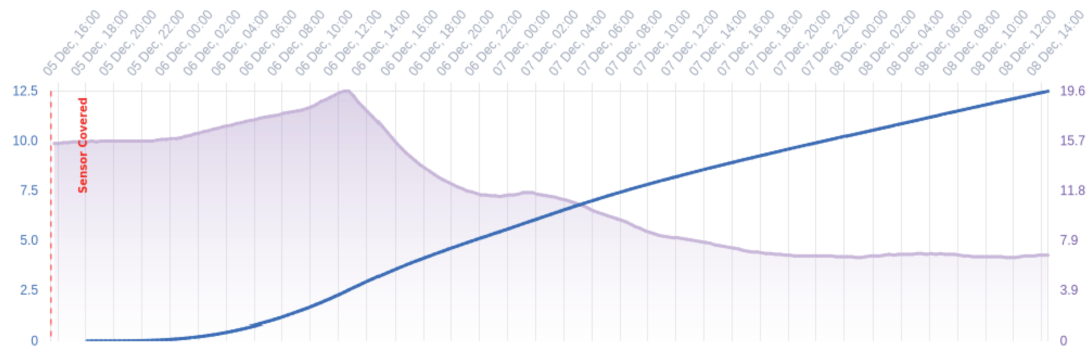
Wembley Park

Wall 1400mm / Signal 1 Signal 1 / Probe 2

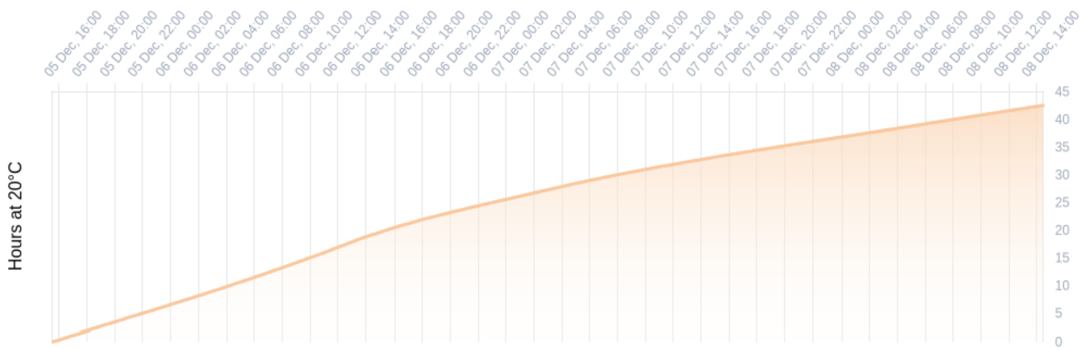
Report generated on Oct 20th, 2025 by Aled Roberts

12.5 MPa	6.7 °C	19.6 °C	6.5 °C
Compressive Strength	Temperature	Highest Temperature	Lowest Temperature
Dec 8th, 2024, 14:27	Dec 8th, 2024, 14:27	Dec 6th, 2024, 12:25	Dec 8th, 2024, 00:46

Temperature & Strength over Time



Equivalent age



Concrete Report

converge

Wembley Park

Wall 1400mm / Signal 1 Signal 1 / Probe 2

Report generated on Oct 20th, 2025 by Aled Roberts

Activity History

Sensor Registered	Dec 4th, 2024, 12:42 by Flavius
Sensor Covered	Dec 5th, 2024, 15:28
Finished Monitoring	Dec 8th, 2024, 14:37

Compressive Strength History

12.5MPa	Dec 8th, 2024, 14:27 (last recorded strength)

Concrete Mix Details

Mix Name:	C50/60
Calibrated:	Nov 21st, 2024, 10:24
Consistence:	

Concrete Report

converge

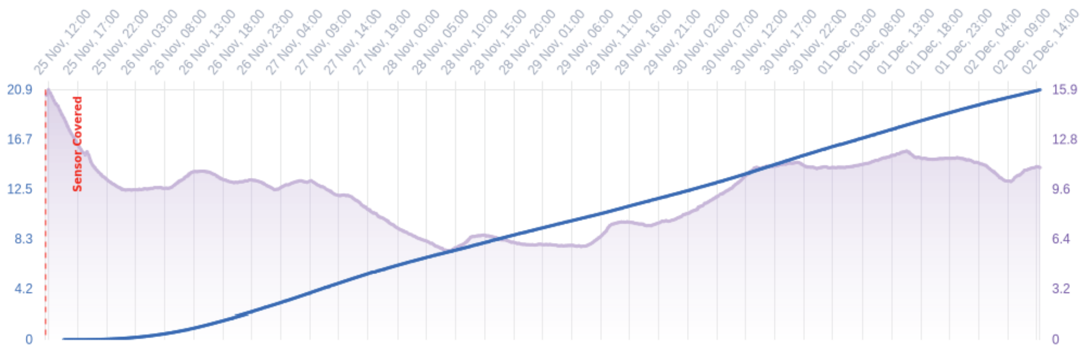
Wembley Park

Raft Foundation / Grid C

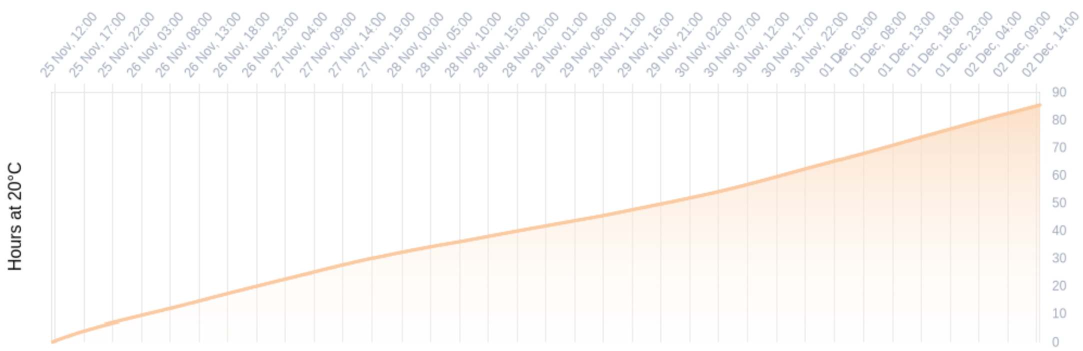
Report generated on Oct 20th, 2025 by Aled Roberts

--.- MPa	11.0 °C	15.9 °C	5.6 °C
Compressive Strength	Temperature Dec 2nd, 2024, 14:35	Highest Temperature Nov 25th, 2024, 11:55	Lowest Temperature Nov 28th, 2024, 08:35

Temperature & Strength over Time



Equivalent age



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Concrete Report

converge

Wembley Park

Raft Foundation / Grid C

Report generated on Oct 20th, 2025 by Aled Roberts

Activity History

Sensor Registered	Nov 22nd, 2024, 16:16 by Flavius
Sensor Covered	Nov 25th, 2024, 11:21
Finished Monitoring	Dec 2nd, 2024, 14:40

Compressive Strength History

50.0MPa	Jan 13th, 2025, 03:52

Concrete Mix Details

Mix Name:	C40/50
Calibrated:	Nov 26th, 2024, 12:41
Consistence:	

Concrete Report

converge

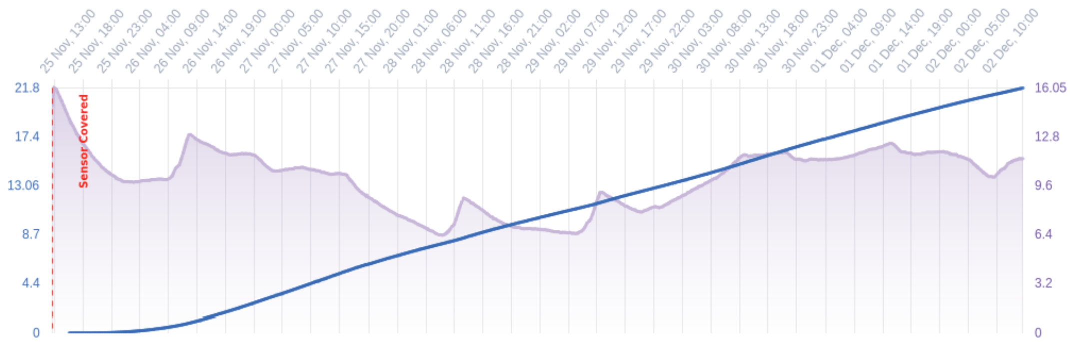
Wembley Park

Raft Foundation / Grid A-B

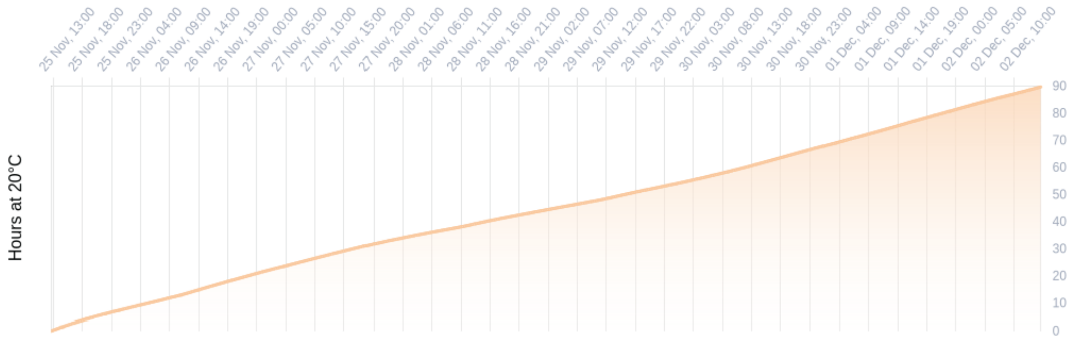
Report generated on Oct 20th, 2025 by Aled Roberts

Compressive Strength	Temperature	Highest Temperature	Lowest Temperature
--.- MPa	11.4 °C	16.1 °C	6.4 °C
	Dec 2nd, 2024, 14:34	Nov 25th, 2024, 12:54	Nov 28th, 2024, 08:54

Temperature & Strength over Time



Equivalent age



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Concrete Report

converge

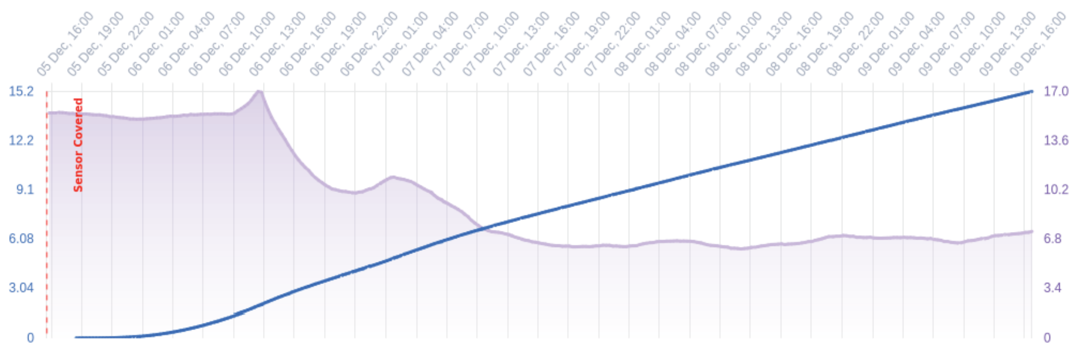
Wembley Park

400X400 column Grd 1B / Signal 1 Signal 1

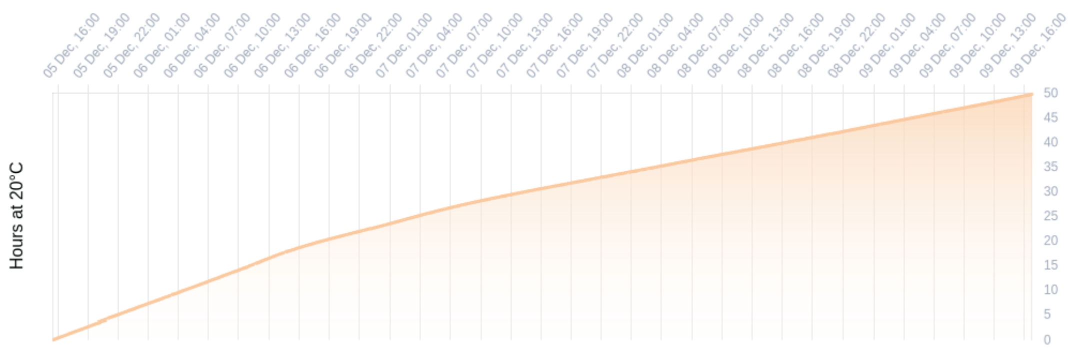
Report generated on Oct 20th, 2025 by Aled Roberts

15.2MPa	7.3°C	17.0°C	6.1°C
Compressive Strength Dec 9th, 2024, 16:45	Temperature Dec 9th, 2024, 16:45	Highest Temperature Dec 6th, 2024, 12:25	Lowest Temperature Dec 8th, 2024, 12:05

Temperature & Strength over Time



Equivalent age



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Concrete Report

converge

Wembley Park

400X400 column Grd 1B / Signal 1 Signal 1

Report generated on Oct 20th, 2025 by Aled Roberts

Activity History

Sensor Registered	Dec 4th, 2024, 12:37 by Flavius
Sensor Covered	Dec 5th, 2024, 15:28
Finished Monitoring	Dec 9th, 2024, 17:00

Compressive Strength History

15.2MPa	Dec 9th, 2024, 16:45 (last recorded strength)

Concrete Mix Details

Mix Name:	C50/60
Calibrated:	Nov 21st, 2024, 10:24
Consistence:	

Concrete Report

converge

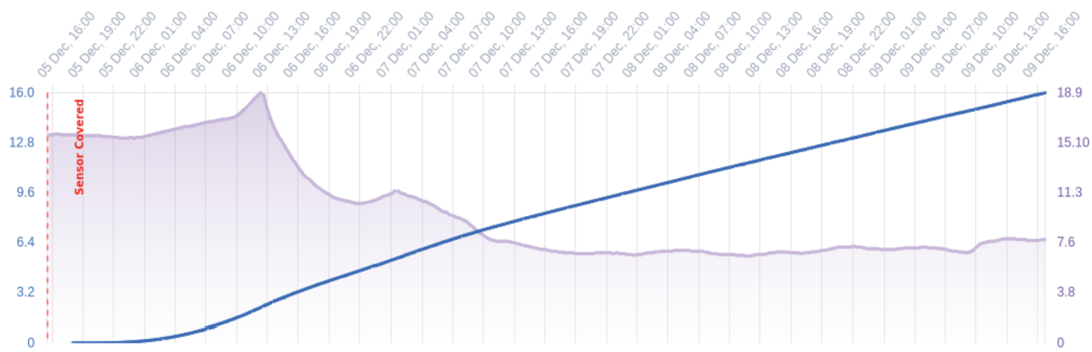
Wembley Park

400X400 column Grd 1B / Signal 1 Signal 1 / Probe 1

Report generated on Oct 20th, 2025 by Aled Roberts

16.0 MPa	7.8 °C	18.9 °C	6.5 °C
Compressive Strength Dec 9th, 2024, 16:43	Temperature Dec 9th, 2024, 16:43	Highest Temperature Dec 6th, 2024, 12:19	Lowest Temperature Dec 8th, 2024, 11:42

Temperature & Strength over Time



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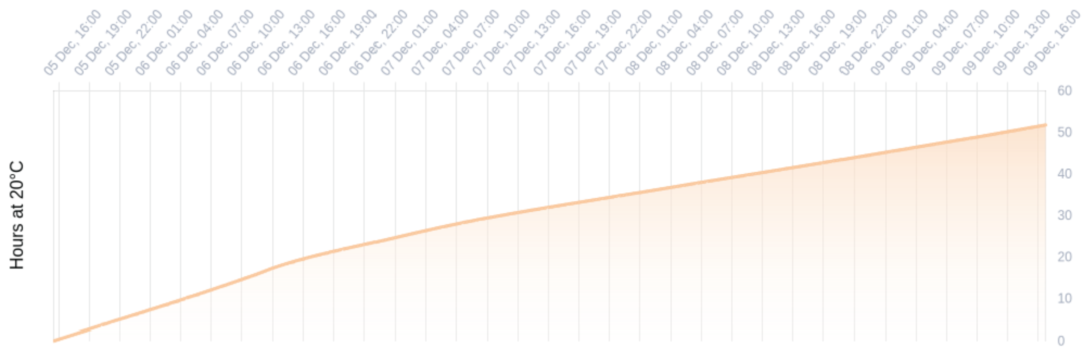

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Concrete Report

converge

Wembley Park

400X400 column Grd 1B / Signal 1 Signal 1 / Probe 1

Report generated on Oct 20th, 2025 by Aled Roberts

Activity History

Sensor Registered	Dec 4th, 2024, 12:37 by Flavius
Sensor Covered	Dec 5th, 2024, 15:28
Finished Monitoring	Dec 9th, 2024, 17:00

Compressive Strength History

16.0MPa	Dec 9th, 2024, 16:43 (last recorded strength)

Concrete Mix Details

Mix Name:	C50/60
Calibrated:	Nov 21st, 2024, 10:24
Consistence:	

Concrete Report

converge

Wembley Park

400X400 column Grd 1B / Signal 1 Signal 1 / Probe 1

Report generated on Oct 20th, 2025 by Aled Roberts

Activity History

Sensor Registered	Dec 4th, 2024, 12:37 by Flavius
Sensor Covered	Dec 5th, 2024, 15:28
Finished Monitoring	Dec 9th, 2024, 17:00

Compressive Strength History

16.0MPa	Dec 9th, 2024, 16:43 (last recorded strength)

Concrete Mix Details

Mix Name:	C50/60
Calibrated:	Nov 21st, 2024, 10:24
Consistence:	

Concrete Report

Wembley Park

400X400 column Grd 1B / Signal 1 Signal 1 / Probe 2

Report generated on Oct 20th, 2025 by Aled Roberts

Activity History

Sensor Registered	Dec 4th, 2024, 12:37 by Flavius
Sensor Covered	Dec 5th, 2024, 15:28
Finished Monitoring	Dec 9th, 2024, 17:00

Compressive Strength History

15.5MPa	Dec 9th, 2024, 16:43 (last recorded strength)

Concrete Mix Details

Mix Name:	C50/60
Calibrated:	Nov 21st, 2024, 10:24
Consistence:	

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Appendix M – Slump Test Pictures

Raft Slab Pour

Ground Floor Slab pour

Ground Floor columns pour

Level 1 – Post tensioned slab pours

Level 2 – Slab Pour

Document ref.	Title	Issue	Date
	Scalable Low Carbon Demonstrator Project	01	Dec 2025

Appendix N – Setting Time

Amtest UK Precision & Accuracy

Amtest UK Ltd
Unit A 2D/6 Project Park
North Cresent, Canning Town
E16 4TQ

Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance ASTM C403/C403M-08 - ISO 1920-14:2019

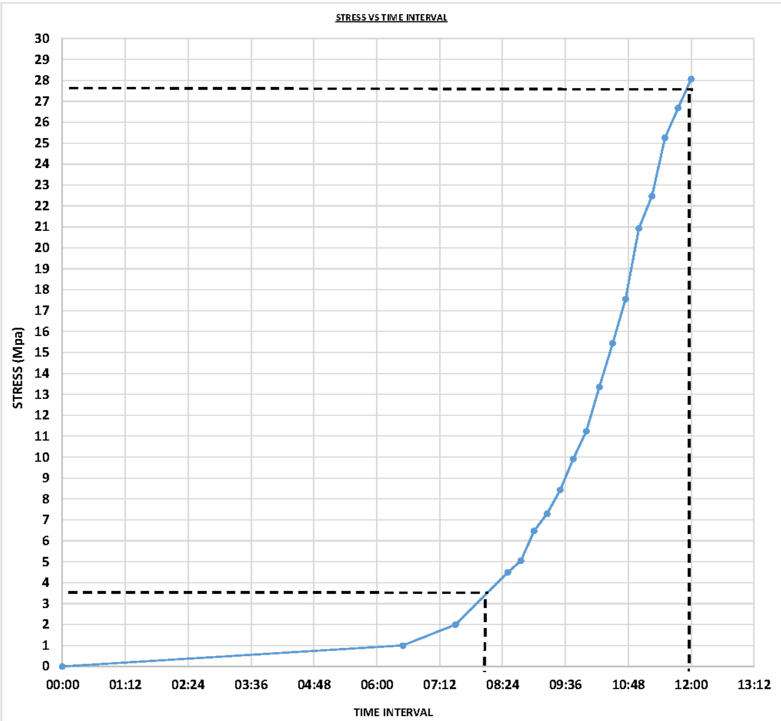
Project Details	Report Details
Client: ECOCEM	**Report No.:**Eco-0009/1
Client Adress:---------	**Issue No.:** 1
Project Name: ACT CONCRETE TRIAL	**Test Start Date:** 22-10-2025
Project Number: ---------	**Test Finish Date:**22-10-2025

Test Results

MIX DETAILS - GRADE C40/50				
	ORIGINAL WEIGHTS kg/m³	W.A (%)	M.C (%)	FINAL WEIGHTS kg/m³
ACT	350	-------	-------	350
20mm	707	0.7	0.5	706
10mm	303	0.8	1.0	304
Sand	910	1.6	4.8	939
Total Water	123	-------	-------	94.7
Optima 100 (L)	5.6	-------	-------	4.1
W/C	0.35	-------	-------	-------
Density	2398	-------	-------	2398

TEST DETAILS	
INITIAL SLUMP T0	200 mm
CONCRETE TEMP.	17^0C
INITIAL SETTING TIME	8.00 h
FINAL SETTING TIME	12.00 h

TIME	STRESS (Mpa)
00:00	0
06:30	1
07:30	2
08:30	4.5
08:45	5.1
09:00	6.5
09:15	7.3
09:30	8.4
09:45	9.9
10:00	11.2
10:15	13.4
10:30	15.4
10:45	17.6
11:00	20.9
11:15	22.5
11:30	25.3
11:45	26.7
12:05	28.1



Date Reported: 13/11/2025

Date Approved: 13/11/2025 **Approved By:** Ahmad Sabra

Appendix O – Loughborough Test Reports

Loughborough University

ECOCEM and John Sisk ACT Project

Test	-	**Rapid chloride penetration test**
Standard followed	-	**NT Build 492**
Sample	-	Cylindrical cores
Diameter of sample	-	100 mm
Length of sample	-	50 mm
Date of casting	-	19/09/2024
Casting performed by	-	Umer Jadoon
Concrete mix ref	-	ACT concrete
w/c ratio	-	0.35
ACT SP dosage (%)	-	1.6
Curing condition of samples	-	Water saturated
Curing temperature	-	20C
Test age	-	28 days
Reagents used	-	$Ca(OH)_2$, NaCl, $AgNO_3$, NaOH
Samples submitted by	-	John Sisk and Sons Ltd and ECOCEM
Test performed at	-	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by		Umer Jadoon

Mix reference	Voltage (V)		Temperature (°C)		Current (mA)		Penetration Depth (mm)								Mean x_d (mm)	Standard deviation (mm)	Coefficient of Variation (%)	D_{nssm} (x 10^{-12} m²/s)
	Initial	Final	Initial	Final	Initial	Final	x_{d1}	x_{d2}	x_{d3}	x_{d4}	x_{d5}	x_{d6}	x_{d7}	x_{d8}				
A1 – sample 1	30.0	30.0	22.1	22.3	40	40	11.1	11.9	10.5	10.7	13.4	10.2	10.2	10.3	**11.0**	1.01	9.43	4.54
A1 – sample 2	30.0	30.0	22.1	22.3	40	40	9.6	8.7	8.9	8.3	10.8	11.2	8.4	9.5	**9.43**	1.04	10.7	3.81
A2 – sample 1	30.0	30.0	20.9	21.5	40	40	17.1	15.5	14.3	14.5	15.7	15.3	13.3	12.7	**14.8**	1.32	8.89	6.23
A2 – sample 2	30.0	30.0	20.9	21.5	40	40	10.2	8.2	7.7	8.3	10.7	9.2	8.3	7.6	**8.78**	1.07	12.2	3.51
A3 – sample 1	30.0	30.0	20.9	22.0	40	40	9.2	8.5	8.6	7.2	10.6	9.6	8.1	7.5	**8.66**	1.05	12.1	3.47
A3 – sample 2	30.0	30.0	20.9	22.0	40	40	9.3	8.0	6.2	6.1	6.3	6.2	8.6	9.4	**7.52**	1.38	18.4	2.96
														Average	**10.03**	**1.15**	**12.0**	**4.08**

Verified by: Prof. Chris Goodier Page **1** ***Test performed by:*** M. Umer Jadoon

School of Architecture, Building, and Civil Engineering, Loughborough University

Loughborough University

ECOCEM and John Sisk ACT Project

Test	-	**Rapid chloride penetration test**
Standard followed	-	**NT Build 492**
Sample	-	Cylindrical cores
Diameter of sample	-	100 mm
Length of sample	-	50 mm
Date of casting	-	04/09/2024
Casting performed by	-	Umer Jadoon
Concrete mix ref	-	ACT concrete
w/c ratio	-	0.35
ACT SP dosage (%)	-	1.6
Curing condition of samples	-	Water saturated
Curing temperature	-	20C
Test age	-	91 days
Reagents used	-	$Ca(OH)_2$, NaCl, $AgNO_3$, NaOH
Samples submitted by	-	John Sisk and Sons Ltd and ECOCEM
Test performed at	-	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by		Umer Jadoon

Mix reference	Voltage (V)		Temperature (℃)		Current (mA)		Penetration Depth (mm)								Mean x_d (mm)	Standard deviation (mm)	Coefficient of Variation (%)	D_{nssm} (x 10^{-12} m^2/s)
	Initial	Final	Initial	Final	Initial	Final	x_{d1}	x_{d2}	x_{d3}	x_{d4}	x_{d5}	x_{d6}	x_{d7}	x_{d8}				
A1 – sample 1	40.0	40.0	18.5	18.5	30.0	30.0	7.0	7.2	10.5	11.3	10.2	9.9	10.2	8.0	**9.3**	1.54	16.5	3.71
A1 – sample 2	40.0	40.0	18.5	18.5	30.0	30.0	6.4	6.0	9.1	9.3	7.7	5.9	7.0	6.1	**7.24**	1.29	17.9	2.79
A2 – sample 1	40.0	40.0	17.5	17.5	30.0	30.0	8.3	9.1	7.8	9.9	9.4	9.2	10.9	9.2	**9.23**	0.88	9.54	3.67
A2 – sample 2	40.0	40.0	17.5	17.5	30.0	30.0	10.5	10.0	9.2	9.2	12.1	8.2	7.6	8.0	**9.35**	1.39	14.9	3.72
A3 – sample 1	40.0	40.0	18.3	18.3	30.0	30.0	8.9	11.8	12.4	12.7	9.4	8.6	10.5	10.2	**10.5**	1.48	14.0	4.27
A3 – sample 2	40.0	40.0	18.3	18.3	30.0	30.0	11.3	10.9	9.7	10.3	7.3	7.3	7.8	8.5	**9.14**	1.52	16.6	3.64
														Average	**9.12**	**1.35**	**14.9**	**3.63**

Verified by: Prof. Chris Goodier Page **2** ***Test performed by:*** M. Umer Jadoon

