Alternative binder systems for lower carbon concrete – Code of Practice

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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.

Acknowledgement is given to the following organizations that funded this BSI Flex:

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- DB Group
- Environment Agency
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- Laing O'Rourke
- Mineral Products Association (MPA) Cement
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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

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Upon release of Version 2 of BSI Flex 350, PAS 8820 is to be withdrawn.

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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*