School of Architecture, Building, and Civil Engineering, Loughborough University

Loughborough University

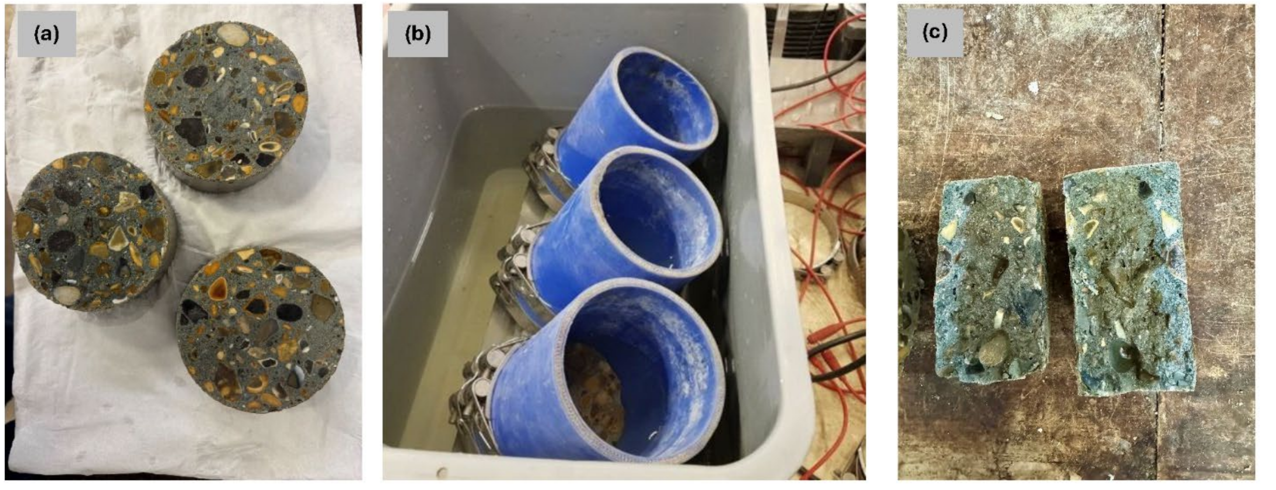


Figure 1: (a) Discs (50x100mm) sliced from ACT concrete, **(b)** Exposure of discs to NaCl and NaOH chemicals, and **(c)** Discs after spraying them with Silver nitrate solution

Loughborough University

ECOCEM and John Sisk ACT Project

Test	-	**Heat of hydration test**
Standard followed	-	**BS EN 12390-14 (in modified form)**
Sample	-	100mm³ cube
Diameter of sample	-	100 mm
Length of sample	-	100 mm
Thickness of Insulation	-	50mm on all sides (see Figure 1 on page 6)
Date of casting	-	19/09/2024
Casting performed by	-	Umer Jadoon
Concrete mix ref	-	ACT concrete
w/c ratio	-	0.35
ACT SP dosage (%)	-	1.6
Curing temperature	-	-
Test age	-	0 to 72 hours continuous
No. of samples used	-	3
Materials submitted by	-	Binder and Superplasticizer by ECOCEM Aggregates by Capital Concrete Water used from Loughborough University Laboratory
Test performed at	-	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by		Umer Jadoon

	Sample 1		Sample 2		Sample 3	
Time (Hr)	**Average temperature thermocouple (1A)**	**Average temperature thermocouple (1B)**	**Average temperature thermocouple (2A)**	**Average temperature thermocouple (2B)**	**Average temperature thermocouple (3A)**	**Average temperature thermocouple (3B)**
1	21.0	21.2	20.9	21.94	20.9	20.6
2	20.5	20.7	20.4	21.9	20.2	20.1
3	20.5	20.5	20.4	20.5	19.9	20.0
4	20.7	20.7	20.6	20.3	20.1	20.2
5	20.9	20.8	20.7	20.6	20.2	20.3

Loughborough University

	Sample 1		Sample 2		Sample 3	
Time (Hr)	Average temperature thermocouple (1A)	Average temperature thermocouple (1B)	Average temperature thermocouple (2A)	Average temperature thermocouple (2B)	Average temperature thermocouple (3A)	Average temperature thermocouple (3B)
6	21.0	21.0	20.9	20.7	20.4	20.4
7	21.1	21.1	21.0	20.8	20.4	20.6
8	21.2	21.1	21.1	21.0	20.5	20.6
9	21.2	21.2	21.2	21.1	20.6	20.7
10	21.2	21.2	21.2	21.1	20.6	20.7
11	21.3	21.2	21.3	21.2	20.7	20.8
12	21.3	21.3	21.4	21.3	20.8	20.9
13	21.4	21.4	21.5	21.4	20.9	21.0
14	21.6	21.6	21.7	21.5	21.0	21.2
15	21.8	21.7	21.9	21.7	21.2	21.3
16	21.9	21.9	22.1	21.8	21.4	21.5
17	22.1	22.1	22.3	22.0	21.5	21.7
18	22.3	22.3	22.5	22.2	21.7	21.8
19	22.4	22.4	22.7	22.4	21.8	22.0
20	22.6	22.6	22.8	22.6	22.0	22.1
21	22.7	22.7	23.0	22.7	22.1	22.2
22	22.9	22.9	23.1	22.9	22.2	22.3
23	23.0	23.1	23.3	23.1	22.4	22.5
24	23.2	23.3	23.5	23.3	22.6	22.6
25	23.3	23.4	23.6	23.5	22.7	22.7
26	23.4	23.5	23.6	23.6	22.7	22.8
27	23.4	23.5	23.6	23.7	22.8	22.8
28	23.4	23.5	23.6	23.7	22.8	22.8
29	23.4	23.5	23.6	23.7	22.8	22.8
30	23.4	23.4	23.5	23.7	22.7	22.7
31	23.3	23.4	23.5	23.6	22.7	22.7
32	23.3	23.3	23.4	23.6	22.6	22.6
33	23.2	23.2	23.4	23.5	22.5	22.6
34	23.1	23.1	23.3	23.4	22.5	22.5

Verified by: Prof. Chris Goodier Page **5** ***Test performed by:*** M. Umer Jadoon

School of Architecture, Building, and Civil Engineering, Loughborough University

Loughborough University

	Sample 1		Sample 2		Sample 3	
Time (Hr)	Average temperature thermocouple (1A)	Average temperature thermocouple (1B)	Average temperature thermocouple (2A)	Average temperature thermocouple (2B)	Average temperature thermocouple (3A)	Average temperature thermocouple (3B)
35	23.0	23.1	23.2	23.3	22.4	22.4
36	22.9	23.0	23.1	23.2	22.3	22.4
37	22.9	22.9	23.1	23.2	22.3	22.3
38	22.8	22.8	23.0	23.1	22.2	22.2
39	22.7	22.7	22.9	23.0	22.1	22.2
40	22.6	22.7	22.8	22.9	22.1	22.1
41	22.5	22.6	22.7	22.9	22.0	22.0
42	22.5	22.5	22.7	22.8	22.0	22.0
43	22.4	22.4	22.6	22.7	21.9	21.9
44	22.3	22.3	22.5	22.6	21.8	21.8
45	22.2	22.3	22.4	22.6	21.7	21.8
46	22.1	22.2	22.3	22.5	21.6	21.7
47	22.1	22.1	22.3	22.4	21.5	21.6
48	22.0	22.1	22.2	22.3	21.5	21.5
49	21.9	22.0	22.1	22.2	21.4	21.5
50	21.9	22.0	22.1	22.2	21.4	21.4
51	21.8	22.0	22.0	22.2	21.4	21.4
52	21.9	22.0	22.1	22.1	21.4	21.4
53	21.9	22.0	22.1	22.1	21.5	21.4
54	22.0	22.1	22.1	22.2	21.5	21.5
55	22.0	22.1	22.1	22.2	21.5	21.5
56	22.0	22.1	22.2	22.2	21.5	21.6
57	22.1	22.1	22.2	22.2	21.5	21.6
58	22.0	22.1	22.2	22.2	21.5	21.6
59	22.0	22.1	22.2	22.2	21.5	21.6
60	22.0	22.1	22.2	22.2	21.5	21.6
61	22.0	22.0	22.1	22.2	21.5	21.6
62	22.0	22.0	22.1	22.2	21.5	21.6
63	21.9	22.0	22.1	22.1	21.5	21.5

	Sample 1		Sample 2		Sample 3	
Time (Hr)	Average temperature thermocouple (1A)	Average temperature thermocouple (1B)	Average temperature thermocouple (2A)	Average temperature thermocouple (2B)	Average temperature thermocouple (3A)	Average temperature thermocouple (3B)
64	21.9	21.9	22.1	22.1	21.5	21.5
65	21.9	21.9	22.0	22.1	21.4	21.5
66	21.8	21.9	22.0	22.0	21.4	21.5
67	21.8	21.8	21.9	22.0	21.4	21.4
68	21.7	21.8	21.9	22.0	21.3	21.4
69	21.7	21.7	21.8	21.9	21.3	21.3
70	21.6	21.7	21.8	21.9	21.3	21.3
71	21.6	21.6	21.7	21.8	21.2	21.2
72	21.5	21.6	21.7	21.8	21.1	21.2

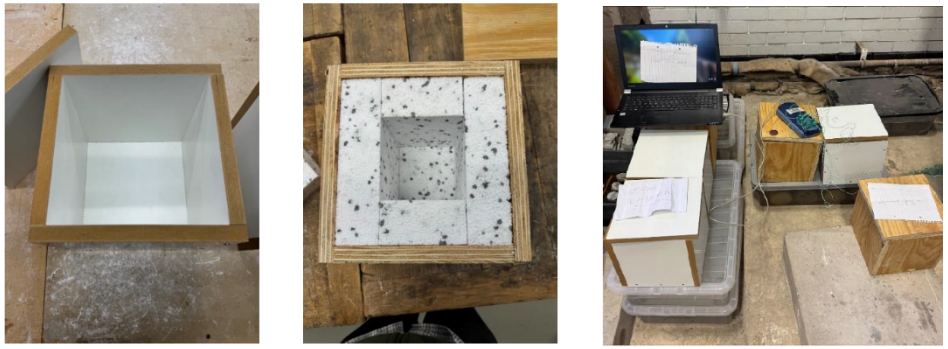


Figure 2: Insulated moulds with samples size 100mm^3 and insulation of 50mm

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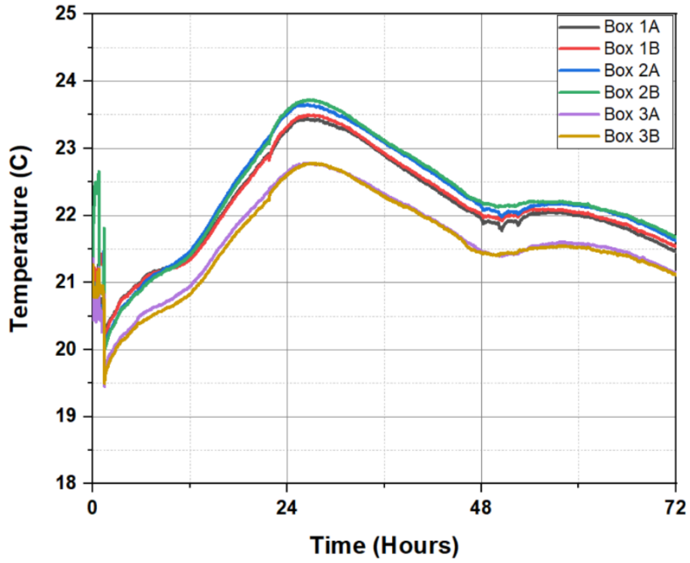

Figure 3: Heat of hydration for ACT concrete samples over first 72 hours

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ECOCEM and John Sisk ACT Project

Test	-	**Drying Shrinkage**
Standard followed	-	**BS EN 12390-16**
Sample	-	Prismatic concrete samples (moulded)
Dimensions of sample	-	63x63mm
Length of sample	-	405mm
Date of casting	-	02/12/2024
Casting performed by	-	John Sisk at Wembley park
Concrete mix ref	-	ACT concrete
w/c ratio	-	0.35
ACT SP dosage (%)	-	1.6
Test age	-	0 to 180 days continuous
Storage condition before start of the test	-	Kept inside the room with temperature maintained at 20°C without any plastic on the samples
Storage condition during testing	-	Kept inside lab with ambient temperature of 20°C and Relative humidity ≈ 65%
Guage length of measuring instrument	-	200mm
Test performed at	-	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by		Umer Jadoon

Date	Age of sample	Sample 1 avg. value	Sample 2 avg. value	Total average	Cumulative Shrinkage	Shrinkage (μmm/mm)
03/12/2024	1	995.0	895.0	945.0	0.0	0.0
04/12/2024	2	979.0	880.0	929.5	-15.5	-196.9
05/12/2024	3	963.0	870.0	916.5	-28.5	-362.0
06/12/2024	4	957.0	863.0	910.0	-35.0	-444.5
07/12/2024	5	954.0	861.0	907.5	-37.5	-476.3
08/12/2024	6	953.0	860.0	906.5	-38.5	-489.0
09/12/2024	7	950.0	860.0	905.0	-40.0	-508.0
16/12/2024	14	942.0	852.0	897.0	-48.0	-609.6
20/12/2024	18	940.0	850.0	895.0	-50.0	-635.0
04/01/2025	33	931.0	839.0	885.0	-60.0	-762.0
13/01/2025	42	923.0	834.0	878.5	-66.5	-844.6
16/01/2025	45	918.0	830.0	874.0	-71.0	-901.7

Verified by: Prof. Chris Goodier Page **9** ***Test performed by:*** M. Umer Jadoon

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21/01/2025	50	920.0	829.0	874.5	-70.5	-895.4
29/01/2025	58	917.0	827.0	872.0	-73.0	-927.1
17/02/2025	77	914.0	830.0	872.0	-73.0	-927.1
24/02/2025	84	914.0	826.0	870.0	-75.0	-952.5
02/03/2025	90	910.0	824.0	867.0	-78.0	-990.6
05/03/2025	93	908.0	824.0	866.0	-79.0	-1003.3
10/03/2025	98	905.0	822.0	863.5	-81.5	-1035.1
19/03/2025	107	900.0	820.0	860.0	-85.0	-1079.5
24/03/2025	112	901.0	820.0	860.5	-84.5	-1073.2
10/04/2025	129	900.0	819.0	859.5	-85.5	-1086
01/05/2025	150	899.0	818.0	858.5	-86.5	-1099
31/05/2025	180	898.0	818.0	858.0	-87.0	-1105

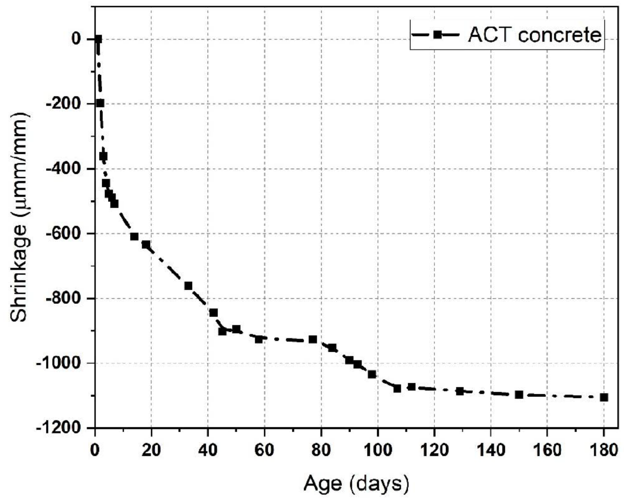

Figure 4: Shrinkage of ACT concrete with time

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ECOCEM and John Sisk ACT Project

Test	**-**	**Thermal Expansion Test**
Standard followed	**-**	**BS EN 1770-1998**
Sample	-	Prismatic mortar samples (moulded)
Dimensions of sample	-	25x25mm
Length of sample	-	300mm
Casting performed by	-	Umer Jadoon
Concrete mix ref	-	ACT concrete
w/b and s/b ratio	-	0.35 and 3.0
ACT SP dosage (% bcw of binder)	-	1.6
Temperature range used for test	-	-20°C to 60°C
Preconditioning	-	7 days at 20°C and Relative humidity ≈ 65%
Guage length of measuring instrument	-	200mm
Instrument used to measure changes in length	-	John Bull Demec Strain Guage
Type of thermocouple used	-	
Type of Environmental chamber used	-	
Test performed at	-	Loughborough University Concrete Laboratory (Sir Frank Gibbs Lab)
Test performed by		Umer Jadoon

Temperature	ACT sample 1 Demec reading (S1)	ACT sample 2 Demec reading (S2)	Average S1, S2	Average shrinkage/Expansion ΔL (inches)	(ΔL/L) *L = 200mm/7.87in*	α ((ΔL/L)/ΔT) (/°C)
18	686	867	776.5	0	0.00000	**11.2 x 10^{-6}**
23	687	873	780.0	0.00035	0.00004	
40	701	886	793.5	0.00170	0.00022	
60	719	904	811.5	0.00350	0.00044	
0	665	852	758.5	-0.00180	-0.00023	
-10	659	845	752.0	-0.00245	-0.00031	
-20	647	835	741.0	-0.00355	-0.00045	

Verified by: Prof. Chris Goodier Page **11** ***Test performed by:*** M. Umer Jadoon

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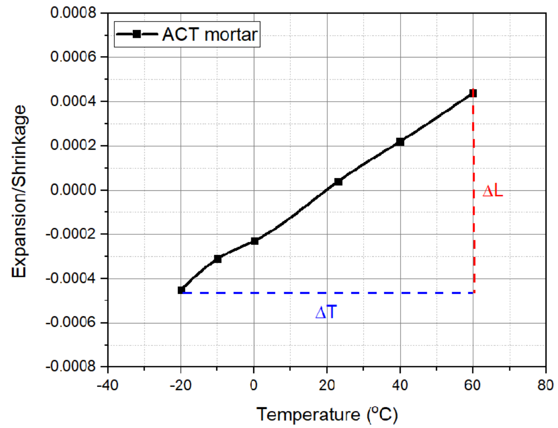

Figure 5: Expansion/Shrinkage of ACT mortar at different temperature regimes

Appendix P – BRE Test Reports

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TEST REPORT

Flexural Strength Testing of Ecocem ACT to BS EN 12390-5.

Prepared for: John Sisk & Son
Date: 10.07.2025
Report number: P128946-1000
Issue: 1
Status: Final - Commercial in Confidence

Prepared for:

Maria Estrada
John Sisk & Son
1 Curo Park
Frogmore
St Albans

Prepared by:

Name	Christopher Yapp
Position	Senior Consultant
Date	10 July 2025
Signature	

Authorised by:

Name	Martyn Webb
Position	Principal Consultant
Date	10 July 2025
Signature	

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Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake flexural strength testing to BS EN 12390-5:2019.

This factual report describes the tests conducted and the results obtained.

2. Test Description

BRE attended a site mixing trial of an Ecocem ACT concrete at Capital Concrete on 4th September 2024 and cast specimens for a range of tests, including beams for flexural strength testing. The fresh concrete was hand-tamped into steel moulds and covered in damp sacking and polythene before being left overnight in a container at Capital Concrete. The following day the specimens were transported back to BRE and demoulded, before being placed in water tanks at 20 °C ± 2 °C.

100 mm by 100 mm by 500 mm beams were cast for flexural tensile strength testing to BS EN 12390-5:2019 at 7, 28, and 90 days after casting. On the day of test, two beams were taken from the water tanks and were weighed and measured. The mass and dimensions were used to calculate specimen densities before the specimens were tested in four-point bending in a universal test machine to obtain a maximum failure load to calculate a flexural tensile strength.

3.Test Results

The results of testing at 7, 28, and 90 days after casting are shown in Table 1.

Age at Test (days)	Specimen ID	Density (kg/m^3)	Flexural Strength (MPa)
7	A24/068/56	2410	4.7
	A24/068/57	2360	2.8
28	A24/068/58	2340	6.1
	A24/068/59	2340	6.2
90	A24/068/60	2390	8.3
	A24/068/61	2390	6.0

Table 1. Results of flexural tensile strength testing

For reference, Table 3 of BSI Flex 350 v2.0 would indicate that a flexural tensile strength of 6.1 at 28 days would correlate with a compressive strength class of C50/60.

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TEST REPORT

Tensile Splitting Testing of Ecocem ACT to BS EN 12390-6.

Prepared for: John Sisk & Son
Date: 10.07.2025
Report number: P128946-1001
Issue: 1
Status: Final - Commercial in Confidence

Prepared for:

Maria Estrada
John Sisk & Son
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Prepared by:

Name Christopher Yapp

Position Senior Consultant

Date 10 July 2025

Signature

Authorised by:

Name Martyn Webb

Position Principal Consultant

Date 10 July 2025

Signature

Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake tensile splitting testing to BS EN 12390-6:2023.

This factual report describes the tests conducted and the results obtained.

2.Test Description

BRE attended a site mixing trial of an Ecocem ACT concrete at Capital Concrete on 4th September 2024 and cast specimens for a range of tests, including cylinders for tensile splitting strength testing. The fresh concrete was hand-tamped into steel moulds and covered in damp sacking and polythene before being left overnight in a container at Capital Concrete. The following day the specimens were transported back to BRE and demoulded, before being placed in water tanks at 20 °C ± 2 °C.

100 mm diameter, 200 mm tall cylinders were cast for tensile splitting strength testing to BS EN 12390-6:2023 at 7, 28, 90, and 180 days after casting. On the day of test, two cylinders were taken from the water tanks and were weighed and measured. The mass and dimensions were used to calculate specimen densities before the specimens were tested in a tensile splitting test rig in a compressive test machine to obtain a maximum failure load to calculate a tensile splitting strength.

3.Test Results

The density and tensile splitting strength results are shown in Table 1.

Age at Test (days)	Specimen ID	Density (kg/m^3)	Tensile Splitting Strength (MPa)
7	A24/068/18	2350	2.90
	A24/068/19	2350	3.30
	A24/068/20	2340	3.25
28	A24/068/34	2340	4.85
	A24/068/35	2350	4.75
90	A24/068/36	2350	5.90
	A24/068/37	2340	5.55
180	A24/068/40	2330	4.65
	A24/068/41	2230	5.55

Table 1. Tensile splitting strength test results

For reference, Table 3 of BSI Flex 350 v2.0 would indicate that a tensile splitting strength of 4.8 at 28 days would correlate with a compressive strength class of C60/75.

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TEST REPORT

Modulus of Elasticity Testing of Ecocem ACT to BS EN 12390-13.

Prepared for: John Sisk & Son
Date: 10.07.2025
Report number: P128946-1002
Issue: 1
Status: Final - Commercial in Confidence

Prepared for:

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Position	Senior Consultant
Date	10 July 2025
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Authorised by:

Name	Martyn Webb
Position	Principal Consultant
Date	10 July 2025
Signature	

Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake modulus of elasticity testing to BS EN 12390-13:2021.

This factual report describes the tests conducted and the results obtained.

2.Test Description

BRE attended a site mixing trial of an Ecocem ACT concrete at Capital Concrete on 4th September 2024 and cast specimens for a range of tests, including 150 mm diameter, 300 mm tall cylinder specimens for modulus of elasticity testing to BS EN 12390-13:2021. The fresh concrete was hand-tamped into steel moulds and covered in damp sacking and polythene before being left overnight in a container at Capital Concrete. The following day the specimens were transported back to BRE and demoulded, before being placed in water tanks at 20 °C ± 2 °C.

150 mm diameter, 300 mm tall cylinders were cast for modulus of elasticity testing to BS EN 12390-13:2021 at 7, 28, 90, 180 and 365 days after casting. The day before each test date, the relevant test specimens were removed from water and had their top cast face ground flat and parallel to the bottom moulded face. They were then taken to the testing room and had three sets of demec pips adhered in vertical lines to measure strain for modulus of elasticity. The specimens were compressed in a 500 kN Universal testing machine between approximately 5 % and 33 % of the calculated compressive cylinder strength, using Method B of the standard. The strains were measured throughout cycled loading until strains did not differ from their average by more than 10 %. These strains and stress were then used to calculate the modulus of elasticity. The specimens were then subsequently crushed to obtain a compressive cylinder strength.

3.Test Results

Table 1 shows the elastic modulus for the tested specimens, as well as the average at each age. Table 2 to Table 5 show the specimen dimensions, densities and compressive cylinder strengths when crushed after elastic modulus testing. Only two of the specimens were able to be tested at 90 due to issues with the demec measurements on the third specimen.

From the compressive strengths tested, and Clause 6.8 and Equation 1 of BSI Flex 350 v1.0, the Ecocem ACT concrete is a normal modulus concrete.

Age at Test (days)	Specimen ID	Elastic Modulus
7	A24/068/43	38.5
	A24/068/44	35.6
	A24/068/46	37.0
	Average	**37.0**
28	A24/068/42	45.3
	A24/068/47	45.3
	A24/068/48	47.7
	Average	**46.1**
90	A24/068/51	49.3
	A24/068/56	52.7
	Average	**51.0**
180	A24/068/53	41.7
	A24/068/54	44.0
	A24/068/55	52.0
	Average	**45.9**

Table 1. Elastic modulus test results

Specimen ID	Dimensions (mm)						Density (kg/m^3)	Compressive Cylinder Strength (MPa)
	Diameter			Length				
43	150	150	150	300	299	299	2340	30.2
	150	150	150					
44	150	150	150	300	300	299	2280	20.6
	150	150	150					
46	150	150	150	299	299	299	2340	27.1
	150	150	150					
Average							2320	26.0

Table 2. Dimensions, densities and compressive cylinder strengths of 7 day elastic modulus specimens

Specimen ID	Dimensions (mm)						Density (kg/m^3)	Compressive Cylinder Strength (MPa)
	Diameter			Length				
42	150	150	150	300	299	299	2330	33.3
	150	150	150					
47	150	150	150	300	299	299	2290	38.7
	150	150	150					
48	150	150	150	298	299	299	2350	36.0
	150	150	150					
Average							2320	36.0

Table 3. Dimensions, densities and compressive cylinder strengths of 28 day elastic modulus specimens

Specimen ID	Dimensions (mm)						Density (kg/m^3)	Compressive Cylinder Strength (MPa)
	Diameter			Length				
51	150	150	150	299	299	299	2350	31.7
	150	150	150					
56	150	150	150	298	299	299	2350	25.7
	150	150	150					
Average							2350	28.7

Table 4. Dimensions, densities and compressive cylinder strengths of 90 day elastic modulus specimens

Specimen ID	Dimensions (mm)						Density (kg/m^3)	Compressive Cylinder Strength (MPa)
	Diameter			Length				
53	151	152	152	301	300	302	2280	40.0
	150	152	151					
54	150	151	151	300	300	301	2290	38.8
	150	150	151					
55	152	151	151	301	301	301	2270	45.8
	151	151	151					
Average							2280	41.5

Table 5. Dimensions, densities and compressive cylinder strengths of 180 day elastic modulus specimens

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TEST REPORT

Compressive Creep Testing of Ecocem ACT to BSI Flex 350.

Prepared for: John Sisk & Son
Date: 10.10.2025
Report number: P128946-1005
Issue: 2
Status: Final - Commercial in Confidence

Prepared for:

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Position	Principal Consultant
Date	10 October 2025
Signature	

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Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake compressive creep testing to BS EN 12390-17:2019, as detailed in BSI Flex 350 v1.0.

This factual report describes the tests conducted and the results obtained.

2.Test Description

BRE attended a site mixing trial of an Ecocem ACT concrete at Capital Concrete on 4th September 2024 and cast specimens for a range of tests, including ten 100 mm diameter, 200 mm tall cylinders for compressive creep testing. The fresh concrete was hand-tamped into steel moulds and covered in damp sacking and polythene before being left overnight in a container at Capital Concrete. The following day the specimens were transported back to BRE and demoulded, before being placed in water tanks at 20 °C ± 2 °C.

The compressive creep test was undertaken to BS EN 12390-17:2019, as amended by BSI Flex 350 v1.0. Ten 100 mm diameter cylinders were cast for creep testing, undertaking both basic and total creep tests. At 14 days after casting, the specimens were removed from water and had their top face ground plano-parallel to the cast bottom face, before being placed into the test room at 20 °C ± 2 °C and 65 %RH ± 5 %RH. Five of the specimens were covered in metal foil tape, to undertake basic creep testing, whilst the remaining five were left uncovered for total creep testing. The cylinders had DEMEC studs glued to their sides to create three equally spaced vertical measurement lines on each cylinder.

Three cylinders for total creep testing were then placed into one creep test loading rig, and three cylinders for basic creep testing were placed into another creep test loading rig. Each rig consisted of three solid steel disc plates, three threaded rods and associated nuts, a hydraulic jack with locking tap, a hemispherical bearing, a calibrated load cell, two flat loading plates and disc springs. An example rig is shown in Figure 1.

Figure 1. A compressive creep test rig

In each rig, the three concrete cylinders in the rig were stacked vertically on top of a loading plate, load cell, hemispherical bearing, and hydraulic jack. This was all sandwiched between the solid steel disc plates, with the disc springs placed between the two steel plates above the specimens. These disc springs allow the specimens to creep without a large reduction in load. The test stack was centralised between the three threaded rods that connect the top and bottom steel plates, before a set of DEMEC measurements was undertaken without any load measured on the load cell. A preload was then applied of 30 kN (approximately 1/4 of the test load) and the DEMEC measurements were again recorded. These values were then used to recentralise the test stack, the stack preloaded again and the DEMEC measurements repeated. Once the three DEMEC measurements from each cylinder were reading similar strains (indicating centralised loading), the load was increased to the test load of 120 kN, the equivalent of 15 MPa. The DEMEC measurements were taken again immediately after loading both rigs, on both the loaded and unloaded specimens. Measurements were then taken later that day, the following two days, after one week, weekly for the first month, fortnightly for another two months and monthly up to 6 months, and then at 9 months and 12 months.

3.Test Results

Table 2 shows the strains (in microstrain) measured during the testing for the total creep specimens, including their associated shrinkage specimens. Table 3 shows the strains measured during the testing for the basic creep specimens, including their associated shrinkage specimens. All of this data is then shown graphically in Figure 2. Table 4 then shows the average strain across each set of specimens, which is also shown graphically in Figure 3.

From this data the total creep strain, basic creep strain, drying creep strain, and total creep coefficient at the end of test can be calculated using the equations from BS EN 12390-17:2019 Clauses 8.1 and 8.2. The outcomes of these calculations are shown in Table 1. It should be noted that for the calculation of the total creep coefficient, the tangent modulus of elasticity has been taken as 1.05 times the initial secant modulus of elasticity measured at 28 days.

Total creep strain at end of test	407 microstrain
Basic creep strain at end of test	278 microstrain
Drying creep strain at end of test	129 microstrain
Total creep coefficient at end of test	1.30

Table 1. Calculated results of compressive creep testing

Age at test (days)	Total Creep Strains			Total Shrinkage Strains	
	Cylinder 1	Cylinder 2	Cylinder 3	Cylinder 1	Cylinder 2
Pre-loading	0	0	0	0	0
Post-loading	429	424	408	0	0
0.25	421	387	408	0	0
1	419	400	408	-115	-161
2	403	451	424	-113	-191
7	472	494	403	-150	-188
14	488	510	539	-86	-201
21	542	601	566	-91	-105
28	593	585	574	-43	-123
42	606	633	647	30	-59
56	692	656	668	51	-47
63	690	695	695	32	-17
77	712	703	698	38	-30
90	773	784	797	48	-8
99	743	773	794	30	-43
126	789	832	848	38	19
180	843	864	875	43	27
261	859	843	832	48	11
365	864	816	920	107	11

Table 2. Strains from total creep testing (in microstrain)

Age at test (days)	Basic Creep Strains			Basic Shrinkage Strains	
	Cylinder 1	Cylinder 2	Cylinder 3	Cylinder 1	Cylinder 2
Pre-loading	0	0	0	0	0
Post-loading	376	365	413	-161	-11
0.25	413	384	467	-161	-11
1	376	360	397	-236	-75
2	376	389	400	-225	-78
7	467	459	491	-236	-64
14	432	582	301	-177	-118
21	339	411	295	-247	-83
28	449	496	417	-244	-75
42	483	486	445	-209	32
56	517	472	507	-186	-48
63	501	490	486	-188	-15
77	515	515	500	-196	-46
90	564	564	601	-188	-48
99	526	537	547	-174	-32
126	531	660	569	-193	-48
180	569	617	644	-182	-64
261	601	558	590	-161	-54
365	569	625	633	-150	-11

Table 3. Strains from basic creep testing (in microstrain)

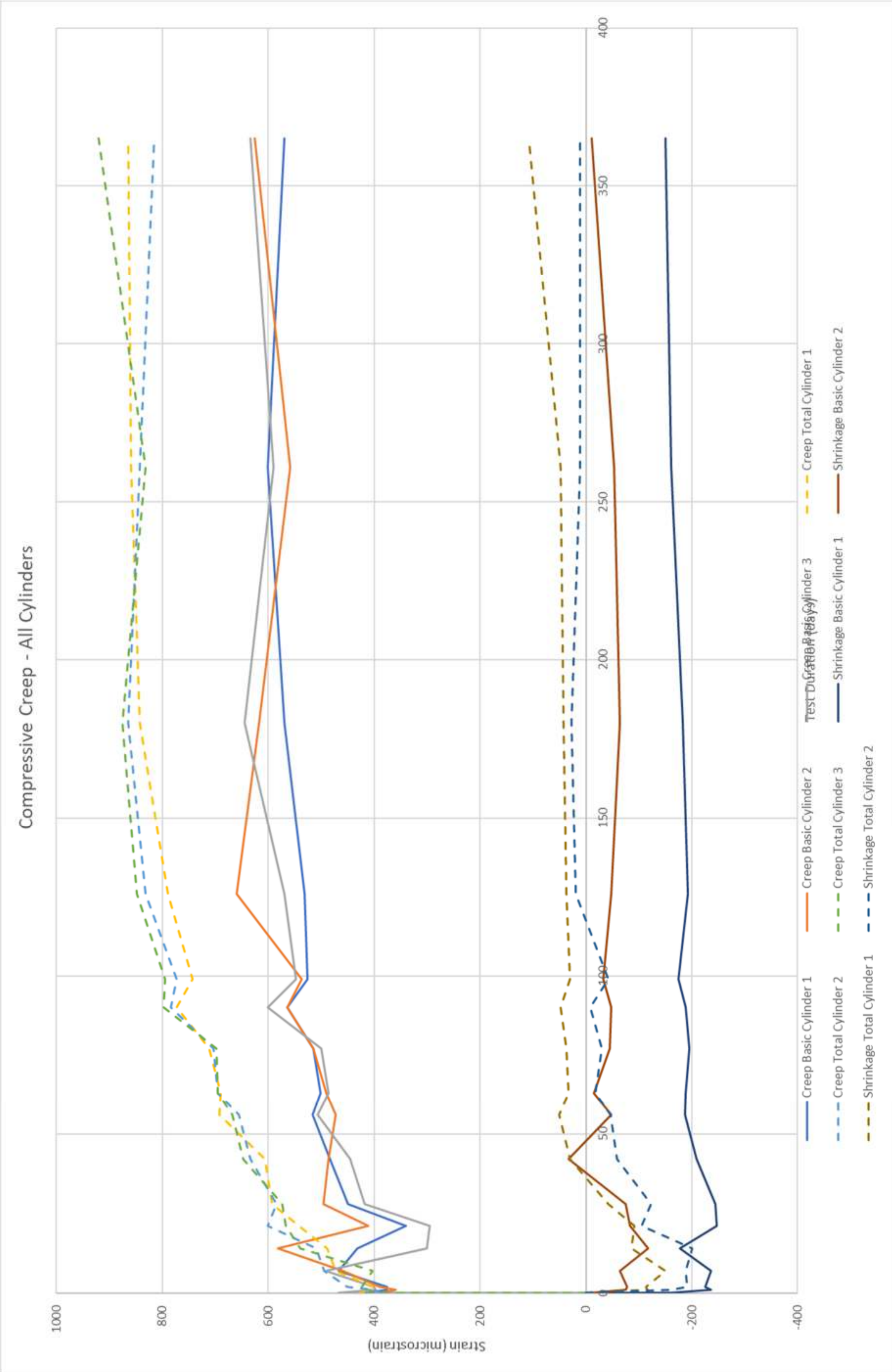

Figure 2. All strains plotted against test time

Age at test (days)	Total Creep		Basic Creep	
	Creep Strain	Shrinkage Strain	Creep Strain	Shrinkage Strain
0	0	0	0	0
0	420	0	385	-57
0	405	0	421	-57
1	409	-92	377	-104
2	426	-101	388	-101
7	456	-113	472	-100
14	513	-96	438	-98
21	570	-65	348	-110
28	584	-55	454	-106
42	629	-10	471	-59
56	672	1	499	-78
63	693	5	492	-68
77	704	3	510	-81
90	784	13	576	-79
99	770	-4	537	-69
126	823	19	587	-81
180	860	23	610	-82
261	844	20	583	-72
365	867	39	609	-54

Table 4. Average strains (in microstrain)

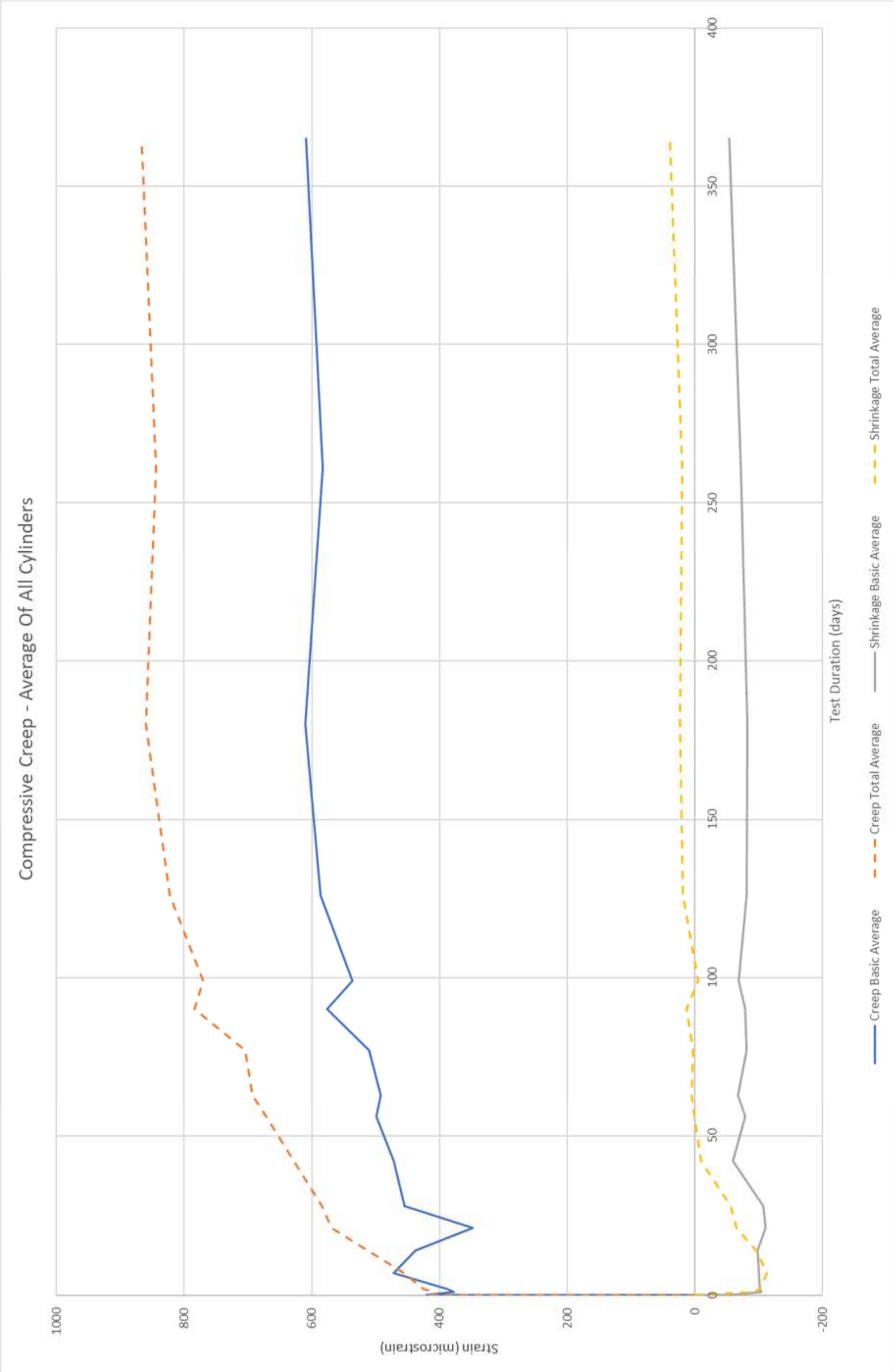

Figure 3. Average strains plotted against test time

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TEST REPORT

Large Scale Flexural Testing of Ecocem ACT Panels.

Prepared for: John Sisk & Son
Date: 10.07.2025
Report number: P128946-1008
Issue: 1
Status: Final - Commercial in Confidence

Prepared for:

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Prepared by:

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Date 10 July 2025

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Authorised by:

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Position Principal Consultant

Date 10 July 2025

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Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake a large scale flexural test on reinforced concrete panels.

This factual report describes the tests conducted and the results obtained.

2.Test Description

The flexural test setup is shown in Figure 1. The specimens were 2.6 m long, 1 m wide and 150 mm deep. The reinforcement in them was laid out as an A252 mesh (8 mm diameter with 200 mm spacing) with 50 mm of concrete cover to the bottom face.

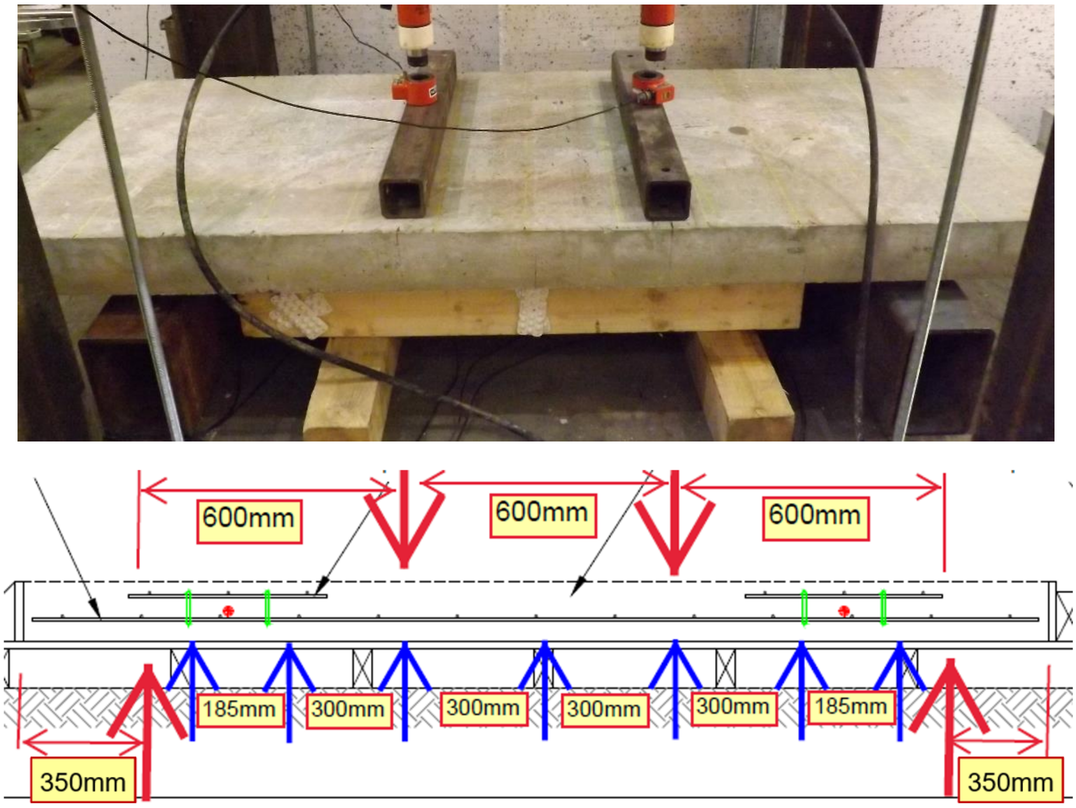


Figure 1. Photograph and schematic of flexural test

The centre of the length of the specimen was marked to be the centre of the test span. Then 300 mm either side of the centre line was marked for the loading positions, and 900 mm either side of the centre line was marked for the support positions. The specimens were supported on rocker bearings, allowing rotation about their centre. The bearings sat on steel box sections on the floor of BRE Structures Laboratory.

The load was applied using hydraulic jacks, through 100 kN Novatech load cells. The load cells were placed in the centre of 900 mm long steel box sections, centred on the loading lines marked on the specimens. The loading and support positions are shown in red in Figure 1.

The deflections of the specimens were measured on the underside of the specimen. Seven Linear Variable Differential Transformers (LVDTs) were used to measure the deflection of the specimen along the length of the span of the test, down the centre of the width. The deflection of the centre of the span was measured, as well as 300 mm, 600 mm, and 785 mm either side of the centre (this final measurement was as close to the support position as possible). The deflection positions are shown in blue in Figure 1.

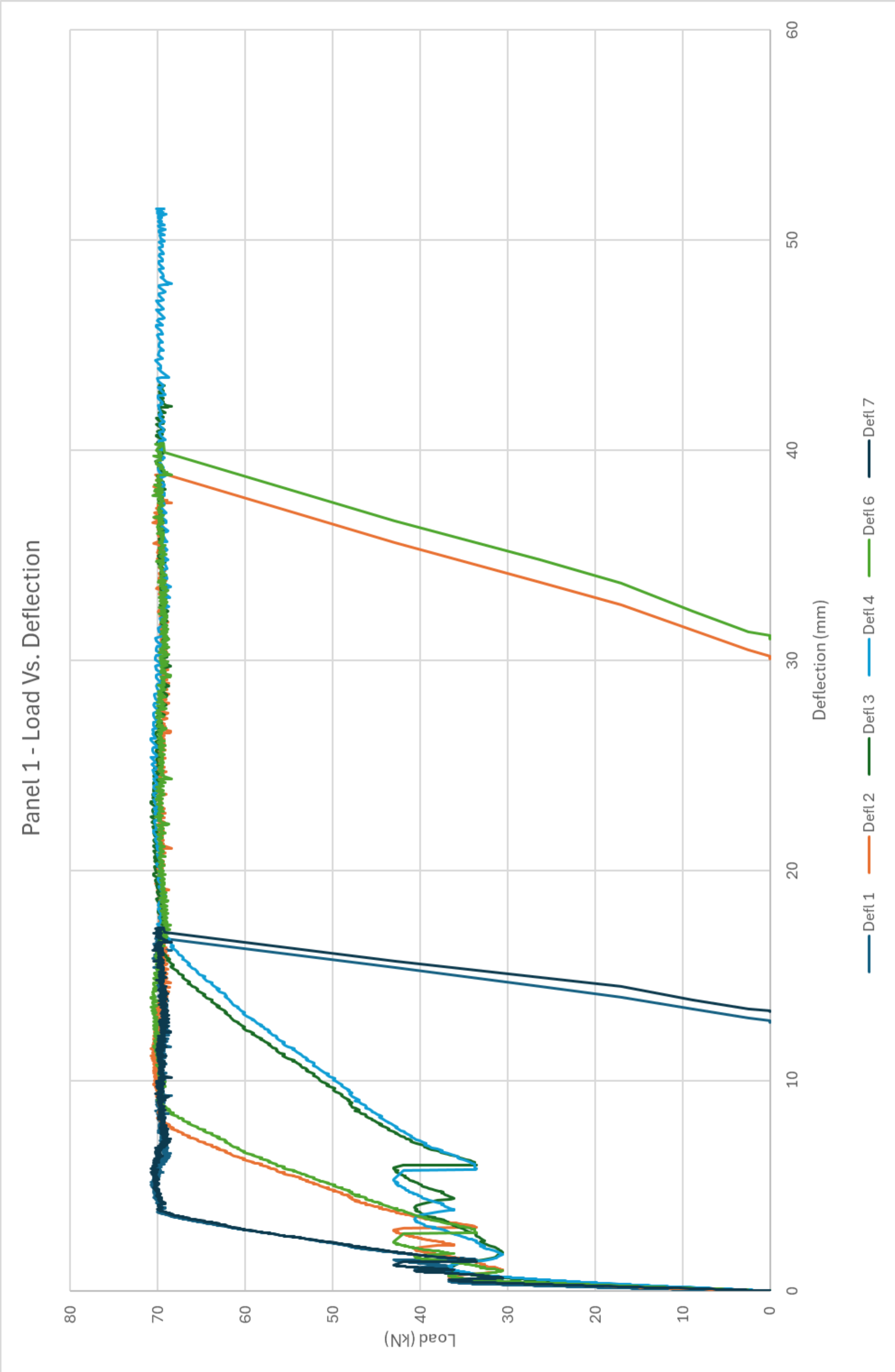
3.Test Results

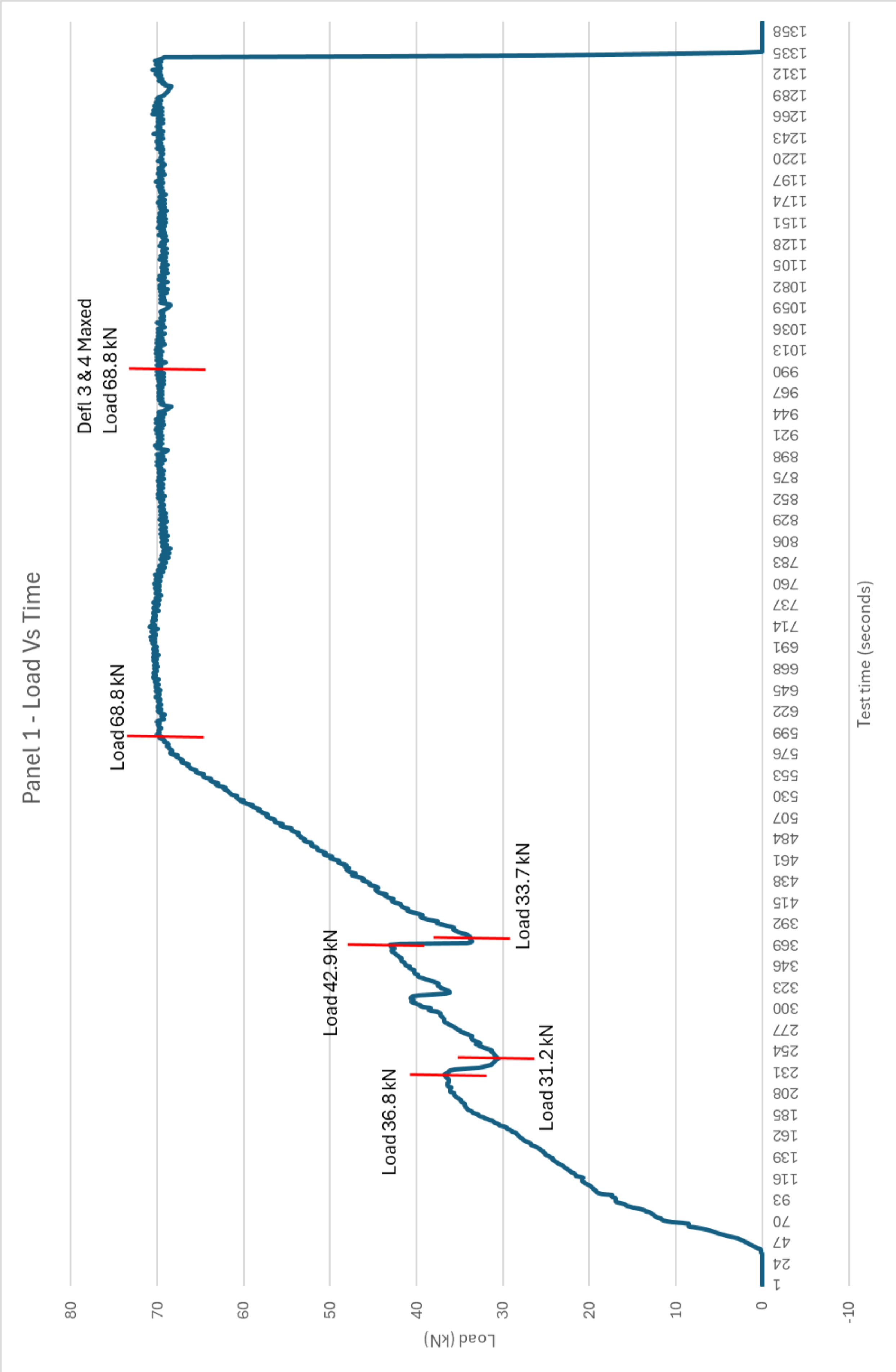
The maximum loads for the flexural tests undertaken are shown in the table below.

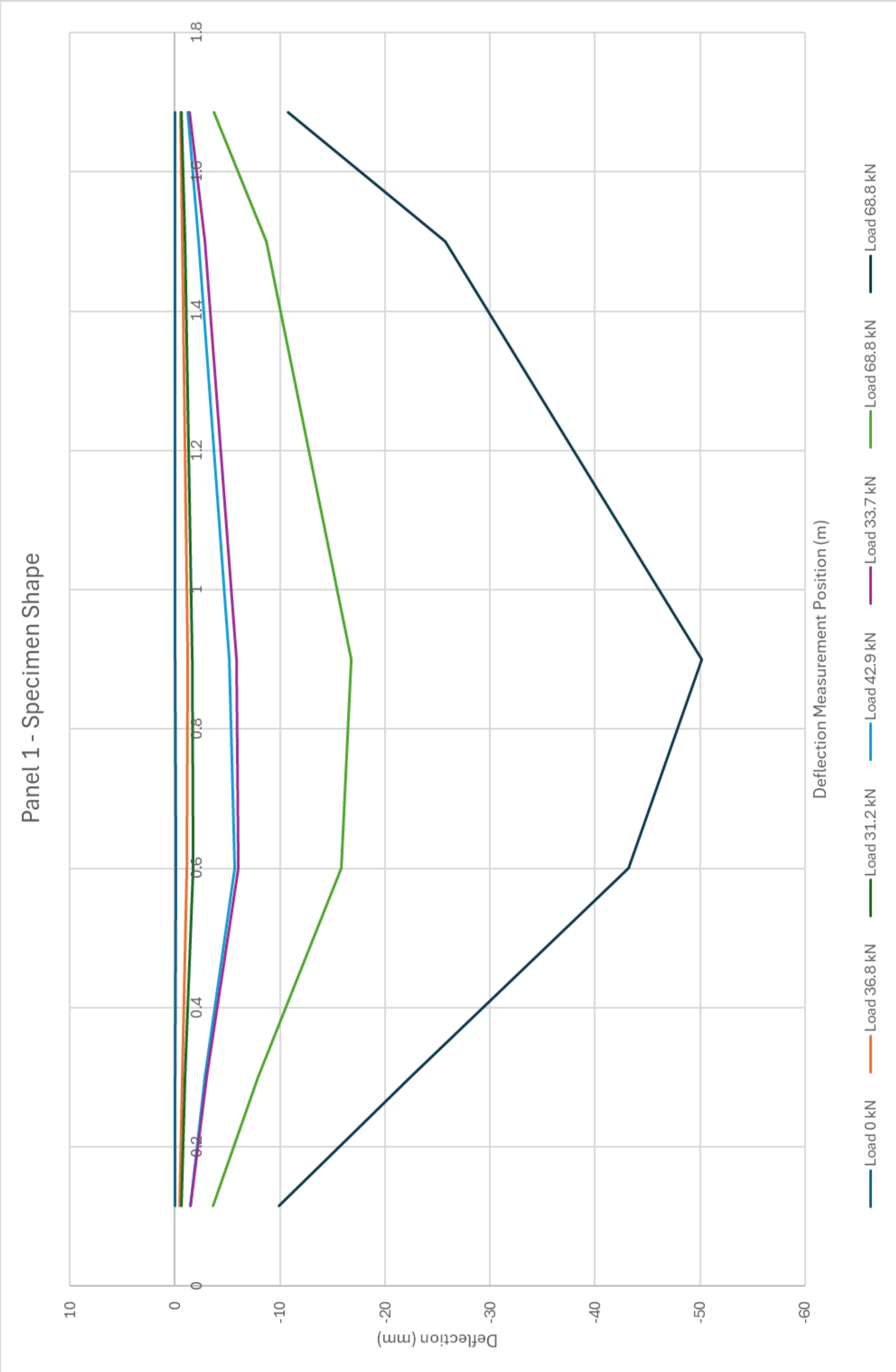
Panel ID	Maximum Load (kN)
1	70.9
2	66.2
3	67.9

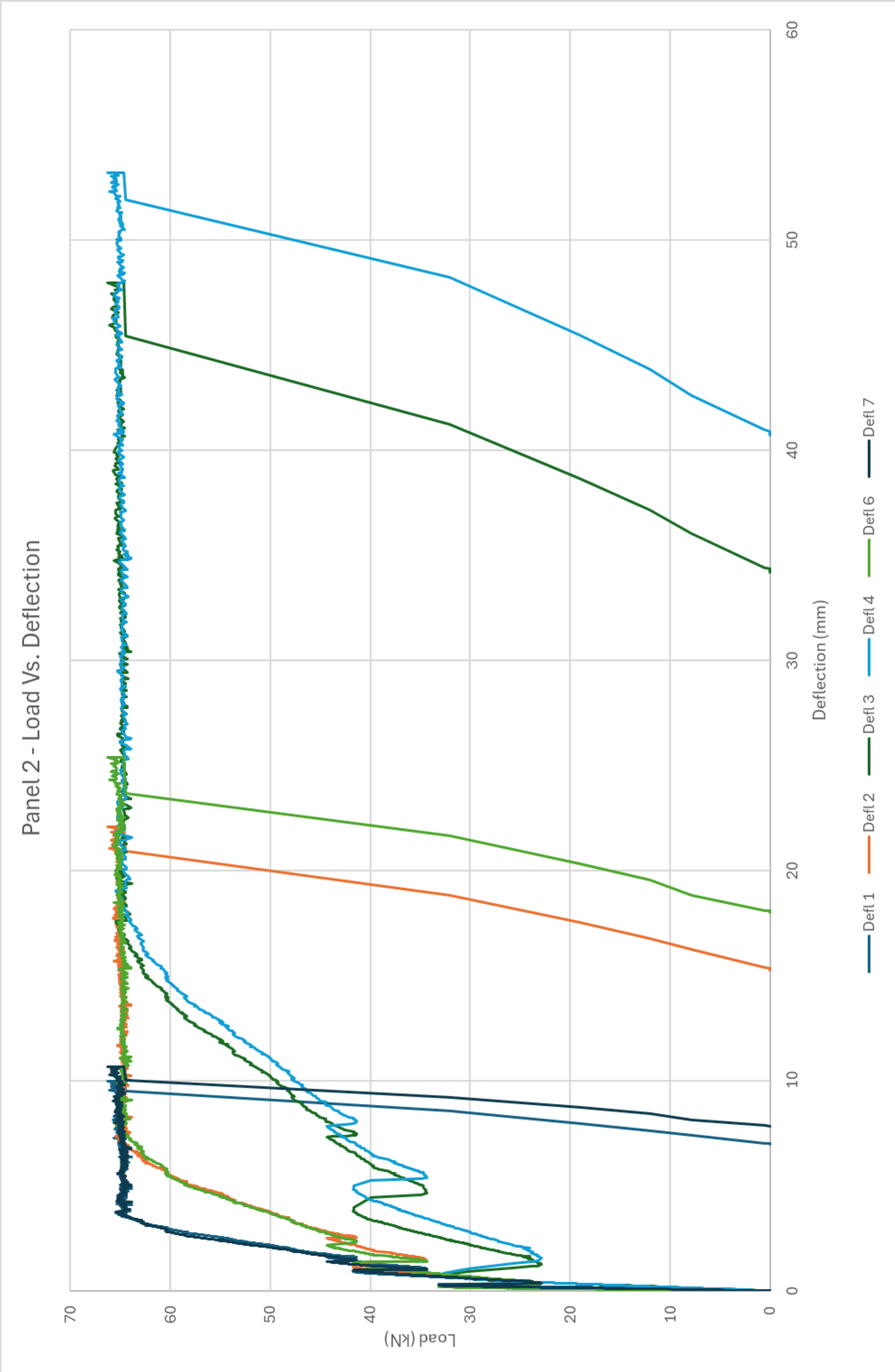
Table 1. Maximum loads for flexural testing

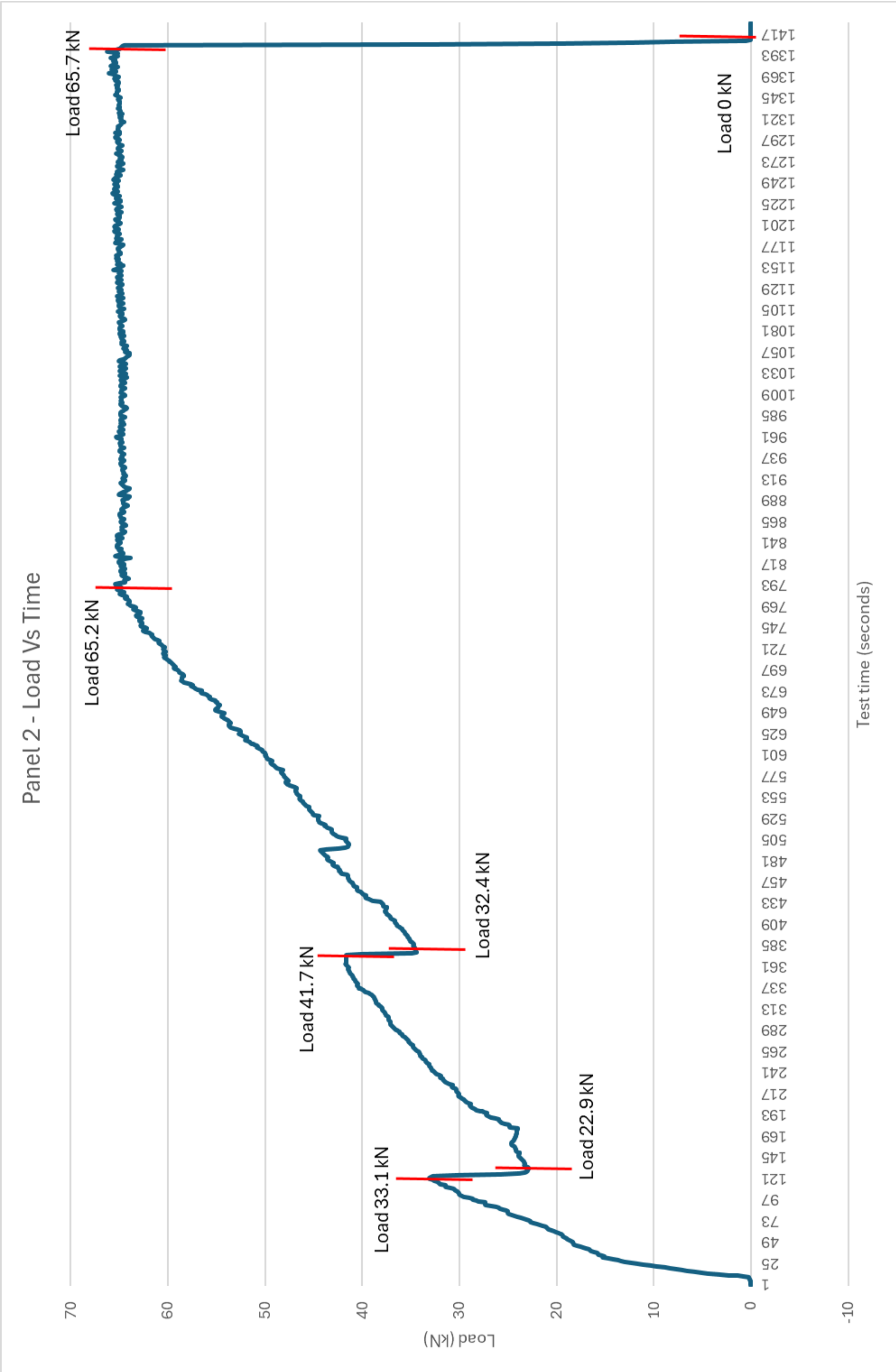
The following graphs show the load against deflections for each panel, the load against time for each panel and the specimen shape at points indicated on the load against time graph. Please note that deflection measurement 5 has been omitted from results due to inconsistent data.

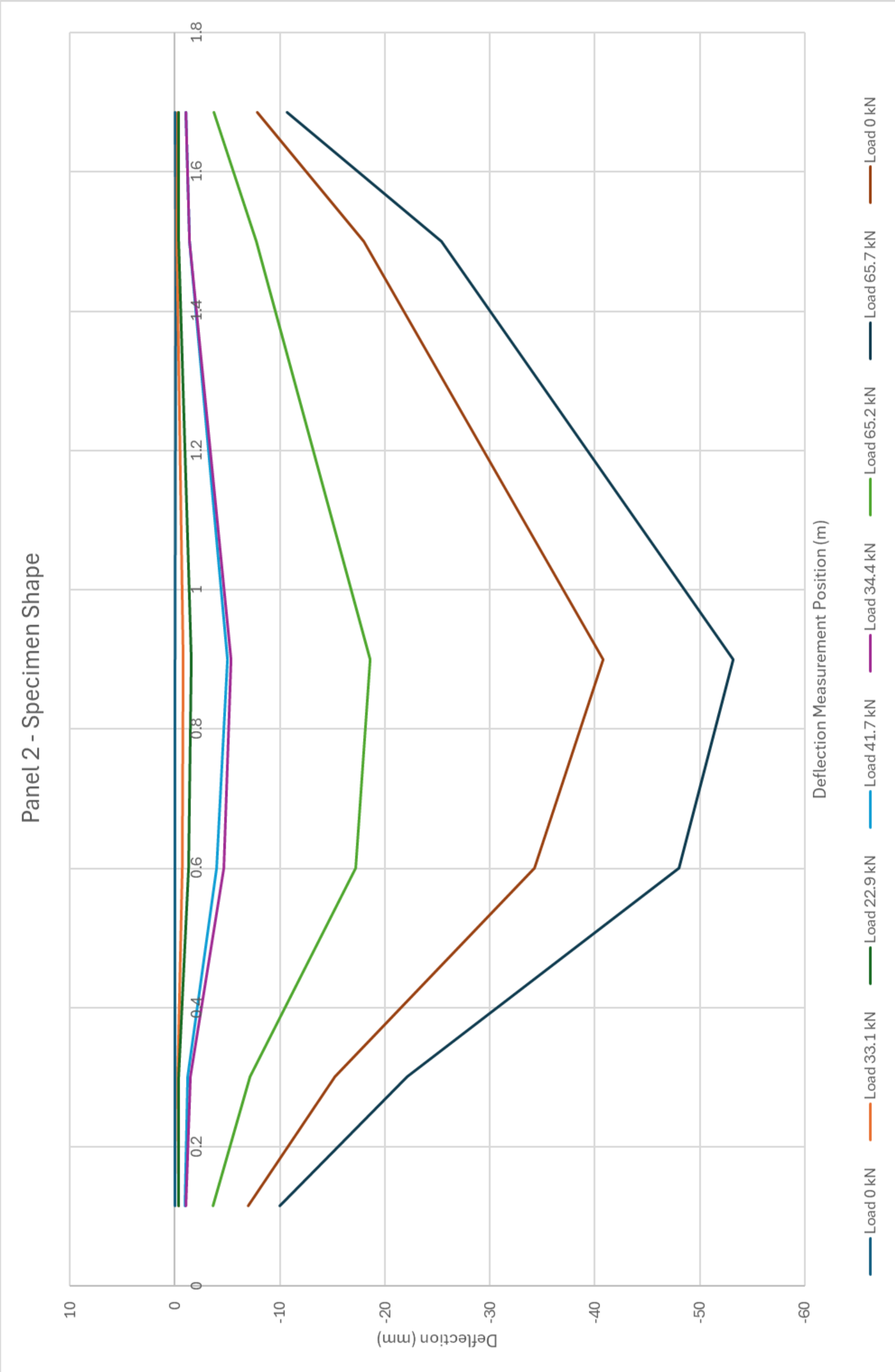

Panel 1 - Load Vs. Deflection
Load (kN)
0
10
20
30
40
50
60
70
80
Deflection (mm)
0
10
20
30
40
50
60
Defl 1
Defl 2
Defl 3
Defl 4
Defl 6
Defl 7

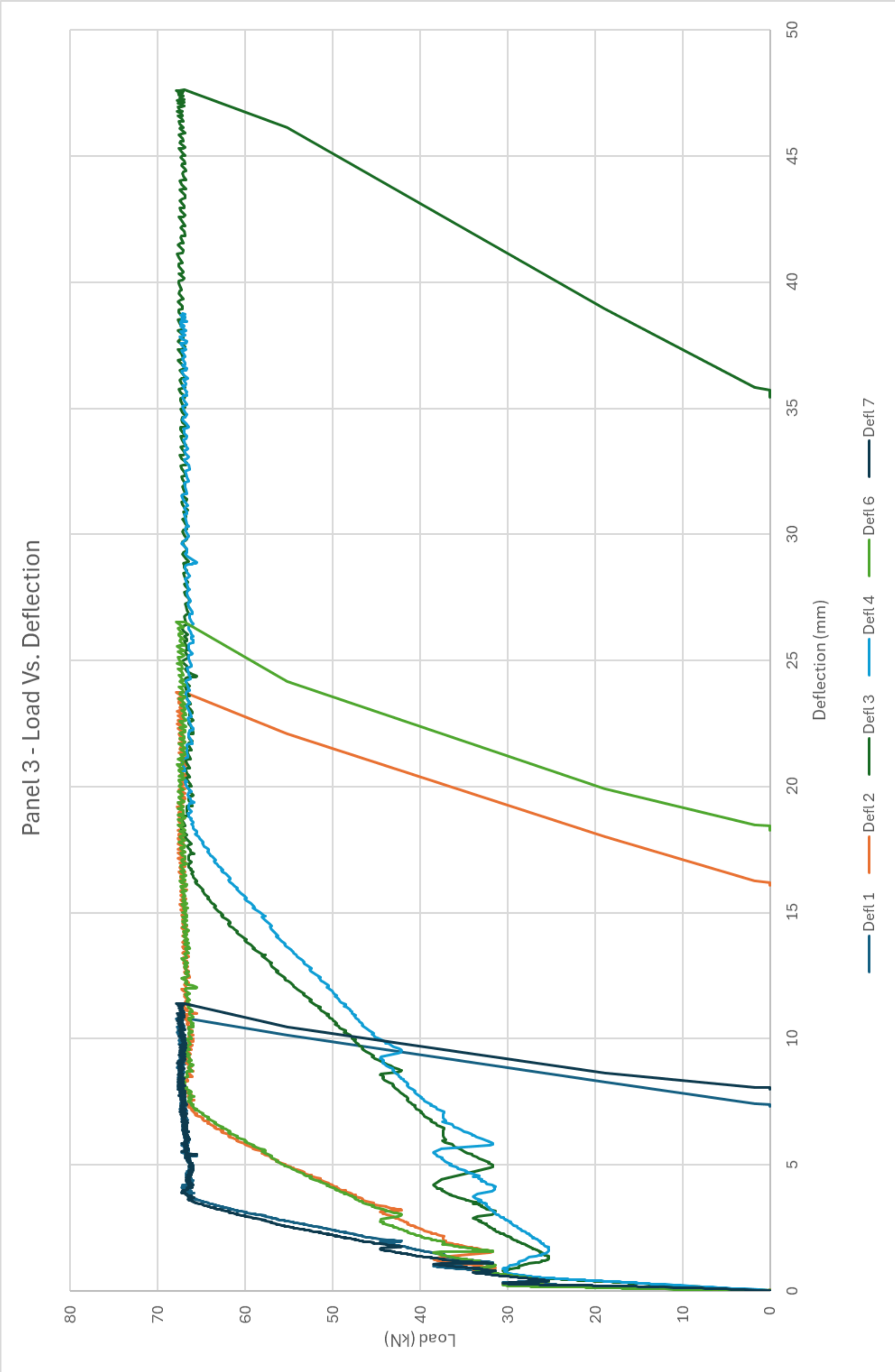

Panel 1 - Load Vs Time
Defl 3 & 4 Maxed
Load 68.8 kN
Load 68.8 kN
Load 33.7 kN
Load 42.9 kN
Load 31.2 kN
Load 36.8 kN
Load (kN)
Test time (seconds)
80
70
60
50
40
30
20
10
0
-10
1
24
47
70
93
116
139
162
185
208
231
254
277
300
323
346
369
392
415
438
461
484
507
530
553
576
599
622
645
668
691
714
737
760
783
806
829
852
875
898
921
944
967
990
1013
1036
1059
1082
1105
1128
1151
1174
1197
1220
1243
1266
1289
1312
1335
1358

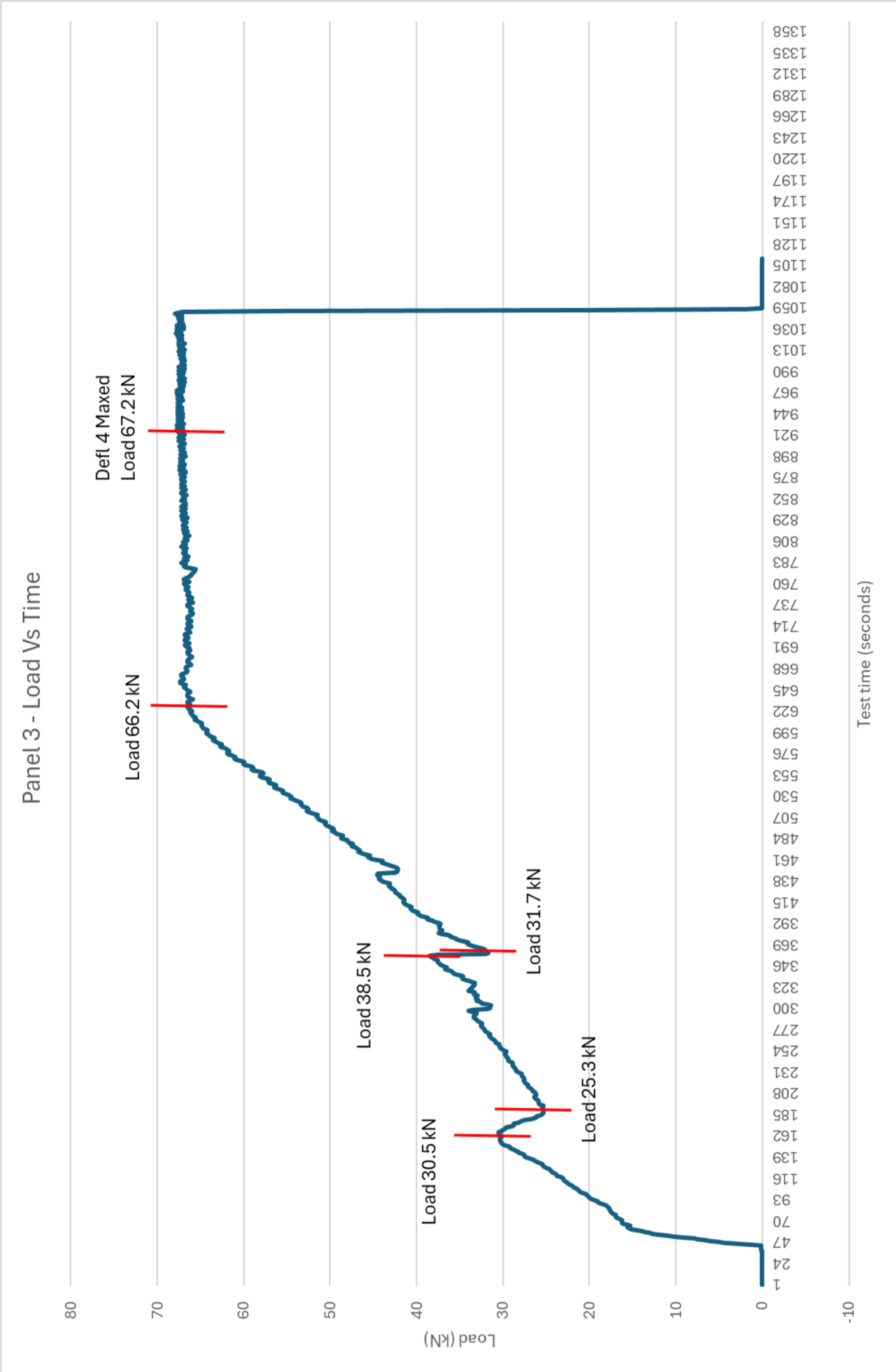

Panel 1 - Specimen Shape
Deflection (mm)
10
0
-10
-20
-30
-40
-50
-60
Deflection Measurement Position (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Load 0 kN
Load 36.8 kN
Load 31.2 kN
Load 42.9 kN
Load 33.7 kN
Load 68.8 kN
Load 68.8 kN

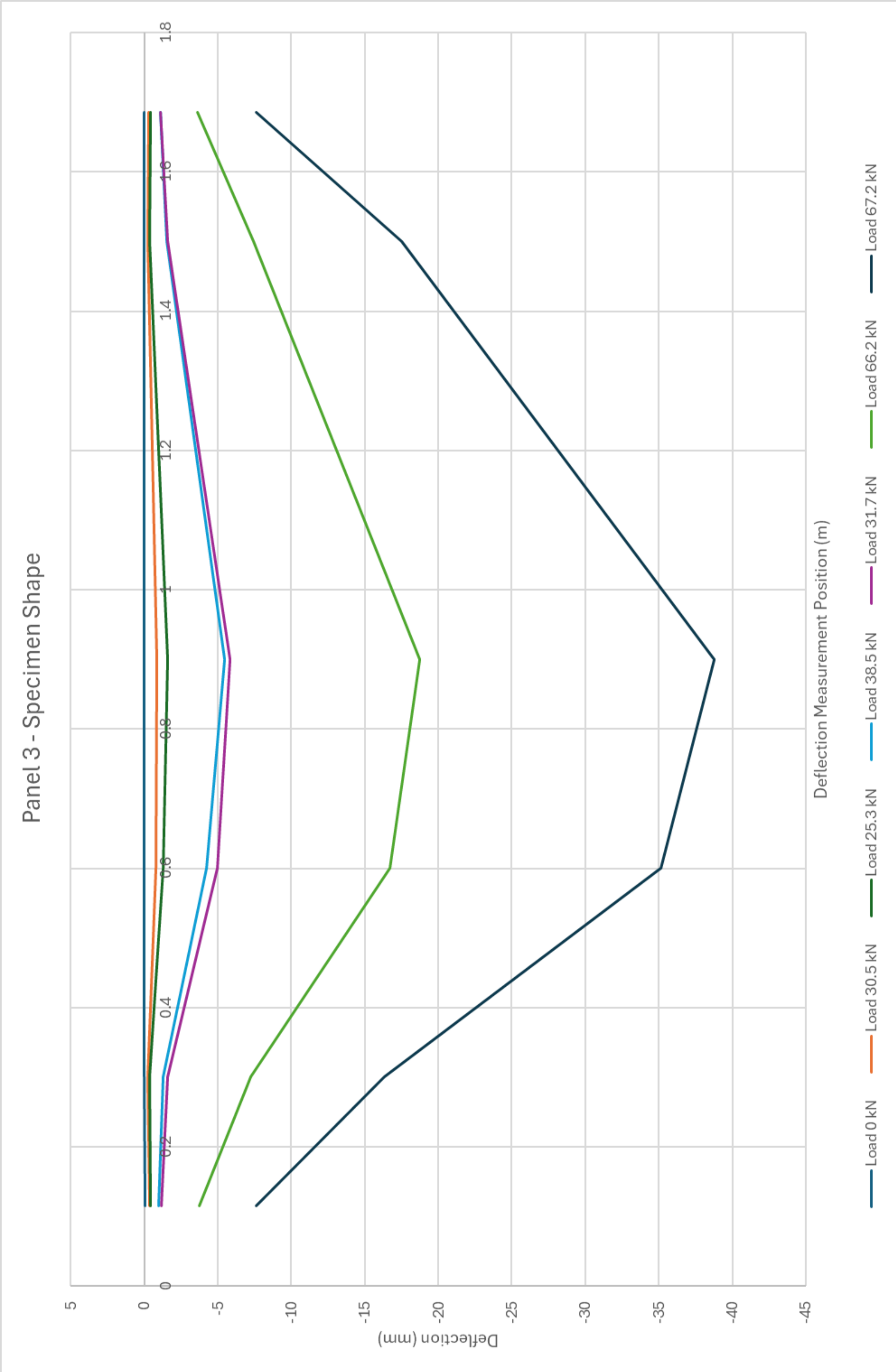

Panel 2 - Load Vs. Deflection
Load (kN)
0
10
20
30
40
50
60
70
Deflection (mm)
0
10
20
30
40
50
60
Defl 1
Defl 2
Defl 3
Defl 4
Defl 6
Defl 7


Panel 2 - Load Vs Time
Load 65.7 kN
Load 65.2 kN
Load 0 kN
Load 32.4 kN
Load 41.7 kN
Load 22.9 kN
Load 33.1 kN
Load (kN)
Test time (seconds)


Panel 2 - Specimen Shape
Deflection (mm)
10
0
-10
-20
-30
-40
-50
-60
Deflection Measurement Position (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Load 0 kN
Load 33.1 kN
Load 22.9 kN
Load 41.7 kN
Load 34.4 kN
Load 65.2 kN
Load 65.7 kN
Load 0 kN


Panel 3 - Load Vs. Deflection
Load (kN)
Deflection (mm)
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40
45
50
Defl 1
Defl 2
Defl 3
Defl 4
Defl 6
Defl 7


Panel 3 - Load Vs Time
Defl 4 Maxed
Load 67.2 kN
Load 66.2 kN
Load 31.7 kN
Load 38.5 kN
Load 25.3 kN
Load 30.5 kN
Load (kN)
Test time (seconds)


Panel 3 - Specimen Shape
Deflection (mm)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
Deflection Measurement Position (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Load 0 kN
Load 30.5 kN
Load 25.3 kN
Load 38.5 kN
Load 31.7 kN
Load 66.2 kN
Load 67.2 kN

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TEST REPORT

Testing of Ecocem ACT to BS EN 12390-12:2020.

Prepared for: John Sisk & Son
Date: 07.11.2025
Report number: P128946-1010
Issue: 2
Status: Final - Commercial in Confidence

Prepared for:

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Date 07 November 2025

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Date 07 November 2025

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1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake accelerated carbonation testing of ACT and a reference concrete to BS EN 12390-12:2020.

This factual report describes the tests conducted and the results obtained.

2.Test Description

Two readymix concretes, one ACT mix and one conventional concrete mix, were delivered to BRE in Garston on 3rd June 2025 for casting of test specimens. Two 500 mm x 100 mm x 100 mm beams were cast from each mix and initially cured in 20 °C water for 28 days. At 28 days after casting, the specimens were moved to cure in 20 °C and 65 %RH for a further 14 days. After this period, the specimens were placed into the carbonation cabinet, set to 20 °C, 65 %RH and 3 % CO_2. A 50 mm section was split off the end of each beam and the carbonation depth measured at 0, 7, 28, and 70 days after being placed into the cabinet. The carbonation depth was measured by spraying the newly exposed face of the split section with phenolphthalein solution. The resulting colour change was measured at 12no. positions on each sprayed face, resulting in 24no. measurements at each age.

3.Test Results

Table 1 shows the average carbonation depth from accelerated exposure on each face of the two split sections for the ACT concrete. It also shows the average carbonation depth for each specimen, and the average carbonation depth at each age. Figure 1 shows the average depth of carbonation for each ACT specimen, plotted against the squareroot of time in days. Table 2 shows the photographs of the sprayed faces taken at each exposure duration.

Date of test	Exposure Duration (days)	Specimen ID	$d_{k,face}$				$d_{k,spec}$	d_k
			Face 1	Face 2	Face 3	Face 4		
15/07/2025	0	A25/037/15	0.0	0.0	0.0	0.7	0.2	0.2
		A25/037/16	0.0	0.0	0.0	0.6	0.1	
22/07/2025	7	A25/037/15	0.0	4.1	6.5	7.6	4.5	3.8
		A25/037/16	0.0	3.8	4.5	3.8	3.0	
12/08/2025	28	A25/037/15	0.0	8.4	9.0	8.1	6.4	5.5
		A25/037/16	0.0	6.4	5.8	6.7	4.7	
23/09/2025	70	A25/037/15	0.0	10.6	8.7	12.3	7.9	8.0
		A25/037/16	0.0	10.7	9.9	12.0	8.1	

Table 1. Average carbonation depths on each face of the ACT concrete specimens during testing

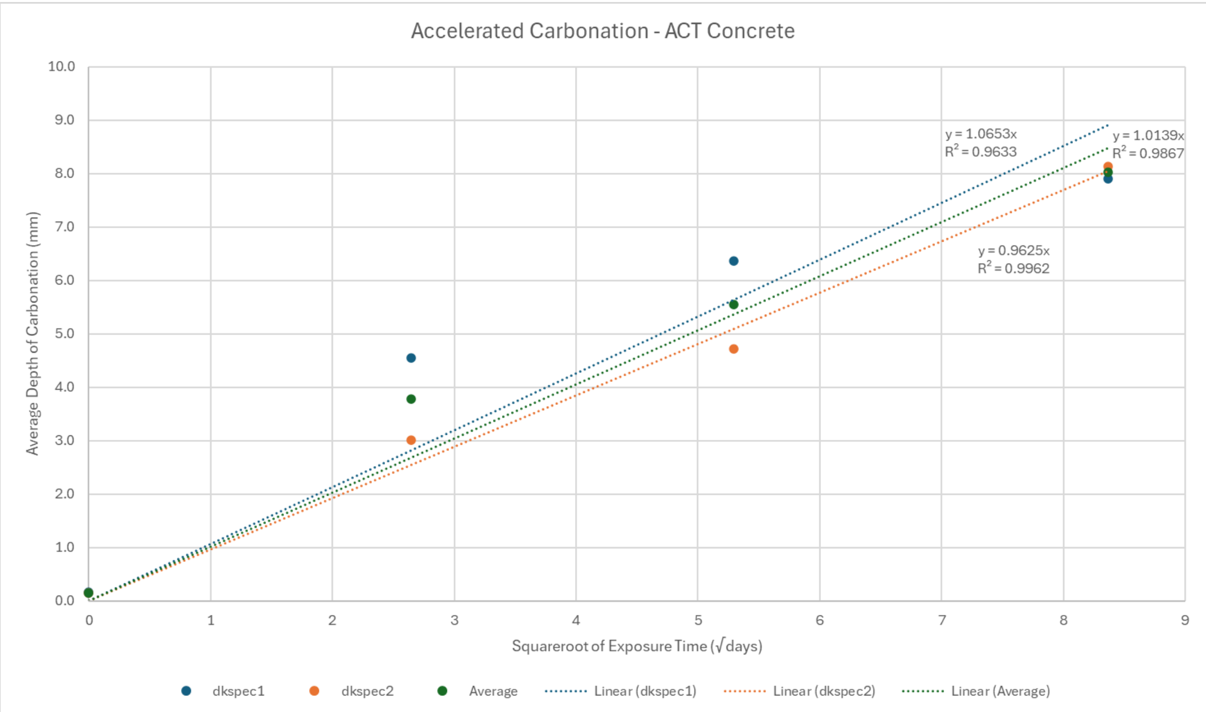


Figure 1. Average rate of carbonation plotted against square root of time for the ACT concrete

The average rate of accelerated carbonation for the ACT concrete was 1.0 mm/√day.

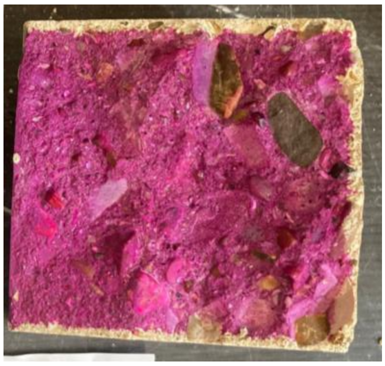
Exposure Time	Specimen 1 – A25/037/15	Specimen 2 – A25/037/16
0 days		
7 days		
28 days		
70 days		

Table 2. Photographs of the sprayed faces for the ACT specimens

Table 3 shows the average carbonation depth from accelerated exposure on each face of the two split sections for the conventional concrete. It also shows the average carbonation depth for each specimen, and the average carbonation depth at each age. Table 4 shows the photographs of the sprayed faces taken at each exposure duration.

Date of test	Exposure Duration (days)	Specimen ID	$d_{k,face}$				$d_{k,spec}$	d_k
			Face 1	Face 2	Face 3	Face 4		
15/07/2025	0	A25/038/13	0.0	0.0	0.0	0.0	0.0	0.0
		A25/038/14	0.0	0.0	0.0	0.0	0.0	
22/07/2025	7	A25/038/13	0.0	0.0	0.0	0.0	0.0	0.0
		A25/038/14	0.0	0.0	0.0	0.0	0.0	
12/08/2025	28	A25/038/13	0.0	0.0	0.0	0.0	0.0	0.0
		A25/038/14	0.0	0.0	0.0	0.0	0.0	
23/09/2025	70	A25/038/14	0.0	0.0	0.0	0.0	0.0	0.0
		A25/038/15	0.0	0.0	0.0	0.0	0.0	

Table 3. Average carbonation depths on each face of the conventional concrete specimens during testing

The average rate of accelerated carbonation for the conventional concrete was 0.0 mm/√day.

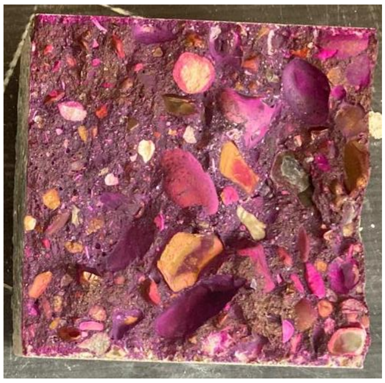
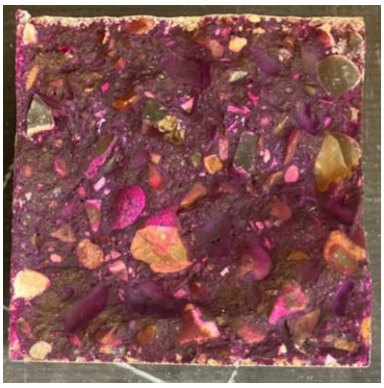
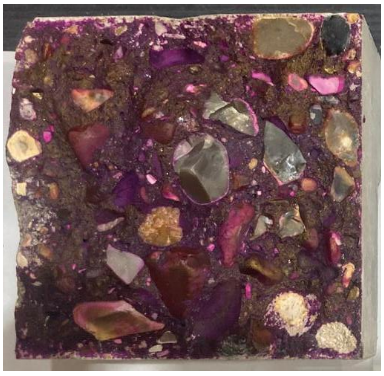
Exposure Time	Specimen 1 – A25/038/13	Specimen 2 – A25/038/14
0 days		
7 days		
28 days		
70 days		

Table 4. Photographs of the sprayed faces for the conventional concrete specimens

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TEST REPORT

Freeze-Thaw Resistance Testing of Ecocem ACT to PD CEN/TS 12390-9:2016.

Prepared for: John Sisk & Son
Date: 10.07.2025
Report number: P128946-1004
Issue: 1
Status: Final - Commercial in Confidence

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Date	10 July 2025
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Authorised by:

Name	Martyn Webb
Position	Principal Consultant
Date	10 July 2025
Signature	

Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake freeze-thaw resistance testing, as outlined in BSI Flex 350 v1.0.

This factual report describes the tests conducted and the results obtained.

2.Test Description

BRE attended a site mixing trial of an Ecocem ACT concrete at Capital Concrete on 4th September 2024 and cast specimens for a range of tests, including 150 mm cubes for freeze-thaw resistance testing through the PD CEN/TS 12390-9:2016 scaling test, as detailed by BSI Flex 350 v1.0. The fresh concrete was hand-tamped into steel moulds and covered in damp sacking and polythene before being left overnight in a container at Capital Concrete. The following day the specimens were transported back to BRE and demoulded, before being placed in water tanks at 20 °C ± 2 °C.

Seven days after casting, the specimens were removed from water and placed into a curing room at 20 ± 2 °C and 65 ± 5 %RH. The specimens were sawn into slabs as per Figure 1 of PD CEN/TS 12390-9:2016 21 days after casting and returned to the curing room. The four sides and base of each specimen were then sealed with a rubber sheet 25 days after casting and the test face was ponded with deionized water 28 days after casting. The ponding water was discarded, and the specimens entered the freeze-thaw cabinet 31 days after casting. Four of the specimens had new deionized water as the scaling solution, and four specimens had a 3 % salt solution. All specimens had polystyrene insulation on all faces except the test face. The specimens then underwent 56 cycles of freezing and thawing in the test cabinet. The scaled material on each specimen was carefully removed through filter paper after 7, 14, 28, 42, and 56 days in the cabinet and weighed after being dried in an oven.

3.Test Results

The mean cumulative scaled material per unit area over the exposure period up to 56 cycles is shown in Table 1 for the deionized water specimens and in Table 2 for the salt solution specimens.

Specimen Number	S_7 kg/m^2	S_{14} kg/m^2	S_{28} kg/m^2	S_{42} kg/m^2	S_{56} kg/m^2
A24/068/10	0	0.0176	0.0252	0.0329	0.0960
A24/068/14	0	0.0036	0.0062	0.0147	0.0290
A24/068/16	0	0.0229	0.0288	0.0367	0.0452
A24/068/19	0	0.0175	0.0242	0.0423	0.0472
Mean	0	0.015	0.021	0.032	0.054

Table 1. Summary of cumulative scaled material per unit area for the deionized water specimens

At each scaling measurement interval, a visual assessment of the cubes did not highlight severe cracking, scaling of the aggregate particles, or loss of the deionized water.

Specimen Number	S_7 kg/m^2	S_{14} kg/m^2	S_{28} kg/m^2	S_{42} kg/m^2	S_{56} kg/m^2
A24/068/11	0	0.7467	1.4428	3.9937	6.6736
A24/068/13	0	0.8381	1.4810	3.3202	6.1464
A24/068/17a	0	0.7519	1.4314	3.3541	5.5715
A24/068/17b	0	0.7370	1.5155	4.1889	7.9980
Mean	0	0.768	1.468	3.714	6.597

Table 2. Summary of cumulative scaled material per unit area for the salt solution specimens

At each scaling measurement interval, a visual assessment of the cubes did not highlight severe cracking, or loss of the salt solution, however aggregate particles were lost from the start of test. It should be noted that the concrete tested was not designed to resist freeze-thaw.

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TEST REPORT

Testing of Ecocem ACT to BSI Flex 350 for Sulfate Resistance.

Prepared for: John Sisk & Son
Date: 07.11.2025
Report number: P128946-1007
Issue: 3
Status: Final - Commercial in Confidence

Prepared for:

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Prepared by:

Name Christopher Yapp

Position Senior Consultant

Date 07 November 2025

Signature

Authorised by:

Name Martyn Webb

Position Principal Consultant

Date 07 November 2025

Signature

Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake sulfate resistance testing of the Ecocem ACT concrete to BSI Flex 350.

This factual report describes the tests conducted and the results obtained.

2.Test Description

BRE attended a site mixing trial of an Ecocem ACT concrete at Capital Concrete on 4th September 2024 and cast specimens for a range of tests, including 4no. 100 mm cubes for sulfate resistance testing. The fresh concrete was hand-tamped into steel moulds and covered in damp sacking and polythene before being left overnight in a container at Capital Concrete. The following day the specimens were transported back to BRE and demoulded, before being placed in water tanks at 20 °C ± 2 °C.

At 28 days after casting, the specimens were removed from water tanks and weighed. A wear rating measurement was then taken on the cubes. The wear rating measurement is a diagonal measurement taken from corner-to-corner on two opposite faces of the cube (with the cube kept in the same orientation as cast) as shown in Figure 1. As the cube is chemically degraded by the sulfate solution, the concrete surface and corners are the first to be degraded and lost, so measuring this concrete face loss is a measurement of the susceptibility of the concrete to sulfate attack. The four measurements taken are then averaged as an average loss per corner (i.e. averaged, then subtracted from the initial measurement and then halved).

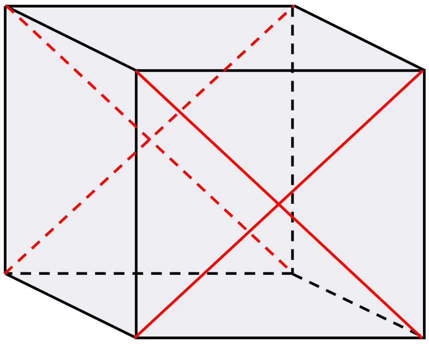

Figure 1. Wear rating measurement locations

Wear rating and mass measurements are taken at 28 days after casting when they are placed into the sulfate solutions at 20 °C ± 2 °C, and then again after 3 months, 6 months, and 12 months in solution. The solutions are refreshed every 3 months to ensure the sulfate concentration is maintained across the length of the test.

Two solutions were used in this test programme, with 2no. 100 mm cubes in a Class 2 sulfate solution stored at 5 °C ± 2 °C and 2no. 100 mm cubes in a Class 5 sulfate solution stored at 5 °C ± 2 °C. A Class 2 sulfate solution is a saturated gypsum (calcium sulfate) solution, whilst a Class 5 sulfate solution contains 5.44 g/l of anhydrous magnesium sulfate and 6.96 g/l of anhydrous sodium sulfate.

3.Test Results

Table 1 shows the wear rating results whilst Table 2 shows the mass changes of the Ecocem ACT specimens after 12 months of sulfate immersion. Table 4 contains photographs taken at the measurement dates of the specimens in Class 2 solution, whilst Table 5 contains photographs taken at the measurement dates of the specimens in Class 5 solution.

Days in Solution	Wear Ratings (mm)	
	Class 2	Class 5
0	0	0
91	0	0
182	1	0
365	1	-1

Table 1. Wear ratings of Ecocem ACT specimens in sulfate solutions

Days in Solution	Mass Change (g)	
	Class 2	Class 5
0	0	0
91	5	4
182	7	5
365	6	5

Table 2. Mass changes of Ecocem ACT specimens in sulfate solutions

Measurements up to 12 months indicate that all specimens are comparable with the best performing reference PC-based concrete mix from another study IEEA/Carbon Trust, (testing CEM I, CEM II/B-V, CEM III-A reference concretes) designed to resist DC-4 conditions- shown in Table 3. This low wear rating, combined with the low mass change per cube is consistent with limited sulfate reactions having occurred within the specimens.

Days in Solution	Wear Ratings (mm)
	Class 5
0	0
91	0
182	1
365	3

Table 3. Wear ratings of CEM III/A specimens in Class 5 solution in previous test regime

Days in Solution	Photographs of Class 2 Specimens
0	
91	
182	
365	

Table 4. Photographs of specimens in Class 2 solution

Days in Solution	Photographs of Class 5 Specimens
0	
91	
182	
365	

Table 5. Photographs of specimens in Class 5 solution

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TEST REPORT

Testing of Ecocem ACT to BSI Flex 350 for Acid Resistance.

Prepared for: John Sisk & Son
Date: 07.11.2025
Report number: P128946-1006
Issue: 3
Status: Final - Commercial in Confidence

Prepared for:

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Prepared by:

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Position	Senior Consultant
Date	07 November 2025
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Authorised by:

Name	Martyn Webb
Position	Principal Consultant
Date	07 November 2025
Signature	

Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake acid resistance testing of the Ecocem ACT concrete to BSI Flex 350.

This factual report describes the tests conducted and the results obtained.

2.Test Description

BRE attended a site mixing trial of an Ecocem ACT concrete at Capital Concrete on 4th September 2024 and cast specimens for a range of tests, including 2no. 100 mm cubes for acid resistance testing. The fresh concrete was hand-tamped into steel moulds and covered in damp sacking and polythene before being left overnight in a container at Capital Concrete. The following day the specimens were transported back to BRE and demoulded, before being placed in water tanks at 20 °C ± 2 °C.

At 28 days after casting, the specimens were removed from water tanks and weighed. A wear rating measurement was then taken on the cubes. The wear rating measurement is a diagonal measurement taken from corner-to-corner on two opposite faces of the cube (with the cube kept in the same orientation as cast) as shown in Figure 1. As the cube is chemically degraded by the acid solution, the concrete surface and corners are the first to be degraded and lost, so measuring this concrete face loss is a measurement of the susceptibility of the concrete to acid attack. The four measurements taken are then averaged as an average loss per corner (i.e. averaged, then subtracted from the initial measurement and then halved).

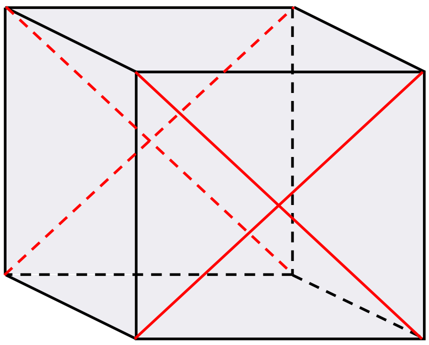

Figure 1. Wear rating measurement locations

Wear rating and mass measurements are taken at 28 days after casting when they are placed into the citric acid solution at 20 °C ± 2 °C, and then again after 3 months, 6 months, and 12 months in solution. The solutions are refreshed every 3 months to ensure the acid concentration is maintained across the length of the test.

3.Test Results

Wear rating measurements showed that all surface concrete was lost after 91 days. Table 1 shows the mass changes of the Ecocem ACT specimens after 12 months of acid immersion. Table 3 contains photographs of the specimens kept in citric acid taken at each measurement date.

Days in Solution	Mass Change (%)
	Citric Acid
0	0
91	4.6
182	5.0
365	4.9

Table 1. Mass changes of Ecocem ACT specimens in sulfate solutions

BSI Flex 350 states to compare these results to a DC-4z concrete (maximum w/c ratio of 0.45, minimum cement content of 360 kg/m^3 for a maximum 20 mm aggregate, using any cement combination listed in Table D2 of SD1). Previous acid resistance testing at BRE of concretes of w/c ratio of 0.45 and slightly lower cement content of 350 kg/m^3 showed mass changes as per the table below.

Days in Solution	Mass Change (%)		
	CEM I	CEM II/B-V	CEM III/A
0	0	0	0
91	4.4	4.3	2.7
182	12.4	13.1	9.8
365	26.6	32.7	25.7

Table 2. Previous acid resistance testing at BRE

Days in Solution	Photographs of Specimens
0	
91	
182	
365	

Table 3. Photographs of specimens in citric acid exposure over time

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TEST REPORT

Fire Testing of Ecocem ACT to bespoke specification.

Prepared for: John Sisk & Son
Date: 11.11.2025
Report number: P128946-1009
Issue: 1
Status: Final - Commercial in Confidence

Prepared for:

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Date 11 November 2025

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Authorised by:

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Position Principal Consultant

Date 11 November 2025

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Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake comparative fire testing of Ecocem ACT and a conventional concrete to a bespoke specification based on EFNARC 132F r3:2006.

This factual report describes the tests conducted and the results obtained.

2.Test Description

On 3rd June 2025, two fire test specimens and accompanying compressive strength cubes were cast at BRE, to the size and specification shown in the Fire Testing Method Statement in the Appendix. One fire test specimen was made from Ecocem ACT concrete, whilst the other was a conventional comparative concrete. Both concretes were supplied by Capital Concrete in Readymix trucks and used wooden moulds supplied by Harringtons. The thermocouples were fixed in position on the morning of the pour by BRE and the concrete vibrated into the moulds using a vibrating poker by Harringtons. The fire test specimens were left to cure overnight under damp sacking and polythene, before being demoulded and moved into indoor curing under damp sacking and polythene the day after casting. The specimens then spent 3 months curing indoors at 20 °C under damp sacking and polythene, before the damp sacking and polythene was removed and they were cured at 20 °C and 50 % RH for a further 28 days. The compressive strength cubes were initially stored indoors under damp sacking and polythene before being demoulded the day after casting and being stored in 20 °C water tanks until compressive strength test to BS EN 12390-3 at 7 and 28 days, as well as on the day of the fire test.

After curing and before testing, the fire test specimens each had a 50 mm diameter x 75 mm long core removed from the back of the slab in each corner. Two of these cores were tested for compressive strength as close to the day of test as possible, whilst the other two cores were weighed and then dried at 110 °C until constant weight to determine the moisture content of the concrete.

On the day of test, the slab was weighed before being braced in front of the test furnace (opening size 900 mm by 1100 mm). Any gaps between the furnace and the slab were filled with a mineral wool insulator to prevent excess heat escape, and the furnace applied a temperature/time curve using the equation below, taken from BS 476:20:1987 and Draft BS ISO 834-1:

$$T = 345 \log_{10} (8t + 1) + 20$$

where

T is the average furnace temperature, in degrees Celsius;

t is the time, in minutes.

The temperature curve was applied for half an hour on each specimen (originally intended to be longer, however spalling in the first test risked the integrity of the furnace, so the test was stopped at half an hour). The temperature of the furnace and the temperature of the embedded thermocouples was measured throughout testing. After testing, the specimens were allowed to cool, before being photographed. The test face was visually monitored for 48 hours following testing to ensure all spalling damage was recorded. The specimens were then laid flat and cored for residual compressive strength testing.

After testing, cores were taken starting in the back of the slab, avoiding rebar, as close to the centre of the slab as possible. The cores were visually inspected for all signs of damage.

After completion of the visual examination of the core, a series of 50 mm x 50 mm cylinders were prepared, working from the exposed face of the concrete, and were tested for compressive strength to BS EN 12390-3 in order to give a strength profile through the concrete.

3.Test Results

3.1 Compressive Strength Cubes

The 7, 28, and 112 day cube compressive strength results are shown in Table 1 for the Ecocem ACT concrete and Table 2 for the conventional concrete.

Age	Specimen ID	Density (kg/m³)		Compressive strength (MPa)	
		Individual	Average	Individual	Average
7	1	2340	2360	25.6	27.2
	2	2370		28.5	
	3	2370		27.4	
28	4	2360	2360	52.5	52.4
	5	2360		53.2	
	6	2370		51.7	
112	7	2370	2370	61.6	62.5
	8	2350		62.1	
	9	2380		63.9	

Table 1. Compressive cube strength results for the Ecocem ACT concrete

Age	Specimen ID	Density (kg/m³)		Compressive strength (MPa)	
		Individual	Average	Individual	Average
7	1	2410	2390	55.4	56.8
	2	2360		56.4	
	3	2410		58.5	
28	4	2380	2380	74.9	73.0
	5	2380		74.1	
	6	2380		70.2	
112	7	2400	2380	85.7	80.1
	8	2350		78.7	
	9	2400		75.9	

Table 2. Compressive cube strength results for the conventional concrete

3.2 Pre-test Core Results

Four cores were taken from each fire test specimen the day before fire testing. Two cores from each specimen were weighed and placed into an oven at 110 °C until they reached constant mass (mass change less than 0.1% over 24 hours). For the Ecocem ACT concrete, the moisture content was 4.9 % as a percentage of the wet weight (5.2 % as a percentage of the dry weight) whilst for the conventional concrete, the moisture content was 4.4 % as a percentage of the wet weight (4.6 % as a percentage of the dry weight).

The other two cores from each fire test specimen were cut and prepped into 1:1 cylinders and were dried in an oven before being tested for compressive strength. The oven dried 1:1 cylinder compressive strength was 44.6 MPa for the Ecocem ACT and 67.8 MPa for the conventional concrete.

3.3 Fire Test Results

Figure 1 shows the temperature over time of the thermocouples during the fire test for the Ecocem ACT specimen, whilst Figure 3 shows the same for the conventional concrete specimen. The first specimen tested was the conventional concrete specimen, and significant spalling was heard during testing, reducing the test time for both specimens. This spalling can be seen in the rise in temperature for the specimens close to the surface after 21 minutes. The thermocouples are labelled with the depth from the test surface followed by their position as shown in the testing methodology document.

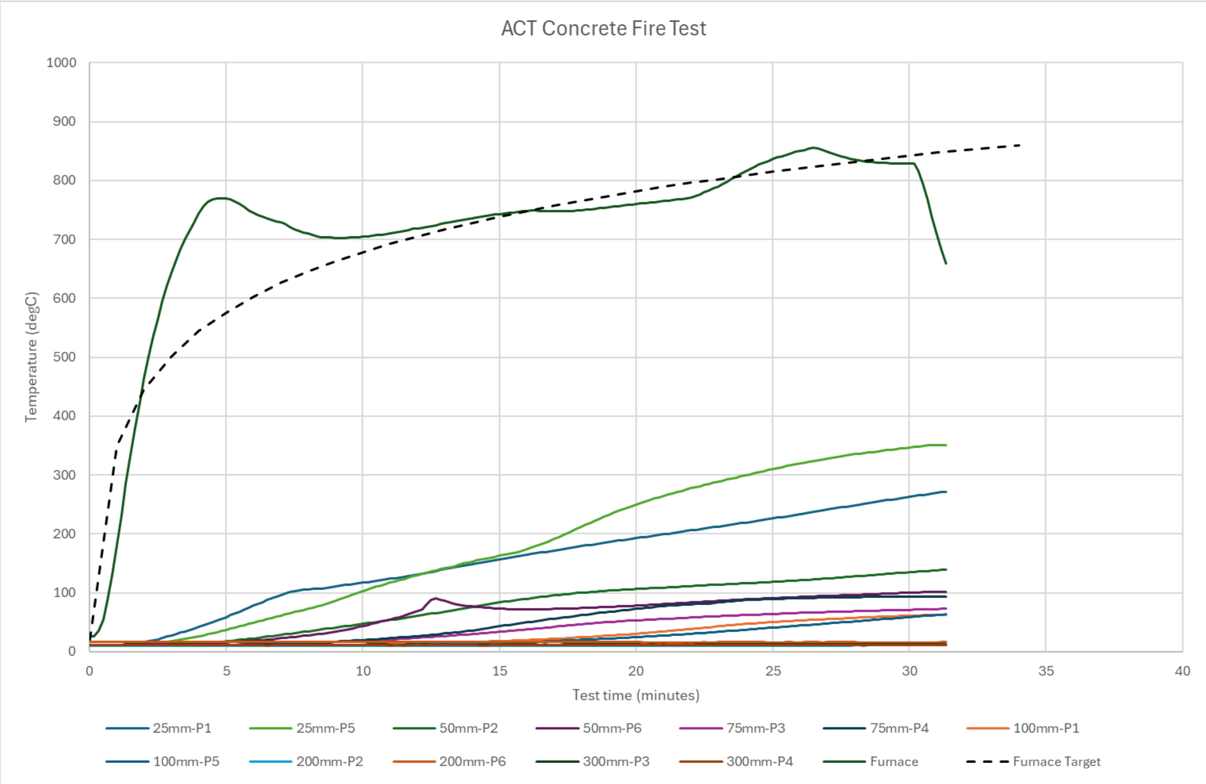


Figure 1. ACT temperature against time graph

Figure 2. ACT specimen after testing showing minor spalling

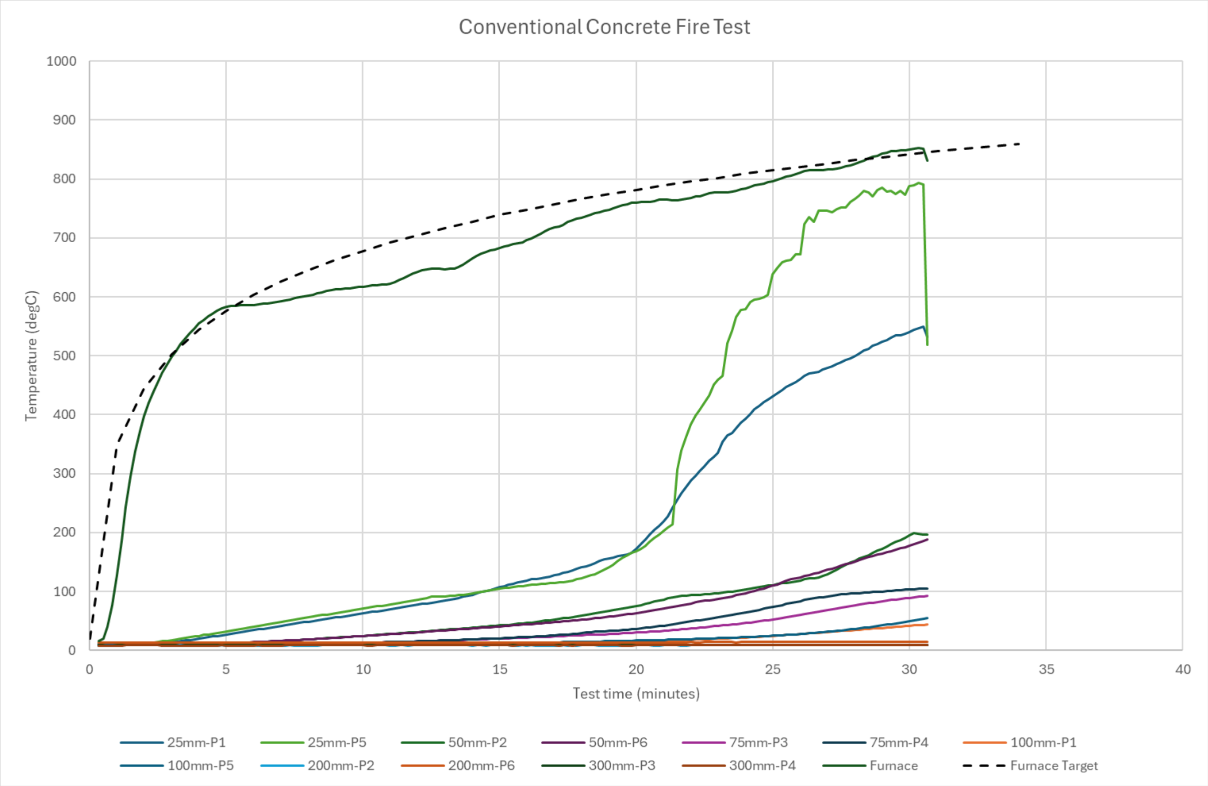


Figure 3. Conventional concrete temperature against time graph

Figure 4. Conventional concrete specimen before (left) and after (right) fire testing

3.4 Post-test Core Results

Two days after testing, the fire test specimens were laid down and cores taken through the centre of the specimens (i.e. straight through the fire affected area). During this process, it was noted that obtaining 60 mm diameter cores from the conventional concrete specimen was difficult, and a 45 mm core was attempted instead, from which a full depth core was obtained, however it is likely that results here could be adversely affected by the specimen diameter to aggregate size ratio. Once obtained, the cores were cut and ground to prepare them for compressive testing as 1:1 cylinders. The specimens were then dried in an oven until at constant mass before being tested in compression to BS EN 12390-3. The compressive strength results are shown in the table below, along with the approximate depth range of the core from the test face.

<table>
<tr><th>Specimen ID</th><th>Core ID</th><th>Specimen depth from fire test face (mm)</th><th>Compressive Strength (MPa)</th></tr>
<tr><td rowspan="10">Ecocem ACT A25/037</td><td rowspan="5">A25/037/Core 5 (60 mm diameter)</td><td>20-80</td><td>8.2</td></tr>
<tr><td>80-140</td><td>13.7</td></tr>
<tr><td>140-200</td><td>40.0</td></tr>
<tr><td>200-260</td><td>67.8</td></tr>
<tr><td>260-320</td><td>62.2</td></tr>
<tr><td rowspan="5">A25/037/Core 6 (60 mm diameter)</td><td>10-70</td><td>22.9</td></tr>
<tr><td>70-130</td><td>14.2</td></tr>
<tr><td>130-190</td><td>(Disintegrated)</td></tr>
<tr><td>190-250</td><td>73.3</td></tr>
<tr><td>250-310</td><td>74.3</td></tr>
<tr><td rowspan="8">Conventional A25/038</td><td rowspan="2">A25/038/Core 5 (60 mm diameter)</td><td>60-120</td><td>32.9</td></tr>
<tr><td>185-245</td><td>19.0</td></tr>
<tr><td rowspan="6">A25/038/Core 6 (45 mm diameter)</td><td>55-100</td><td>12.1</td></tr>
<tr><td>100-145</td><td>31.5</td></tr>
<tr><td>145-190</td><td>(Disintegrated)</td></tr>
<tr><td>205-250</td><td>62.8</td></tr>
<tr><td>250-295</td><td>40.3</td></tr>
<tr><td>295-340</td><td>22.4</td></tr>
</table>

Table 3. Post-fire test core compressive strength results

Appendix – Fire Test Methodology

This appendix contains the fire test methodology agreed for testing before casting.

P128946 Fire Testing Method Statement

Scope

Whilst the BSI Flex 350 doesn't give an explicit test standard for fire resistance, it notes that the EFNARC 'Guidelines for testing fire protection systems for tunnels' contains concrete testing methods for concrete fire resistance. This document amends the large-scale test method from those Guidelines to undertake fire resistance comparison tests on two slabs, one made with Ecocem's ACT concrete and one made with a 50% GGBS reference concrete. Data from embedded thermocouples in the slabs can be used to compare the heat transfer through the panels, and spalling behaviour can also be visually compared between the slabs. Finally, residual compressive strength through the depth of the fire tested slabs can be measured using cores taken after fire testing. It should be noted that changes have been made to the EFNARC test in part because of limitations on available test equipment and in part to better suit the application of this concrete.

Specimen Manufacture

Wooden moulds will be made by Harringtons, 1.5 m long by 1.0 m wide by 0.4 m deep. A cage of reinforcement mesh (12 mm diameter, 200 mm grid in plan) will be supported 75 mm from all faces, while the base of the slab will be the test face. Type K thermocouples will be embedded in the concrete to measure the temperature in at least two positions for each of the following depths: 25 mm from the base, 50 mm from the base, 75 mm from the base, 100 mm from the base. Thermocouples will be added before testing to measure the temperature of the back face of the concrete. Lifting eyes will also be cast into the slabs (lifting eye design to be provided by Ramboll or Sisk).

The two slab specimens (one of ACT concrete, one of the conventional reference concrete) will be cast on the same day at BRE by Harringtons, with the concretes provided by Capital Concrete. Companion cubes will be cast at the same time for compressive strength testing to BS EN 12390-3 at 28 days. Once cast, the specimens will be cured under damp sacking and polythene for at least 24 hours. After demoulding, the slab specimens will be cured wrapped in damp sacking and polythene for 3 months. After this time, the specimens will be cured in 20 °C and 50 %RH for a further 28 days.

Test Regime

After curing and before testing, the slab will have a 50 mm diameter x 75 mm long core removed from the back of the slab in each corner. Two of these cores will be prepared and tested for compressive strength as close to the day of test as possible, whilst the other two cores will be weighed and then dried at 110 °C until constant weight to determine the moisture content of the concrete.

On the day of test, the slab will be weighed before being braced in front of (or restrained to) the test furnace (opening size 900 mm by 1100 mm). Any gaps between the furnace and the slab will be filled with a suitable insulator to prevent excess heat escape, and the furnace will apply a temperature/time curve using the equation below (taken from BS 476:20:1987 and Draft BS ISO 834-1):

$$T = 345 \log_{10} (8t + 1) + 20$$

where

T is the average furnace temperature, in degrees Celsius;

t is the time, in minutes.

The temperature curve will be applied for the same length of time on each specimen. The temperature of the furnace and the temperature of the embedded thermocouples will be measured throughout testing. After testing, the specimens will be allowed to cool, before being disengaged from the furnace and photographed. The test face will be visually monitored for 48 hours following testing to ensure all spalling damage is recorded. The specimens will then be laid flat and be cored for compressive strength testing.

After testing, at least one 50 mm diameter core will be taken (starting in the back of the slab, avoiding rebar, as close to the centre of the slab as possible). The core(s) will be visually inspected for all signs of damage.

After completion of the visual examination of the core, a series of 50 mm x 50 mm cylinders will be prepared, working from the exposed face of the concrete, and will be tested for compressive strength to BS EN 12390-3 in order to give a strength profile through the concrete.

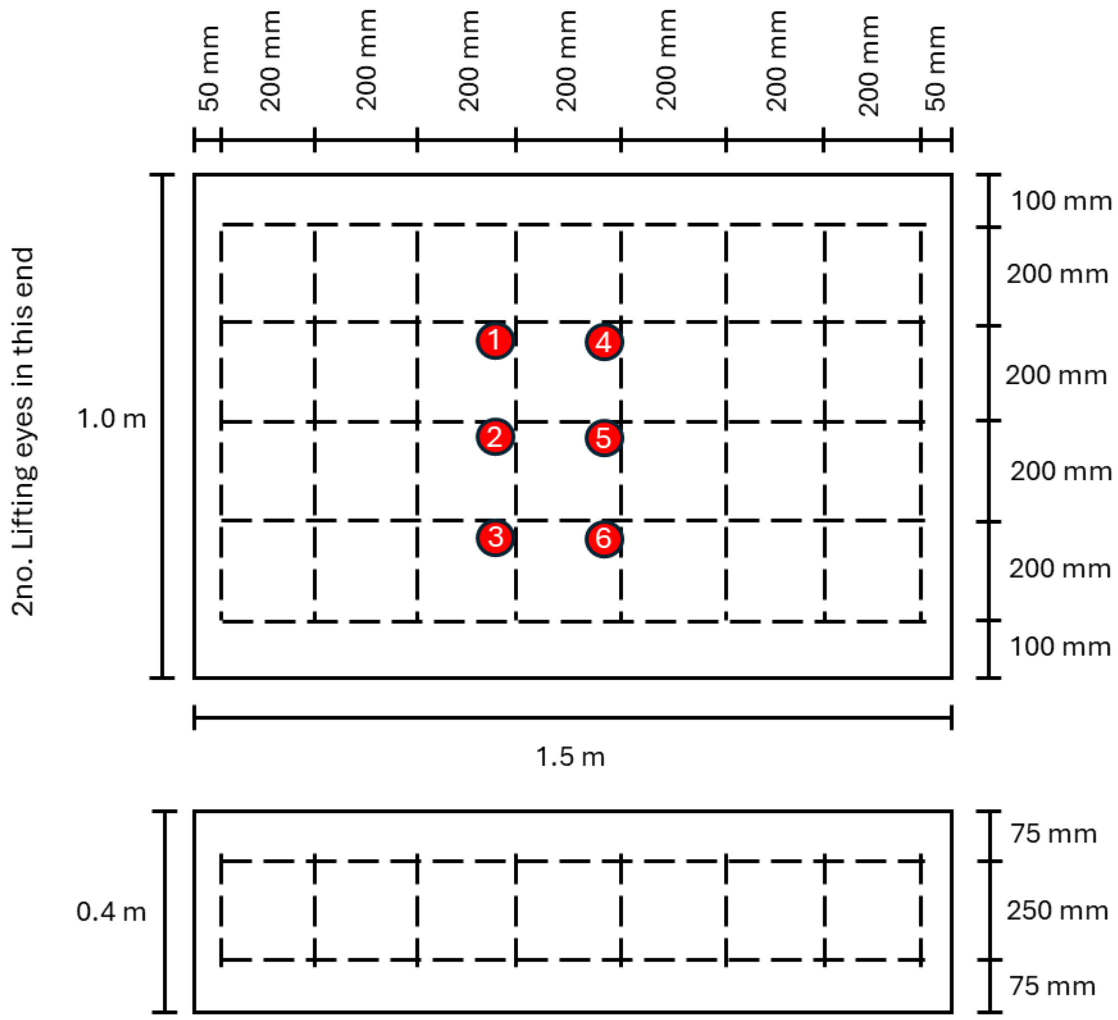
A report on the condition of the core will be produced in the form of a labelled diagram giving the condition and strength of the cores against depth from the front (fire exposed) surface. Photographs of the core should also be included in the report.

Results

The results of the testing will be:

- the compressive strength at 28 days (from the companion cubes) to confirm the mix designs
- the compressive strength and moisture content of the cores taken before fire testing
- The temperature/time graphs of the furnace thermocouple and the embedded specimen thermocouples
- Photographs of the test faces before and after testing
- Any spalling information noted during and up to 48 hours after testing

Reinforcement and Thermocouple Positions



N.B. All reinforcement is 12 mm diameter.

Thermocouple to measure temperature at 25 & 100 mm from test face in Positions 1 and 5.

Thermocouple to measure temperature at 50 & 200 mm from test face in Positions 2 and 6.

Thermocouple to measure temperature at 75 & 300 mm from test face in Positions 3 and 4.

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TEST REPORT

Water Penetration Testing of Ecocem ACT to BS EN 12390-8:2019.

Prepared for: John Sisk & Son
Date: 10.07.2025
Report number: P128946-1003
Issue: 1
Status: Final - Commercial in Confidence

Prepared for:

Maria Estrada
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Prepared by:

Name Christopher Yapp

Position Senior Consultant

Date 10 July 2025

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Authorised by:

Name Dr. Martyn Webb

Position Principal Consultant

Date 10 July 2025

Signature

Table of Contents

1.Introduction

As part of the Innovate UK funded project investigating Ecocem ACT concrete, BRE was commissioned by Maria Estrada (John Sisk & Son) to undertake water penetration tests to BS EN 12390-8:2019 on three cast specimens.

This factual report describes the tests conducted and the results obtained.

2.Test Description

BRE attended a site mixing trial of an Ecocem ACT concrete at Capital Concrete on 4th September 2024 and cast specimens for a range of tests, including water penetration testing to BS EN 12390-8:2019. The fresh concrete was hand-tamped into steel moulds and covered in damp sacking and polythene before being left overnight in a container at Capital Concrete. The following day the specimens were transported back to BRE and demoulded, before being placed in water tanks at 20 °C ± 2 °C.

The water penetration resistance was determined using BS EN 12390-8:2019. Upon demoulding, one face of each of the three 150 mm concrete cube specimens was roughened with a wire brush and the specimens were cured in water at 20 °C ± 2 °C until the day of test. At 28 days of age, the specimens were placed into the test rig, where a 100 mm circle on the roughened face was subjected to water pressure of 500 kPa ± 50 kPa for a duration of 72 hours. After the test period, the specimens were removed, split perpendicular to the test face, and the depth of water penetration measured. This measurement was taken from the surface exposed to water to the furthest point reached by the water inside the concrete.

3.Test Results

The following table shows the maximum depth of penetration for each specimen.

Test Start Date	02/10/2024	
Specimen ID	Maximum Penetration (mm)	Comments
A24/068/8	16	No leaks noted during test.
A24/068/12	9	No leaks noted during test.
A24/068/15	17	No leaks noted during test.

Appendix Q – ACT Safety Data Sheets

Ecocem Global

Safety Data Sheet

according to Regulation (EC) No 1907/2006

ACT Cement

Revision date: 14.09.2022 Product code: Page 1 of 10

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1. Product identifier

ACT Cement

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of the substance/mixture

Binder for concrete, mortar and chemistry products for building industries.

Uses advised against

Any non-intended use.

1.3. Details of the supplier of the safety data sheet

Company name:	Ecocem Global	
Street:	F1 East Point Office Park	
Place:	Dublin 3, Ireland	
Telephone:	+353 16781800	
e-mail:	info@ecocemglobal.com	
Internet:	www.ecocemglobal.com	
Responsible Department:	Dr. Gans-Eichler Chemieberatung GmbH Otto-Hahn-Str. 36 D-48161 Münster	e-mail: info@tge-consult.de Tel.: +49(0)2534 6441185 www.tge-consult.de

1.4. Emergency telephone number: Poisons Information Centre Ireland: (01) 8092166

SECTION 2: Hazards identification

2.1. Classification of the substance or mixture

Regulation (EC) No 1272/2008

Skin Irrit. 2; H315
Eye Dam. 1; H318
Skin Sens. 1; H317

Full text of hazard statements: see SECTION 16.

2.2. Label elements

Regulation (EC) No 1272/2008

Hazard components for labelling

Portland cement
Flue dust, portland cement

Signal word: Danger

Pictograms:

Hazard statements

H315	Causes skin irritation.
H317	May cause an allergic skin reaction.
H318	Causes serious eye damage.

Precautionary statements

P261	Avoid breathing dust/fume/gas/mist/vapours/spray.
P280	Wear protective gloves/protective clothing/eye protection/face protection/hearing

protection.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P333+P313 If skin irritation or rash occurs: Get medical advice/attention.
P362+P364 Take off contaminated clothing and wash it before reuse.
P501 Dispose of contents/container to local/regional/national/international regulations.

2.3. Other hazards

For information or further instructions, see also section 11 or 12.

SECTION 3: Composition/information on ingredients

3.2. Mixtures

Hazardous components

CAS No	Chemical name			Quantity
	EC No	Index No	REACH No	
	Classification (Regulation (EC) No 1272/2008)			
65997-15-1	Portland cement			15 - < 20 %
	266-043-4			
	Skin Irrit. 2, Eye Dam. 1, Skin Sens. 1B, STOT SE 3; H315 H318 H317 H335			
68475-76-3	Flue dust, portland cement			0.5 - < 1 %
	270-659-9		01-2119486767-17	
	Skin Irrit. 2, Eye Dam. 1, Skin Sens. 1, STOT SE 3; H315 H318 H317 H335			

Full text of H and EUH statements: see section 16.

Further Information

Product does not contain listed SVHC substances > 0,1 % according to Regulation (EC) No. 1907/2006 Article 59 (REACH)

SECTION 4: First aid measures

4.1. Description of first aid measures

General information

In case of accident or unwellness, seek medical advice immediately (show directions for use or safety data sheet if possible).

After inhalation

In case of accident by inhalation: remove casualty to fresh air and keep at rest. In case of respiratory tract irritation, consult a physician.

After contact with skin

Gently wash with plenty of soap and water. In case of skin irritation, seek medical treatment.

After contact with eyes

Rinse cautiously with water for several minutes. In case of troubles or persistent symptoms, consult an ophthalmologist.

After ingestion

Rinse mouth thoroughly with water. Let water be drunken in little sips (dilution effect). Do NOT induce vomiting. In all cases of doubt, or when symptoms persist, seek medical advice.

4.2. Most important symptoms and effects, both acute and delayed

No information available.

4.3. Indication of any immediate medical attention and special treatment needed

Treat symptomatically.

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media

The product itself does not burn. Co-ordinate fire-fighting measures to the fire surroundings.

Unsuitable extinguishing media

High power water jet.

5.2. Special hazards arising from the substance or mixture

No information available.

5.3. Advice for firefighters

In case of fire: Wear self-contained breathing apparatus.

Additional information

Collect contaminated fire extinguishing water separately. Do not allow entering drains or surface water.
Co-ordinate fire-fighting measures to the fire surroundings.

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

General advice

Avoid dust formation.
Do not breathe dust.

For non-emergency personnel

Wear personal protection equipment (refer to section 8).

For emergency responders

No special measures are necessary.

6.2. Environmental precautions

Discharge into the environment must be avoided.

6.3. Methods and material for containment and cleaning up

For containment

Take up mechanically.
Treat the recovered material as prescribed in the section on waste disposal.

For cleaning up

Clean contaminated objects and areas thoroughly observing environmental regulations.

6.4. Reference to other sections

Safe handling: see section 7
Disposal: see section 13

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Advice on safe handling

Wear personal protection equipment (refer to section 8).

Advice on protection against fire and explosion

Usual measures for fire prevention. Dust clouds may present an explosion hazard.

Advice on general occupational hygiene

Always close containers tightly after the removal of product. Do not eat, drink, smoke or sneeze at the workplace.
Wash hands before breaks and after work.

Further information on handling

Avoid generation of dust.
General protection and hygiene measures: refer to chapter 8

7.2. Conditions for safe storage, including any incompatibilities

Requirements for storage rooms and vessels

Keep container tightly closed in a cool, well-ventilated place.

Hints on joint storage

Do not store together with: Explosives. Oxidizing solids. Oxidizing liquids. Radioactive substances. Infectious substances. Food and animal feedingstuff.

Further information on storage conditions

Keep the packing dry and well sealed to prevent contamination and absorbtion of humidity.
Recommended storage temperature: 20°C
Protect against: frost. UV-radiation/sunlight. heat. Humidity

7.3. Specific end use(s)

See section 1.

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Occupational exposure limits

CAS No	Substance	ppm	mg/m³	fib/cm³	Category	Origin
1317-65-3	Calcium carbonate, total inhalable dust	-	10		TWA (8 h)	
7778-18-9	Calcium sulphate	-	10		TWA (8 h)	
65997-15-1	Cement (Portland) (Respirable Fraction)	-	1		TWA (8 h)	

DNEL/DMEL values

CAS No	Substance		
DNEL type	Exposure route	Effect	Value
7778-18-9	calcium sulfate		
Consumer , long-term	oral	systemic	1,52 mg/kg bw/day
Consumer , acute	oral	systemic	11,4 mg/kg bw/day
Worker , long-term	inhalation	systemic	21,17 mg/m³
Worker , acute	inhalation	systemic	5082 mg/m³
Consumer , long-term	inhalation	systemic	5,29 mg/m³
Consumer , acute	inhalation	systemic	3811 mg/m³

PNEC values

CAS No	Substance
Environmental compartment	Value
7778-18-9	calcium sulfate
Micro-organisms in sewage treatment plants (STP)	100 mg/l

8.2. Exposure controls


Appropriate engineering controls

Technical measures and the application of suitable work processes have priority over personal protection

equipment.
Dust must be exhausted directly at the point of origin.

Individual protection measures, such as personal protective equipment

Eye/face protection

Dust protection goggles.

Hand protection

Wear suitable gloves.
Suitable material:
FKM (fluororubber). - Thickness of glove material: 0,4 mm
Breakthrough time >= 8 h
Butyl rubber. - Thickness of glove material: 0,5 mm
Breakthrough time >= 8 h
CR (polychloroprenes, Chloroprene rubber). - Thickness of glove material: 0,5 mm
Breakthrough time >= 8 h
NBR (Nitrile rubber). - Thickness of glove material: 0,35 mm
Breakthrough time >= 8 h
PVC (Polyvinyl chloride). - Thickness of glove material: 0,5 mm
Breakthrough time >= 8 h
For special purposes, it is recommended to check the resistance to chemicals of the protective gloves mentioned above together with the supplier of these gloves.
The selected protective gloves have to satisfy the specifications of EU Directive EC/2016/425 and the standard EN 374 derived from it.
Check leak tightness/impermeability prior to use. In the case of wanting to use the gloves again, clean them before taking off and air them well.

Skin protection

Suitable protective clothing: Lab apron.
Minimum standard for preventive measures while handling with working materials are specified in the TRGS 500 (D).

Respiratory protection

With correct and proper use, and under normal conditions, breathing protection is not required.
Respiratory protection necessary at:
-Exceeding exposure limit values
-Generation/formation of dust
Suitable respiratory protective equipment: particulates filter device (DIN EN 143). type: P1-3
The filter class must be suitable for the maximum contaminant concentration (gas/vapour/aerosol/particulates) that may arise when handling the product. If the concentration is exceeded, self-contained breathing apparatus must be used.

Thermal hazards

Material handled at elevated temperature may cause thermal burns by contact with molten product.

Environmental exposure controls

Do not allow uncontrolled discharge of product into the environment.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state:	solid
Colour:	not determined
Odour:	characteristic

Changes in the physical state

Melting point/freezing point:	not determined
Boiling point or initial boiling point and boiling range:	not determined

Sublimation point:	not determined
Softening point:	not determined
Pour point:	not determined
Flash point:	not determined

Explosive properties

Dust clouds may present an explosion hazard.

Lower explosion limits:	not determined
Upper explosion limits:	not determined
Auto-ignition temperature:	not determined

Self-ignition temperature

Solid:	not determined
Decomposition temperature:	not determined
pH-Value:	not determined
Viscosity / dynamic:	not determined
Viscosity / kinematic:	not determined
Flow time:	not determined
Water solubility:	not determined

Solubility in other solvents

not determined

Partition coefficient n-octanol/water:	SECTION 12: Ecological information
Vapour pressure:	not determined
Density:	not determined
Bulk density:	not determined
Relative vapour density:	not determined

9.2. Other information

Information with regard to physical hazard classes

Sustaining combustion: Not sustaining combustion

Oxidizing properties

none

Other safety characteristics

Solvent separation test:	not determined
Solvent content:	not determined
Solid content:	not determined
Evaporation rate:	not determined

Further Information

No information available.

SECTION 10: Stability and reactivity

10.1. Reactivity

No information available.

10.2. Chemical stability

The product is chemically stable under recommended conditions of storage, use and temperature.

10.3. Possibility of hazardous reactions

No hazardous reaction when handled and stored according to provisions.

Refer to chapter 10.5.

10.4. Conditions to avoid

No information available.

10.5. Incompatible materials

No information available.

10.6. Hazardous decomposition products

Does not decompose when used for intended uses.

SECTION 11: Toxicological information

11.1. Information on hazard classes as defined in Regulation (EC) No 1272/2008

Toxicocinetics, metabolism and distribution

No data available.

Acute toxicity

Based on available data, the classification criteria are not met.
The product has not been tested.

Irritation and corrosivity

Causes skin irritation.
Causes serious eye damage.
The product has not been tested.

Sensitising effects

May cause an allergic skin reaction. (Portland cement; Flue dust, portland cement)
The product has not been tested.

Carcinogenic/mutagenic/toxic effects for reproduction

Based on available data, the classification criteria are not met.
No data available

STOT-single exposure

Based on available data, the classification criteria are not met.
No data available .

STOT-repeated exposure

Based on available data, the classification criteria are not met.
No data available .

Aspiration hazard

Based on available data, the classification criteria are not met.
No data available .

Specific effects in experiment on an animal

No data available.

11.2. Information on other hazards

Endocrine disrupting properties

No data available.

SECTION 12: Ecological information

12.1. Toxicity

The product has not been tested.

12.2. Persistence and degradability

The product has not been tested.

12.3. Bioaccumulative potential

No indication of bioaccumulation potential.

12.4. Mobility in soil

No data available.

12.5. Results of PBT and vPvB assessment

The substances in the mixture do not meet the PBT/vPvB criteria according to REACH, annex XIII.
The aforementioned statement applies to substances contained in the product with a minimum content of 0.1%.

12.6. Endocrine disrupting properties

This product does not contain a substance that has endocrine disrupting properties with respect to non-target organisms as no components meets the criteria.
The aforementioned statement applies to substances contained in the product with a minimum content of 0.1%.

12.7. Other adverse effects

No data available.

Further information

Do not allow to enter into surface water or drains.

SECTION 13: Disposal considerations

13.1. Waste treatment methods

Disposal recommendations

Observe in addition any national regulations! Consult the local waste disposal expert about waste disposal. Non-contaminated packages may be recycled.
According to (EWC) European Waste Catalogue, allocation of waste identity numbers/waste descriptions must be carried out in a specific way for every industry and process.
Control report for waste code/ waste marking according to (EWC) European Waste Catalogue:

List of Wastes Code - residues/unused products

170903 CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES); other construction and demolition wastes; other construction and demolition wastes (including mixed wastes) containing hazardous substances; hazardous waste

List of Wastes Code - used product

170903 CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES); other construction and demolition wastes; other construction and demolition wastes (including mixed wastes) containing hazardous substances; hazardous waste

List of Wastes Code - contaminated packaging

150110 WASTE PACKAGING; ABSORBENTS, WIPING CLOTHS, FILTER MATERIALS AND PROTECTIVE CLOTHING NOT OTHERWISE SPECIFIED; packaging (including separately collected municipal packaging waste); packaging containing residues of or contaminated by hazardous substances; hazardous waste

Contaminated packaging

Handle contaminated packages in the same way as the substance itself.

SECTION 14: Transport information

Land transport (ADR/RID)

14.1. UN number or ID number:	No dangerous good in sense of this transport regulation.
14.2. UN proper shipping name:	No dangerous good in sense of this transport regulation.
14.3. Transport hazard class(es):	No dangerous good in sense of this transport regulation.
14.4. Packing group:	No dangerous good in sense of this transport regulation.

Inland waterways transport (ADN)

14.1. UN number or ID number:	No dangerous good in sense of this transport regulation.
14.2. UN proper shipping name:	No dangerous good in sense of this transport regulation.
14.3. Transport hazard class(es):	No dangerous good in sense of this transport regulation.
14.4. Packing group:	No dangerous good in sense of this transport regulation.

Marine transport (IMDG)

14.1. UN number or ID number:	No dangerous good in sense of this transport regulation.
14.2. UN proper shipping name:	No dangerous good in sense of this transport regulation.
14.3. Transport hazard class(es):	No dangerous good in sense of this transport regulation.
14.4. Packing group:	No dangerous good in sense of this transport regulation.

Air transport (ICAO-TI/IATA-DGR)

14.1. UN number or ID number:	No dangerous good in sense of this transport regulation.
14.2. UN proper shipping name:	No dangerous good in sense of this transport regulation.
14.3. Transport hazard class(es):	No dangerous good in sense of this transport regulation.
14.4. Packing group:	No dangerous good in sense of this transport regulation.

14.5. Environmental hazards

ENVIRONMENTALLY HAZARDOUS: No

14.6. Special precautions for user

refer to chapter 6 - 8

14.7. Maritime transport in bulk according to IMO instruments

not relevant

SECTION 15: Regulatory information

15.1. Safety, health and environmental regulations/legislation specific for the substance or mixture

EU regulatory information

Restrictions on use (REACH, annex XVII):

Entry 3, Entry 47

2010/75/EU (VOC):	No information available.
2004/42/EC (VOC):	No information available.
Information according to 2012/18/EU (SEVESO III):	Not subject to 2012/18/EU (SEVESO III)

Additional information

Safety Data Sheet according to Regulation (EC) No. 1907/2006 (amended by Regulation (EU) No 2020/878)
The mixture is classified as hazardous according to regulation (EC) No 1272/2008 [CLP].
REACH 1907/2006 Appendix XVII, No (mixture): -

National regulatory information

Employment restrictions:	Observe restrictions to employment for juveniles according to the 'juvenile work protection guideline' (94/33/EC).
Water hazard class (D):	1 - slightly hazardous to water

15.2. Chemical safety assessment

For the following substances of this mixture a chemical safety assessment has been carried out:
Flue dust, portland cement

SECTION 16: Other information

Changes

Rev. 1.0; Initial release 14.09.2022

Abbreviations and acronyms

ADR: Accord européen sur le transport des marchandises dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road)
CAS: Chemical Abstracts Service
CLP: Classification, Labelling and Packaging of substances and mixtures
DNEL: Derived No Effect Level
d: day(s)
EINECS: European INventory of Existing Commercial chemical Substances
ELINCS: European LIst of Notified Chemical Substances

ECHA: European Chemicals Agency
EWC: European Waste Catalogue
IARC: INTERNATIONAL AGENCY FOR RESEARCH ON CANCER
IMDG: International Maritime Code for Dangerous Goods
IATA: International Air Transport Association
IATA-DGR: Dangerous Goods Regulations by the "International Air Transport Association" (IATA)
ICAO: International Civil Aviation Organization
ICAO-TI: Technical Instructions by the "International Civil Aviation Organization" (ICAO)
GHS: Globally Harmonized System of Classification and Labelling of Chemicals
GefStoffV: Gefahrstoffverordnung (Ordinance on Hazardous Substances, Germany)
h: hour
LOAEL: Lowest observed adverse effect level
LOAEC: Lowest observed adverse effect concentration
LC50: Lethal concentration, 50 percent
LD50: Lethal dose, 50 percent
NOAEL: No observed adverse effect level
NOAEC: No observed adverse effect concentration
NLP: No-Longer Polymers
N/A: not applicable
OECD: Organisation for Economic Co-operation and Development
PNEC: predicted no effect concentration
PBT: Persistent bioaccumulative toxic
RID: Regulation Concerning the International Transport of Dangerous Goods by Rail
REACH: Registration, Evaluation, Authorisation of Chemicals
SVHC: substance of very high concern
TRGS: Technische Regeln für Gefahrstoffe
UN: United Nations
VOC: Volatile Organic Compounds

Classification for mixtures and used evaluation method according to Regulation (EC) No 1272/2008 [CLP]

Classification	Classification procedure
Skin Irrit. 2; H315	Calculation method
Eye Dam. 1; H318	Calculation method
Skin Sens. 1; H317	Calculation method

Relevant H and EUH statements (number and full text)

Causes skin irritation.
May cause an allergic skin reaction.
Causes serious eye damage.
May cause respiratory irritation.

Further Information

Classification according to Regulation (EC) No 1272/2008 [CLP] - Classification procedure:
Health hazards: Calculation method.
Environmental hazards: Calculation method.
Physical hazards: On basis of test data and / or calculated and / or estimated.

The above information describes exclusively the safety requirements of the product and is based on our present-day knowledge. The information is intended to give you advice about the safe handling of the product named in this safety data sheet, for storage, processing, transport and disposal. The information cannot be transferred to other products. In the case of mixing the product with other products or in the case of processing, the information on this safety data sheet is not necessarily valid for the new made-up material.

(The data for the hazardous ingredients were taken respectively from the last version of the sub-contractor's safety data sheet.)

Appendix R – Flex 350

Alternative binder systems for lower carbon concrete – Code of Practice

October 2023 Version 1

BSI Flex 350 v1.0:2023-10

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Release history

First version, October 2023

Contents

Foreword

This BSI Flex was sponsored by the Institution of Civil Engineers (ICE). Its development was facilitated by BSI Standards Limited and it was released under licence from The British Standards Institution. It came into effect on 31 October 2023.

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- AMCRETE UK
- DB Group
- Environment Agency
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- Laing O'Rourke
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- Mineral Products Association (MPA) Cement
- OTB Concrete
- Ramboll Buildings
- University of Sheffield

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The BSI Flex process enables a standard to be rapidly developed, on an iterative basis, in order to fulfil an immediate stakeholder need. A BSI Flex can be considered for further development as a PAS or British Standard, or constitute part of the UK input into the development of a European or international standard.

The content in this version is part of an iterative process. It is likely to change from time to time with subsequent iterations.

Information about this document

This is Version 1 of BSI Flex 350, which has been released to enable stakeholders to engage with the initial content and feed back comments for further versions of the document to be developed. This is the first public consultation of this BSI Flex and so the content is not to be considered as having received wider feedback. Users are therefore encouraged to comment on this version.

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Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Relationship with other publications

Upon release of Version 2 of BSI Flex 350, PAS 8820 is to be withdrawn.

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As a code of practice, this BSI Flex takes the form of recommendations and guidance. It is not to be quoted as if it were a specification. Users are expected to ensure that claims of compliance are not misleading.

Users may substitute any of the recommendations in this BSI Flex with practices of equivalent or better outcome. Any user claiming compliance with this BSI Flex is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions of this document are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. "organization" rather than "organisation").

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WARNING. Where skin is in contact with fresh alternative binder system (ABS) concrete, skin irritations are likely to occur owing to the alkaline nature of cement. The abrasive effects of sand and aggregate in ABS concrete can aggravate the condition. Potential effects range from dry skin, irritant contact dermatitis, to – in cases of prolonged exposure – severe burns. Take precautions to avoid dry ABS entering the eyes, mouth and nose when mixing mortar or concrete by wearing suitable protective clothing. Care is necessary to prevent fresh ABS concrete from entering boots and use working methods that do not require personnel to kneel in fresh ABS concrete. Unlike heat burns, ABS and alkali burns might not be felt until sometime after contact with fresh ABS concrete, so there might be no warning of damage occurring. If ABS or ABS concrete enters the eye, immediately wash it out thoroughly with clean water and seek medical treatment without delay. Wash wet ABS concrete off the skin immediately. Barrier creams can be used to supplement protective clothing but are not an alternative means of protection.

0 Introduction

The UK consumed 11.7 million metric tonnes of Portland cement in 2022 according to the ICE low carbon routemap (ICE 2023) [N1]. This resulted in the emission of approximately 9 million metric tonnes of CO_2 equivalent or nearly 90% of the greenhouse gas emissions associated with concrete production. Alternative binder systems (ABS) can be used to reduce the emissions from the concrete binder by up to 85% compared to Portland cement while continuing to provide the many benefits of concrete construction. ABS are expected to play an increasingly important role in achieving the target of net zero by 2050 in concrete construction.

ABS have a history of over 100 years. An ABS based on vitreous slag was first patented by Whiting in 1895 [1] and described as providing performance "equal in quality to the best Portland or similar cement". Xu et al (2008) [2] investigated the long-term performance of activated slag concretes from the former Soviet Union. The slag component had been activated by carbonates and by carbonate/hydroxide mixtures. The research found high compressive strengths that were significantly higher than when initially cast, and excellent durability over a service life of up to 35 years. Xu et al (2008) [2] and Shi et al. (2006) [3] reported that the carbonation depths are relatively low for their age and no microcracks were observed after prolonged service. While the performance of each type of ABS concrete is established by comprehensive assessment in accordance with Clause **6**, it is helpful to know that there are examples of ABS concretes which are durable with reaction products that have been stable over time.

Following on from PAS 8820:2016, *Construction materials – Alkali-activated cementitious material and concrete – Specification*, this BSI Flex recommends a framework for assessing ABS concretes to facilitate their acceptance as suitable alternatives to Portland cement-based concrete when designing and building structures.

Where ABS concrete has substantially lower performance than traditional concrete, BSI Flex 350 recommends its use in lower risk applications when it provides reduced emissions.

1 Scope

This BSI Flex provides recommendations for the assessment and use of alternative binder systems (ABS) as part of a strategy for meeting the proposed Net Zero 2050 target when building structures in accordance with BS 8500 and BS EN 1992.

This BSI Flex covers properties of ABS and provides recommendations on testing and monitoring to demonstrate conformity with the recommended performance for different applications.

The types of ABS covered include, but are not limited to, geopolymer or alkali-activated materials. It does not cover the cement types covered in BS EN 197, BS EN 15743, BS EN 14216 or BS EN 14647.

This BSI Flex is not applicable to any other methods of concrete carbon reducing measures.

This BSI Flex is intended for use by ABS and ABS concrete manufacturers/producers. It may also be of interest to engineers, designers, end users, and contractors.

It is intended that:

a) all the recommended performance tests are conducted on a representative grade of ABS concrete on behalf of the producers to demonstrate acceptable properties of the ABS; and
b) project specific testing and conformance testing are conducted on behalf of the engineer/designer to demonstrate suitability of the specific ABS concrete mixes and quality control.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

BS 476, *Fire tests on building materials and structures*

BS 812-104, *Testing Aggregates – Part 104: Method for Qualitative and Quantitative Petrographic Examination of Aggregates*

BS 7542, *Method of test for Curing compounds for Concrete*

BS 8204-2 2003+A2:2011, *Screeds, bases and in situ floorings Concrete wearing surfaces – Code of practice*

BS 8500, *Concrete – Complementary British Standard to BS EN 206*

BS 8500-2:2015+A2:2019, *Concrete – Complementary British Standard to BS EN 206 – Specification for constituent materials and concrete*

BS EN 196-1, *Methods of testing cement – Part 1: Determination of strength*

BS EN 196-3, *Methods of testing cement – Part 3: Determination of setting times and soundness*

BS EN 197, *Cement*

BS EN 197-1:2011, *Cement – Composition, specifications and conformity criteria for common cements*

BS EN 206:2013, *Concrete – Specification, performance, production and conformity*

BS EN 934-1:2008, *Admixtures for concrete, mortar and grout – Part 1: Common requirements*

BS EN 934-2:2009+A1:2012, *Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures – Definitions, requirements, conformity, marking and labelling*

BS EN 1008, *Mixing water for concrete – Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*

BS EN 1770, *Products and systems for the protection and repair of concrete structures – Test methods – Determination of the coefficient of thermal expansion*

BS EN 1990:2002+A1:2005, *Eurocode – Basis of structural design*

BS EN 1992, *Eurocode 2: Design of concrete structures*

BS EN 1992-1-1, *Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings*

BS EN 1992-1-2, *Eurocode 2: Design of concrete structures – Part 1-2: General rules – Structural fire design*

BS EN 12620:2002+A1:2008, *Aggregates for concrete*

BS EN 12350 (all parts), *Testing fresh concrete*

BS EN 12390 (all parts), *Testing hardened concrete*

BS EN 14216, *Cement – Composition, specifications and conformity criteria for very low heat special cements*

BS EN 14227-4:2013, *Hydraulically bound mixtures – Specifications Part 4: Fly ash for hydraulically bound mixtures*

BS EN 14647, *Calcium aluminate cement – Composition, specifications and conformity criteria*

BS EN 15743, *Supersulfated cement – Composition, specifications and conformity criteria*

BS ISO 14067:2018, *Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification*

BS ISO 1920-14, *Testing of concrete – Setting time of concrete by resistance to penetration*

CEN/TR 15177:2006, *Testing the freeze-thaw resistance of concrete – Internal structural damage*

CEN/TS 12390-9:2017, *Testing hardened concrete – Part 9: Freeze-thaw resistance with de-icing salts – Scaling*

SA TS 199:2023, *Technical Specification – Design of geopolymer and alkali-activated binder concrete structures*

Other publications

[N1] ICE Low Carbon Concrete Routemap[1)]

[N2] MPA Fact sheet 18 (2019) Embodied CO2e of UK cement, additions and cementitious material

[N3] AASHTO T 336, Standard method of test for coefficient of thermal expansion of hydraulic cement concrete

[N4] NORDIC COUNCIL OF MINISTERS. Concrete, mortar and cement-based repair materials: Chloride migration coefficient from non-steady-state migration experiments (NT BUILD 492). Nordtest, 1999.

[1)] Available at https://www.ice.org.uk/media/200i0yqd/2022-04-26-low-carbon-concrete-routemap-final_rev.pdf

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

3.1.1 activator

source of one or more elements in the alkali metals group, and/or magnesium, and/or calcium and/or other, which when incorporated in aqueous or solid form, induces a reaction, setting and hardening of an ABS

3.1.2 admixture

chemical substance, often organic in nature, which has no cementitious value but is added to concrete to manipulate its fresh or hardened state properties

3.1.3 alkali activated material (AAM)

type of ABS consisting of one or more powders containing both oxides of aluminium and silicon which can be induced to react and harden through the addition of an alkali activator

NOTE *Typically high calcium AAM is used in ambient cure applications and low calcium AAM is used in heat cured precast applications.*

3.1.4 alternative binder system (ABS)

substance formed by a combination of one or more constituent materials together with chemicals or activators which react to form a hardened monolithic material analogous to cement

3.1.5 alternative binder system (ABS) concrete

substance formed by combining ABS with fine and coarse aggregates and water, with or without the incorporation of admixtures

3.1.6 exposure class

category of environmental actions that pose a risk of damage to concrete or its reinforcement

3.1.7 intended working life

assumed period for which a structure or a part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary

NOTE *This might also be known as design working life.*

3.1.8 lower carbon concrete

concrete with an embodied CO_2 equivalent (kg CO_2e/m^3) lower than 80% of the concretes in use across the market for the relevant strength class

3.1.9 reference concrete

Portland cement-based concrete of established performance for direct comparison with an ABS concrete sample

3.2 Abbreviated terms

ACEC Aggressive Chemical Environment for Concrete Classification

4 Alternative binder systems

4.1 Main constituents

The main constituents of an ABS for use in lower carbon concrete should be selected from the following classes of material:

a) granulated blast furnace slag (GGBS) conforming to BS EN 197-1:2011, 5.2.2;

b) natural or manufactured pozzolanic material, with or without calcination, in accordance with BS EN 197-1:2011, 5.2.3, with the modification that the requirement for a minimum reactive silicon dioxide content is removed;

c) siliceous or calcareous fly ash, conforming to BS EN 197-1:2011, 5.2.4 or BS EN 14227-4;

d) burnt shale conforming to BS EN 197-1:2011, 5.2.5;

e) limestone conforming to BS EN 197-1:2011, 5.2.6; and

f) silica fume conforming to BS EN 197-1:2011, 5.2.7.

NOTE 1 *Optionally, constituents which are not referenced in a) to f) or are outside the allowable compositional range described in BS EN 197-1, may be used provided those constituents are demonstrated to be of consistent quality and the ABS concrete containing these constituents satisfies with the performance recommendations given in Clause* ***6****.*

NOTE 2 *Where limestone or silica fume are used as main constituents at least one other main constituent from the other listed categories is necessary for the main constituents to supply both aluminium and silicon as oxides to form an AAM type of ABS.*

4.2 Performance assessment

Where the ABS is supplied to a concrete supplier as a separate binder system to replace Portland or blended cement, supersulfated cement or calcium aluminate cement in the production of concrete, the manufacturer should test the ABS for mechanical and physical properties in accordance with BS EN 196-1 and BS EN 196-3. If separately supplied, the ABS should be classified into a standard 28-day strength class and applicable early 2-day or 7-day strength class in accordance with the physical recommendations given in Table 1.

NOTE *This assists the concrete supplier in achieving the performance properties of the concrete recommended in Clause* ***6****.*

Table 1 – Mechanical and physical requirements of ABS given as characteristic values

<table>
<tr><th rowspan="3">Strength class</th><th colspan="4">Compressive strength / MPa</th><th rowspan="2">Initial setting time (min)</th><th rowspan="2">Soundness (expansion) (mm)</th></tr>
<tr><th colspan="2">Early strength</th><th colspan="2">Standard strength</th></tr>
<tr><th>2 days</th><th>7 days</th><th colspan="2">28 days</th><th></th><th></th></tr>
<tr><td>22.5 [A)]</td><td>—</td><td>—</td><td>≥22.5</td><td>≤42.5</td><td>≥75</td><td rowspan="10">≤10</td></tr>
<tr><td>32.5 L</td><td>—</td><td>≥12.0</td><td rowspan="3">≥32.5</td><td rowspan="3">≤52.5</td><td rowspan="3">≥75</td></tr>
<tr><td>32.5 N</td><td>—</td><td>≥16.0</td></tr>
<tr><td>32.5 R</td><td>≥10.0</td><td>—</td></tr>
<tr><td>42.5 L</td><td>—</td><td>≥16.0</td><td rowspan="3">≥42.5</td><td rowspan="3">≤62.5</td><td rowspan="3">≥60</td></tr>
<tr><td>42.5 N</td><td>≥10.0</td><td>—</td></tr>
<tr><td>42.5 R</td><td>≥20.0</td><td>—</td></tr>
<tr><td>52.5 L</td><td>≥10.0</td><td>—</td><td rowspan="3">≥52.5</td><td rowspan="3">—</td><td rowspan="3">≥45</td></tr>
<tr><td>52.5 N</td><td>≥20.0</td><td>—</td></tr>
<tr><td>52.5 R</td><td>≥30.0</td><td>—</td></tr>
<tr><td colspan="7">A) Strength class 22.5 is only allowed for very low heat ABS.</td></tr>
</table>

Where the manufacturer does not supply the ABS (inclusive of potentially multiple liquid or powder activators) separately, it should work with the concrete supplier to produce lower carbon ABS concrete which meets the recommendations of Clause **6**. The manufacturer should provide compressive strength development data to indicate the appropriate early age strength class of the ABS supplied.

4.3 Emissions

The ABS supplier should provide a validated carbon footprint of the binder system upon request. The validated carbon footprint of the ABS in terms of carbon dioxide equivalents (kgCO_2e/tonne of binder) should be based on calculations in accordance with BS ISO 14067 and inputs for relevant constituents from MPA Fact sheet 18 [N2].

ABS concrete mixes should have an embodied CO_2 equivalent to not greater than benchmark rating A for the relevant strength class according to the ICE Low Carbon Concrete Routemap [N1].

***NOTE** The benchmark ratings given in ICE Low Carbon Concrete Routemap (ICE 2023) [N1] are based on embodied CO_2 equivalent of normal weight concrete mixes used recently in the UK. Benchmark rating C is approximately equivalent to the current UK average.*

Opportunities for reducing the embodied CO_2 equivalent of ABS concrete focuses on reducing ABS content while achieving the required strength class and other properties. Reductions might be achieved by adjustments to sources of constituents, the requirements for early strength gain, consistence, type and grading of aggregates and age at which the specified strength can be achieved.

5 ABS concrete materials

5.1 Aggregates

Aggregates used in the production of ABS concrete should conform with BS EN 12620. Aggregates should be classified as having low or normal reactivity when petrographically examined in accordance with BS 812-104.

NOTE *RILEM TC 247-DTA round robin test (2020) [4] found that only concrete containing highly reactive aggregates with binders based on alkali activated ABS exhibited significant expansion due to alkali silica reaction. It is advised to use highly reactive aggregates with caution where adequate information is available to demonstrate acceptable performance in the proposed application. Both the ASTM C1293 [5] and RILEM AAR-3.1 [4] test methods for the determination of ASR expansion appear to give reliable identification of expansion caused by highly reactive aggregates.*

There is limited published information of ABS concrete made with lightweight or heavy weight aggregates. It is advised that light weight and heavy weight aggregates are used with caution and adequate information is sought to demonstrate acceptable performance in the proposed application.

5.2 Water

Water added during the mixing of an ABS concrete should conform to BS EN 1008 unless it is provided as part of a liquid activator or as part of an admixture, if these are added as aqueous solutions.

NOTE *The water component of liquid activators in ABS can be a significant part of the total water content of the mix.*

5.3 Admixtures

Chemical admixtures that have been developed for application with specific ABS concrete mixes to improve consistence or change setting times should be assessed to confirm performance against a reference ABS concrete before use.

NOTE *It cannot be assumed that admixtures conforming with BS EN 934 provide similar effects on setting time or consistence of ABS concrete.*

5.4 Other constituents

The total chloride content of the concrete constituents should be determined in accordance with the relevant method specified in BS 8500-2:2015+A2:2019, Table 5.

The limits on total chloride content as a percentage of the mass of ABS solids within the concrete should conform to the values in Table 2.

Table 2 – Recommended limits on chloride content of ABS concrete

Type of concrete	% chloride by mass of ABS solids
Unreinforced concrete containing no embedded metal other than corrosion-resistant lifting devices	0.50
Containing steel reinforcement or other embedded metal	0.20
Prestressed; heat-cured in contact with steel	0.10

6 ABS concrete properties

6.1 General

Lower carbon concrete containing ABS should be specified as a designed concrete with compressive strength class, exposure class and a target value for consistence, together with any specific parameters by which conformance of the ABS concrete can be assessed.

In addition to achieving basic performance requirements, ABS concrete should demonstrate acceptable performance with respect to the range of fresh and hardened properties that might affect the behaviour of the element or structure in which ABS concrete is used.

Supply of ABS concrete should be done in accordance with Annex A.

NOTE 1 *A summary of the recommended test procedures is given in Table 3.*

NOTE 2 *BS EN 206 specifies a limited number of basic requirements for concrete containing established binders and specifies optional additional requirements where appropriate. Lower carbon concrete containing ABS might have a limited history of proven performance.*

Table 3 – Summary of the recommended verification and project testing for ABS concrete

Clause	Property	Test procedure A)	Verification testing B)			Project-specific	
—	—	—	Ages	Structural Criteria	Non-structural	Age	Frequency
6.2	Consistence	BS EN 12350-2 or BS EN 12350-8	—	Reported	Reported	—	Every truck
6.3	Setting time	BS ISO 1920-14	—	Reported	Reported	—	—
6.4	Heat of reaction	BS EN 12390-14	Optional	—	—	—	—
6.5	Coefficient of thermal expansion	BS EN 1770 or AASHTO T 336–11 [N3]	Optional	—	—	—	—
6.6	Compressive strength class	BS EN 12390-3	3, 7, 28, 56, 90, 180, 365	$f_{ck,}$ Strength development class	f_{ck}	7, 28, 56	Every 50m^3 or part thereof
6.7	Tensile strength	BS EN 12350-6	7, 28, 90, 180, 365	Mean f_{ctm}≥ 90%	Mean f_{ctm} < 90%	If specified	Every 250 m^3 or part thereof
6.8	Secant modulus of elasticity	BS EN 12390-13	7, 28, 90, 180, 365	Mean E_{cm}≥ 60%	Mean E_{cm} < 60%	If specified	Every 250 m^3 or part thereof
6.9	Shrinkage	BS EN 12390-16	7, 28, 90, 180	ε_{cd},0 reported	N/A	—	—

Table 3 – Summary of the recommended verification and project testing for ABS concrete *(continued)*

Clause	Property	Test procedure [A)]	Verification testing [B)]			Project-specific	
—	—	—	Ages	Structural Criteria	Non-structural	Age	Frequency
6.10	Creep	BS EN 12390-17	7, 14, 28, 90, 180, 365	$\Phi(t, t0)$ reported	N/A	—	—
6.11	Fire resistance	BS 476	28	Reported	N/A	—	—
7.2	Carbonation	BS EN 12390-12/10	28	Reported	N/A	—	—
7.3	Chloride migration	Nordtest NT Build 492 [N4]	28	Reported	N/A	If specified	Every 250 m^3 or part thereof
7.4	Freeze-thaw resistance without de-icing agents	CEN/TR 15177	28	≥ 75% after 28 cycles	N/A	—	—
7.4	Freeze-thaw resistance without de-icing salts	CEN/TS 12390-9	28	<1000 g/m^2 after 28 cycles	N/A	—	—
7.5.1	Sulfate resistance	Class 2/Class 5 sulfate immersion	28 (12 months)	Equivalent DC-2/DC-4	N/A	—	—
7.5.2	Acid resistance	pH 2.5 immersion	28 (12 months)	Equivalent DC-4z	N/A	—	—
7.5.3	Microbial induced corrosion resistance	Biogenic corrosion chamber	28 (12 months)	Reported	N/A	—	—

A) A minimum of 3 specimens per sample or in accordance with standard whichever is the greater.

B) Verification testing on a representative concrete strength class to demonstrate conformance of the ABS concrete should be conducted by the ABS or ABS concrete supplier.

6.2 Consistence

The target value for consistence at delivery should be established by trials when the parties concerned have no prior experience with the proposed ABS concrete.

NOTE 1 The target values are typically slump to BS EN 12350-2 or slump flow to BS EN 12350-8.

The target value for consistence should include the tolerances allowed in BS EN 206 Table 23 and any adjustments so that the ABS concrete can be effectively placed and finished at the minimum allowable consistence at delivery. The appropriate consistence class should be determined after establishing the target value for consistence.

NOTE 2 ABS concrete might be more thixotropic than concrete made with BS EN 197 cements. When these ABS concretes are stationary, they might appear to be of insufficient consistence but have adequate consistence when pumped or vibrated. Some chemical admixtures have been developed for application with specific ABS concrete mixes to improve consistence.

6.3 Setting time

Adjustments to setting time to allow for concrete placement and finishing within an acceptable period should be made through changes to the ABS chemistry or the use of chemical admixtures that have been demonstrated as suitable for application with specific ABS concrete mixes to modify setting time.

NOTE 1 *Set retarding or set accelerating admixtures conforming to BS EN 934 have been developed for Portland cement-based concrete but do not necessarily produce similar effects in ABS concrete.*

The setting time of ABS concrete should be determined in accordance with BS ISO 1920-14.

NOTE 2 *The setting time of ABS concrete depends on the chemistry of the activators and binder system and the temperature. There are ABS that are only suitable for heat cured applications which might not achieve set when tested at 20 °C.*

6.4 Heat of reaction

The heat of reaction of ABS concrete should be measured with a semi-adiabatic test to predict the temperature rise in an ABS element if deformation is critical for design (CIRIA C766 [6]).

NOTE 1 *BS EN 12390-14 contains a suitable semi-adiabatic test method.*

NOTE 2 *ABS concrete typically has a lower heat evolution than Portland cement-based concrete.*

6.5 Coefficient of thermal expansion

Where the influence of thermal expansion is of minor or moderate concern, the coefficient of thermal expansion of ABS concrete should be taken as equal to 10 x 10^{-6} / °C ± 20% (SA TS 199:2023).

Where thermal expansion is critical for design, the coefficient of thermal expansion should be determined from suitable test data in accordance with AASHTO T 336–11 [N3] or similar.

6.6 Compressive strength class

When determined statistically from compressive strength tests in accordance with BS EN 12350-3, using a method conforming to BS 8500-2, the characteristic compressive strength should be 28 days (f_{ck}) or 56 days where suitable.

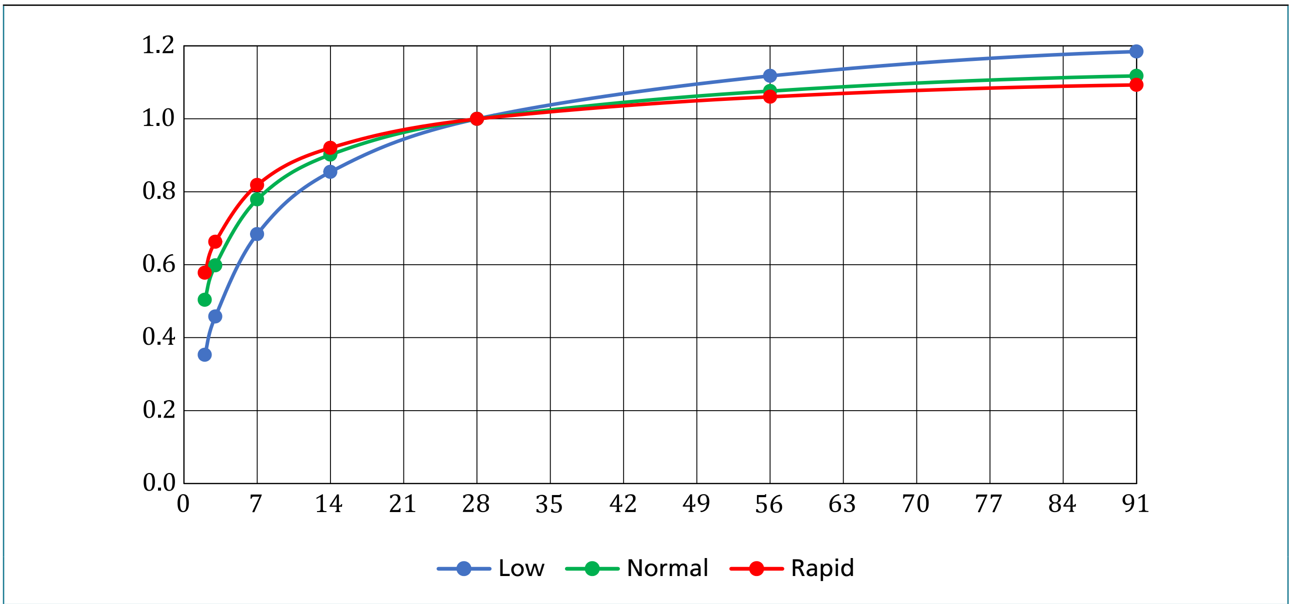
NOTE 1 *Recommended compressive strength classes are C16/20, C20/25, C25/30, C28/35, C30/37, C32/40, C35/45, C40/50, C45/55, C50/60, C55/67 and C60/75.*

Compressive strength testing of a representative strength class of the ABS concrete (see Figure 1) should be conducted on a minimum of three specimens at 3, 7, 28, 56, 90, 180 and 365 days to determine the equivalent strength development class for the ABS (Slow, Normal or Rapid) to that given in BS EN 1992-1-1:2004+A1:2014, 3.1.2.

Compressive strength classes greater than C60/75 should be tested in a laboratory or with field data to confirm satisfactory performance in accordance with Clause **6**.

NOTE 2 *There is limited data available on ABS concretes with compressive strength greater than C60/75.*

Figure 1 – Relative strength compared to 28 day for different strength development classes based on BS EN 1992-1-1, 3.1.2



6.7 Tensile strength

The mean tensile strength of ABS concrete should be determined by either the tensile splitting test in accordance with BS EN 12390-6 or the flexural tensile strength test in accordance with BS EN 12390-5. Where ABS concrete is to be used in a structural application designed in accordance with BS 8500, the ABS concrete should achieve a mean tensile strength not less than 90% of the relevant derived tensile strengths in Table 4.

Table 4 – 28 day tensile strengths derived from BS EN 1992-1-1 related to compressive strength class after Bamforth

Compressive strength class	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60	C55/67	C60/75
Mean splitting tensile strength $f_{ctm, sp}$	2.1	2.5	2.8	3.2	3.6	3.9	4.2	4.5	4.7	4.8
Mean flexural tensile strength $f_{ctm, fl}$	2.9	3.3	3.8	4.3	4.8	5.3	5.7	6.1	6.3	6.5

***NOTE** Data available in the literature of different ABS concretes indicates that the relationship between compressive strength and tensile strength is similar to that for Portland cement-based concrete.*

6.8 Secant modulus of elasticity

*COMMENTARY ON **6.8***

In BS EN 1992-1-1, the secant modulus of elasticity, E_{cm} (GPa), is derived from the mean compressive strength, f_{cm} (MPa), using the following formula based on quartzite aggregates:

$$E_{cm} = 22\,[f_{cm}/10]^{0.3} \qquad (1)$$

The mean secant modulus of elasticity of the ABS concrete, E_{cm}, should be determined in accordance with the BS EN 12390-13 procedure at 28 days. The potential influence of not using a quartzite aggregate should be assessed. The following classifications for the ABS concrete with respect to the value of E_{cm} based on Equation 1 using the mean compressive strength should apply:

a) normal modulus ABS concrete should have a measured mean E_{cm} equal to or greater than 80% of the value of E_{cm} determined by Equation 1;

b) low modulus ABS concrete should have a measured mean E_{cm} equal to or greater than 60% of the value of E_{cm} determined by Equation 1 but less than 80%; and

c) very low modulus ABS concrete should have a measured mean E_{cm} less than 60% of the value of E_{cm} determined by Equation 1.

Very low modulus ABS concrete should not be used in a structural application designed in accordance with BS 8500 or BS EN 1992.

***NOTE** Secant modulus of elasticity is affected by the modulus of elasticity of the aggregate used in the ABS concrete. As a general guideline, for limestone and sandstone aggregates, the value is reduced by 10% and 30% respectively and for basalt aggregates it is increased by 20%.*

The secant modulus of elasticity is dependent on the chemical composition of ABS as well as the aggregate. The data available in the literature indicates that high calcium ABS tends to produce normal modulus ABS concrete. Low calcium ABS tends to produce low or very low modulus ABS concrete. In BS EN 1992-1-1, Poisson's ratio is taken as 0.2 for uncracked concrete. When testing the secant modulus of elasticity of ABS concrete, the Poisson's ratio is measured.

6.9 Shrinkage

*COMMENTARY ON **6.9***

In BS EN 1992-1-1, shrinkage is taken as the sum of autogenous shrinkage and drying shrinkage of concrete.

Shrinkage of the ABS concrete should be determined in accordance with BS EN 12390-16 using specimens with a cross-section not greater than (100 × 100) mm. Subject to the agreement of relevant parties, the following modifications should be taken into account:

a) adjustments to the standard curing procedure should be made where exposure of the specimens directly to water could detrimentally affect the properties of the ABS concrete, or when an accelerated curing procedure is adopted;

b) the first gauge measurement should be taken after stripping each specimen within (24 ±2) h after moulding to help assess the effect of early autogenous shrinkage;

c) shrinkage measurements should be taken after standard drying at 65% relative humidity for periods of 1 week, 2 weeks, 3 weeks, 4 weeks, 8 weeks, 3 months, 4 months, 5 months and 6 months.

The shrinkage value measured after 6 months should be treated as the basic drying shrinkage strain, $\varepsilon_{cd,0}$. The development of the drying shrinkage strain values in time should be estimated by Equation 2 (BS EN 1992-1-1:2004+A1:2014, Expression 3.9):

$$\beta_{ds}(t) = \beta_{ds}(t,t_s) \cdot k_h \cdot \varepsilon_{cd,0} \qquad (2)$$

where:

k_h is a coefficient depending on the notional size, h_0, according to Table 5.

$$\beta_{ds}(t,t_s) \frac{(t - t_s)}{(t - t_s) + 0.04\sqrt{h_0^3}} \qquad (3)$$

where:

t is the age of the concrete in days at the moment considered;

t_s is the age of the concrete in days at the beginning of drying shrinkage (or swelling), normally the end of curing.

h_0 is the notional size (mm) of the cross-section = $2A_c/u$

where:

A_c is the concrete cross-sectional area (mm²)

u is the perimeter of that part of the cross-section (mm) which is exposed to drying

Table 5 – Values for k_h in Expression 2

h_0	k_h
100	1.0
200	0.85
300	0.75
≥500	0.70

NOTE *Design values for autogenous shrinkage in BS EN 1992-1-1 are calculated from the characteristic cylinder strength of concrete. These values cannot be assumed to apply to ABS concrete which might have different autogenous shrinkage behaviour and can be checked by shrinkage assessment from the time of stripping the specimens. ABS concrete based on GGBS can have increased rates of early autogenous shrinkage.*

6.10 Creep

Where ABS concrete is used in an element or structure subject to sustained load, it should be tested for creep after 28 days curing in accordance with BS EN 12390-17 for a period of one year under a constant stress of 0.4 f'_c.

NOTE 1 *It is recommended that the temperature and relative humidity for the creep and companion drying shrinkage specimens during testing are representative of the average conditions expected in service.*

The basic creep strain should be calculated by subtracting the initial elastic strain due to the applied load and the drying shrinkage strain from the total creep strain measured.

The basic creep coefficient of concrete should be calculated from the mean value of the ratio of creep strain to elastic strain for a specimen loaded at 28 days under a constant stress of 0.4 f'_c.

The design creep coefficient for ABS concrete at any time should be determined from the basic creep coefficient using an accepted mathematical model for creep behaviour, calibrated so that the measured basic creep coefficients during testing are also predicted by the chosen model.

NOTE 2 *AS SA TS 199:2023 Clause 4.1.8.2 provides an acceptable model of creep behaviour for ABS concrete.*

After the initial transition period, the rate of increase of creep strain of ABS concrete should be not greater than a linear when plotted against the logarithm of time (SA TS 199:2023).

NOTE 3 *As with Portland cement-based concrete, creep in ABS concrete is influenced by the relative humidity and temperature of the environment, the dimensions of the element as well as its maturity when loaded and the duration and magnitude of that load.*

6.11 Fire resistance

Members and structural elements constructed with normal and low modulus ABS concrete should conform to the requirements for fire resistance given in BS EN 1990:2002+A1:2005 Section 5 and BS EN 1992-1-2.

Fire testing should be undertaken to confirm that the behaviour of ABS concrete is consistent with the assumptions in the modelling.

NOTE 1 *An example of fire testing is given in the EFNARC Specification and guidelines for testing of passive fire protection [7].*

Spalling can play a significant role in certain types of ABS concrete depending on the rate of temperature rise, moisture content, porosity and type of aggregates and should be tested when there is a significant risk of spalling.

NOTE 2 *The design of concrete structures for fire resistance outlined in BS EN 1992-1-2 considers the properties of the concrete materials at high temperatures, namely thermal conductivity, thermal capacity, strength and stiffness changes. Investigations of these properties in normal and low modulus ABS concrete indicate that they are generally in a similar range to those for Portland cement-based concrete.*

7 Durability of ABS concrete

7.1 General

*COMMENTARY ON **7.1***

This clause discusses the ABS concrete performance recommended to achieve a durability of 50 or 100 years for elements, subject to the exposure classes given in Table 4.1 of BS EN 1992-1-1:2004+A1:2014 and Table A.1 of BS 8500-1:2015+A2:2019 and aggressive chemical environment for concrete (ACEC) exposure classes in Table A.2 of BS 8500-1:2015+A2:2019.

Durability is a complex topic and conformance to the recommendations of this clause does not guarantee element or structure durability. Protection of steel reinforcement largely depends on the thickness and penetrability of the ABS concrete cover.

The minimum cover thickness in millimetres, $C_{min,dur}$, for ABS concrete should be based on the values given for structural class S4 (50 years) or S6 (100 years) as shown in Table 6.

Table 6 – Recommended values of minimum cover, $C_{min,dur}$, for reinforcement and prestressing steel for ABS concrete based on exposure class

Dimensions in millimetres								
Design Life	Structural Class	Exposure Class according to Table 4.1 (BS EN 1992-1-1)						
		X0	XC1	XC2/XC3	XC4	XD1/XS1	XD2/XS2	XD3/XS3
Reinforcing steel								
50 Years	S4	10	15	25	30	35	40	45
100 Years	S6	20	25	35	40	45	50	55
Pre-stressing steel								
50 Years	S4	10	25	35	40	45	50	55
100 Years	S6	20	35	45	50	55	60	65
NOTE *These values are based on the values given for structural class S4 (50 years) or S6 (100 years) in BS EN 1992-1-1:2004+A1:2014 Table 4.4N for reinforcement steel and Table 4.5N for prestressing steel without the reductions in class given in Table 4.3N.*								

NOTE *To calculate the nominal cover, C_{nom}, an addition to the minimum cover is made in design to allow for the deviation (ΔC_{dev}). 10 mm can be considered a suitable value.*

7.2 Corrosion induced by carbonation (XC1, XC2, XC3, XC4)

Accelerated testing in accordance with BS EN 12390-12 should be used to calculate the carbonation coefficient in mm/year$^{0.5}$ of ABS concrete. This coefficient should be used to estimate the minimum cover to achieve the required design working life adjusting for the environmental conditions to which the element or structure would be exposed. Where available, accelerated carbonation tests should be compared with carbonation rates from ABS concrete in natural exposure conditions in accordance with BS EN 12390-10.

NOTE *For some ABS concrete types, phenolphthalein indicator causes a faded purple colour over an extended depth under both accelerated and natural* CO_2 *exposure. An alternative is to use a universal solution indicator that provides a wide range of colours over pH variations between 1 and 14, and therefore, provides clear colour variation to identify both full carbonation and partial carbonation zones of some ABS concretes.*

Leaching of alkalis from the surface of ABS concrete after water curing can greatly increase the initial carbonation rate.

Corrosion of reinforcement in Portland cement-based concrete subject to carbonation generally includes a prolonged propagation phase which might not occur in some ABS concretes.

7.3 Corrosion induced by chloride (XS1, XS2, XS3, XD1, XD2, XD3)

*COMMENTARY ON **7.3***

Chloride migration testing of the ABS concrete in accordance with BS EN 12390-18 may be carried out to measure the chloride migration coefficient in m²/s. This coefficient can be used to estimate the minimum cover to achieve the required design working life based on the surface chloride level to which the element would be exposed.

Service life prediction modelling of ABS concrete exposed to chloride should take account of the limited chloride binding capacity in some ABS concretes and limited data on the reduction in chloride diffusion over time.

In chloride rich environments, the total acid soluble chloride content should be limited to 0.1% of ABS solids as that recommended for prestressed concrete in Table 1.

NOTE *Research indicates that admixed or penetrating chloride ions in some ABS concrete types can be conservatively assumed to be free chloride ions with no chemical binding reducing concentration.*

The suggested chloride threshold value of 0.4 % (wt. % by binder mass) for PC binders appears suitable for ABS concretes with high alkalinity binders.

Research on electrochemical aspects of corrosion of reinforcement in ABS concrete samples has shown that the traditional benchmarks might be misleading. The low porosity of some ABS concrete types can inhibit oxygen diffusion which can lead to more negative potential values. Additionally, the high contents of reduced sulfur provided by GGBS in many ABS concretes can also induce a strongly negative potential. Accordingly, half cell potential might not be a reliable corrosion detection parameter for ABS concrete and would need to be confirmed by visual inspection. A polarization resistance of 100 kΩ.cm² or above appears to offer a suitable indicator of passivity of mild steel reinforcement in ABS concrete.

Alternatively, non-corroding reinforcement can be used in ABS concrete where there are concerns regarding chloride induced corrosion.

7.4 Freeze/thaw attack with or without de-icing agents (XF1, XF2, XF3, XF4)

ABS concrete expected to be exposed to freeze/thaw without de-icing agents should be tested in accordance with CEN/TR 15177 to determine resistance to internal damage. The relative dynamic modulus of elasticity of a freeze/thaw resistant ABS concrete should be not less than 75% after 28 freeze/thaw cycles.

ABS concrete expected to be exposed to freeze/thaw with de-icing agents should be tested in accordance with CEN/TS 12390-9 to determine resistance to salt scaling. The average loss of ABS concrete due to scaling after 28 freeze/thaw cycles should be not greater than 1,000 g/m².

NOTE *There is a strong influence of the curing and experimental conditions on the results of freeze/thaw testing of ABS concretes (with and without de-icing agents) to be considered during the interpretation of test outcomes (RILEM TC 247-DTA)[4].*

7.5 Chemical attack [Aggressive Chemical Environment for Concrete Classification (ACEC) exposure class]

7.5.1 Sulfate attack

Where the ABS concrete surface is exposed to sulfates, the durability of ABS concrete should be assessed by immersion in Class 2 and Class 5 sulfate solutions at 5 °C for a minimum period of one year and compared to a reference Portland cement-based concrete conforming to DC-4.

NOTE 1 *Equivalent or superior performance to the conventional DC-4 concrete in the Class 2 solution but inferior in the Class 5 solution would indicate that the ABS concrete is suitable for application in sulfate classes up to DS-2 for an intended working life of at least 50 or 100 years without an additional protective measure (APM).*

NOTE 2 *See BS 8500-1:2015+A2:2019 Tables A.2, A.10 and A.11.*

NOTE 3 *Equivalent or superior performance to the conventional DC-4 concrete in the Class 5 sulfate solution would indicate that the ABS concrete is suitable for application in sulfate classes up to DS-5m for an intended working life of at least 50 or 100 years without an additional protective measure (APM) where the ACEC exposure class is AC-4ms or with an APM where the ACEC exposure class is AC-4m or AC-5m.*

NOTE 4 *See BS 8500-1:2015+A2:2019 Tables A.2, A.10 and A.11.*

NOTE 5 *Some ABS concretes have shown better resistance to sulfate attack than Portland cement-based concretes in Class 5 sulfate solution immersion tests at 5 °C with less deterioration when exposed to ACEC exposure class AC-5m.*

7.5.2 Acidic environments

Where the ABS concrete surface is exposed to acidic environments (such as ACEC exposure classes AC-2z – AC-5z), the durability of ABS concrete should be assessed by immersion in an agitated acidic solution with a controlled pH 2.5 for a minimum period of one year and compared to a reference Portland cement based concrete conforming to DC-4z.

NOTE 1 *Equivalent or superior performance to the conventional DC-4z concrete in the agitated acidic solution would indicate that the ABS concrete is suitable for application in acidic environments up to ACEC exposure class AC-4z for an intended working life of at least 50 or 100 years without an additional protective measure (APM) or up to ACEC exposure class AC-5z with an APM.*

NOTE 2 *Laboratory testing has shown that some ABS concretes have better resistance to acids than Portland cement-based concretes (Fernández-Jiménez and Palomo, 2009 [8]; Pacheco-Torgal et al., 2012 [9]; Bakharev et al. 2002 [10], Bakharev 2005 [11], Wimpenny et al., 2011 [12], Aldred, 2013 [13]).*

When assessing pH test results, the level of acidity might change over the service life of the ABS concrete element or structure.

7.5.3 Microbially induced corrosion of concrete (MICC)

Where ABS concrete is exposed to environments with significant potential for microbially induced corrosion of concrete (MICC), the MICC resistance of the ABS concrete should be compared to a reference Portland cement-based concrete. Test specimens should be assessed using an established biogenic exposure test for a minimum of 12 months to determine the required sacrificial layer to achieve the intended working life in the proposed exposure based on an accepted deterioration model.

NOTE 1 *Pomeroy equation given in US EPA Process design manual [14] is an accepted deterioration model.*

NOTE 2 *Microbially induced corrosion of concrete (MICC) typically occurs in sewage and wastewater treatment environments. Established biogenic test procedures are: "Accelerated Biogenic Sulphuric-Acid Corrosion Test" by KIWA GmbH [15], "Concrete Corrosion Chamber" by University of Queensland Advanced Water Management Centre [16] and "Biogenic sulphuric acid (BSA) testing" Fraunhoffer UMSICHT [17].*

7.6 Abrasion (XM1, XM2, XM3)

When ABS concrete is subject to abrasion, special attention should be given to the hardness of the aggregates to help provide abrasion resistance. Abrasion of ABS concrete should be determined by testing in accordance with BS 8204-2:2003+A2:2011 Annex B and the results compared with a reference Portland cement-based concrete. The ABS concrete should perform at least as well as the reference mix.

An additional sacrificial layer of 5 mm, 10 mm and 15 mm for XM1, XM2 and XM3 respectively should be used for ABS concrete in accordance with BS EN 1992-1-1:2004+A1:2014, 4.4.1.2.

Where skid resistance is of importance for the intended application, performance-based testing should be undertaken in accordance with BS 8204-2:2003+A2:2011 Annex C, as appropriate, to verify the suitability of the ABS concrete for skid resistance.

Annex A (normative) Supply of ABS concrete

A.1 General

The ABS concrete producer in principle should comply with the requirements of BS EN 206/BS 8500 with respect to production, quality control and conformity.

A.2 Plant and equipment

*COMMENTARY ON **A.2***

*The plant and equipment used to supply ABS concrete is typically similar to that used for traditional concrete based on BS EN 197 cements, but the silos would contain one or more of the constituent materials listed in Clause **5**.*

ABS which contain preblended activator powders and the other constituent materials should be discharged in a similar manner to BS EN 197 cements.

***NOTE 1** For ABS in which the activators are added separately, a difference from traditional concrete plants is the storage and dispensing equipment for the activators used in ABS concrete. Activators may be in powder or liquid form. Liquid activators are often highly alkaline and can be corrosive which needs to be considered for any equipment in contact with such materials.*

Dispensing equipment should be capable of consistently measuring the volume or weight of activators to be added to the mix within an accuracy conforming to BS 8500-2.

Plant and equipment that may have been in contact with Portland cement powder or concrete should be cleaned before batching.

***NOTE 2** Some ABS concretes based on ABS can be sensitive to the presence of Portland cement.*

A.3 Batching

For one part preblended ABS, the water should be added to other components of the concrete as soon as practicable to facilitate proper mixing similar to the procedure for Portland cement based concrete.

For liquid activator ABS concretes, the liquid activator component should be added to the other components as soon as is practicable to facilitate proper mixing.

***NOTE 1** The quantity of water within liquid activator components of an ABS might be a significant portion of the total batch water of the ABS concrete.*

Only specific admixtures confirmed to be compatible with the proposed ABS should be used and their effectiveness might differ from the expectations for admixtures in Portland cement based concrete.

***NOTE 2** Consistence adjustment in ABS concrete is usually done by adjusting composite aggregate grading and water content.*

***NOTE 3** Adding water without adjusting overall binder amount has a detrimental effect on hardened properties as is the case for Portland cement based concrete.*

***NOTE 4** The water/binder solids ratio is a key parameter for achieving the required concrete properties in ABS concrete mixes (analogous to water/cement in Portland cement based concrete).*

Plant trials should be done to confirm that the fresh and hardened concrete properties needed are achieved and to determine the technical upper limit on water addition.

A.4 Placing and finishing

Trials should be conducted to establish the required consistence at delivery.

NOTE 1 *Some ABS concrete may be more thixotropic than concrete made with BS EN 197 cements. When these ABS concretes are stationary, they may appear to be of insufficient consistence but actually have adequate consistence when pumped or vibrated.*

If ABS concrete is placed by pump, the pump should be primed with a suitable slurry that does not detrimentally affect the ABS concrete, preferably a slurry composed of the proposed ABS with fine aggregate.

NOTE 2 *ABS concrete might have very little bleed water and the surface might be resistant to finishing tools.*

The ABS concrete supplier should provide information regarding the appropriate finishing aids and the recommended placement method for the ABS concrete.

The time needed for stiffening and familiarity with the different behaviour of ABS concrete should be established by trial prior to the commencement of any permanent work.

A.5 Early protection and curing

The surface of freshly laid ABS concrete should not be allowed to dry out as this may result in a weak surface layer. The surface should be covered with polythene sheeting or a compatible evaporation retarder immediately after finishing.

NOTE *Typically, ABS concrete hardens through a chemical reaction between the constituent materials and alkalis in solution. Therefore, the early application of water to ABS concrete may dilute the alkali solutions and weaken the concrete surface.*

ABS concrete should be cured with a suitable barrier, such as plastic sheeting or a curing compound which is resistant to the higher alkalinity of the surface. The curing compound should achieve a minimum curing efficiency of 90% when tested in accordance with BS 7542.

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