Special Digest 1:2005

Third edition

Concrete in aggressive ground

BRE Construction Division

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Cover photo by Graham Gaunt, courtesy of Arup©

SD1

First published 2001
Second edition 2003
Third edition 2005
ISBN 1 86081 754 8

Acknowledgements
The principal funding for the preparation of this Special Digest was provided by The Concrete Centre. A list of sponsors and members of the steering group who advised on its preparation is shown on page vi.

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Part A
Introduction

A1 Problem of chemical attack

Chemical agents that are destructive to concrete may be found in the ground. In the UK, sulfates and acids, naturally occurring in soil and groundwater, are the agents most likely to attack concrete. The effects can be serious (Figure A1) resulting in expansion and softening of the concrete to a mush. A substantial number of other substances are known to be aggressive, most resulting from human activity, but collectively these are a lesser problem as they are encountered only rarely by concrete in the ground.

It has been standard practice in the UK for at least six decades to design concrete for installation in the ground to be resistant to attack from commonly found chemicals, including sulfates and acids. BRE has underpinned this approach by issuing a series of guidance notes and Digests, dating back to 1939, on the causes of chemical attack and how to specify chemically resistant concrete.

Consequently, most concrete installed in the ground has performed entirely satisfactorily and is expected to do so for its required working life. Occasionally, however, cases of chemical attack have come to light and have been subject to research by BRE and others. Some of these cases have been attributed to rarely occurring chemicals not specifically covered by BRE Digests: some to natural ground conditions for which there was insufficient guidance, such as occurrence of pyrite; and some to the emergence of previously unrecognised attack mechanisms, such as the thaumasite form of sulfate attack (TSA) which has been extensively reported in the last decade[1].

Guidance in BRE Digests has necessarily evolved to cater for successive adverse field findings; to take advantage of the emergence of new concrete constituents and construction methods; and to maintain harmony with newly published standards, latterly European ones. In order to be both comprehensive and flexible, Digests have tended to become longer and more complex. One objective of this third edition of Special Digest 1 (SD1) is to simplify the guidance. Other aims and changes are discussed later.

A2 Scope and structure of the guidance

A2.1 Types of site and chemical agents covered

SD1 provides guidance on the specification of concrete for installation in natural ground and in brownfield locations. The definition of a brownfield location adopted here is one that has been subject to industrial development, storage of chemicals, or deposition of waste, and which may contain aggressive chemicals in residual surface materials or in ground penetrated by leachates. The procedures given for ground assessment and concrete specification cover the fairly common occurrence of sulfates, sulfides and acids. They also cover the more rarely occurring aggressive carbon dioxide found in some ground and surface waters.

Figure A1 Extreme example of sulfate attack in a 30-year-old highway bridge sub-structure exposed to wet, pyritic clay fill

While SD1 discusses several aggressive agents (eg ammonium salts and phenols) occasionally found in heavily contaminated ground, no specific procedures are included for dealing with these. Specialist advice should be sought if they are encountered.

A2.2 Readership

SD1 provides practical guidance to ground specialists on the assessment of ground in respect of aggressiveness to concrete, and to concrete designers, contractors, specifiers and producers on the specification of concrete to resist chemical attack.

A2.3 Structure of the guidance

Guidance is given in Parts B to F as follows.

Part B describes modes of chemical attack and discusses the mechanisms of the principal types, including sulfate and acid attack, and the action of aggressive carbon dioxide.

Part C deals with assessment of the chemical aggressiveness of the ground. It gives procedures for the determination of Design Sulfate Class (DS Class) from soluble sulfate and magnesium, and from the potential sulfate (eg from oxidation of pyrite). It shows how the DS Class together with pH and mobility of groundwater may be collectively taken into account for natural ground and brownfield sites to classify a location in terms of Aggressive Chemical Environment for Concrete Class (ACEC Class).

Part D gives recommendations for the specification of concrete for general cast-in-situ use in the ground. It explains how to derive an appropriate quality of concrete, termed the Design Chemical Class (DC Class), from a consideration of the ACEC Class together with the hydraulic gradient due to groundwater, the type and thickness of the concrete element, and its intended working life. In some cases, where conditions are highly aggressive, additional protective measures (APMs) are recommended.

Part D follows this with guidance on the constituents of concrete required to achieve the identified DC Class. Specification is shown as maximum free-water/cement ratio, minimum cement content and type of cement.

Part E gives recommendations for specifying surface-carbonated precast concrete for general use in the ground. An essential requirement for compliance with this part is that surface carbonation is assured by exposure of the precast concrete to air for a minimum of 10 days after curing. Since such carbonation provides a degree of resistance to sulfate attack, the recommendations for the derivation of DC Class in respect of sulfates is relaxed by one level. Other than this, the recommendations of Part D are followed for concrete specification.

Part F includes design guides for specification of specific precast concrete products, including pipeline systems, box culverts, and segmental linings for tunnels and shafts. These products are manufactured under rigorous quality control to ensure appropriate mix composition and achieve relatively low concrete permeability. Together these provide an inherently high quality in respect of chemical resistance. Consequently, a further relaxation (beyond that allowed for surface carbonation) is permitted in respect of specification of DC Class for aggressive sulfate conditions. In practice this relaxation is used to offset the general-use recommendation that a higher DC Class should be specified where concrete is of thin cross-section, or will encounter a relatively high hydraulic gradient.

Part F also covers specification of precast concrete masonry units (concrete blocks) for aggressive ground conditions. The guidance is based on Design Sulfate Class rather than ACEC Class as there is currently no correlation of block performance with the latter, though work on this is ongoing.

A glossary of terms is included as Appendix A1 on page 6.

A2.4 Diagrammatic overview of ground assessment and concrete specification

An overview of the various procedures for ground assessment and specification of concrete is given in Figure A2. This is arranged in four stages according to the construction sector that has key responsibility. Within each of these stages, the principal tasks are shown in boxes with references to the relevant sections of SD1. While most steps are equally applicable to all uses of concrete, there is a differentiation in Stage 3 for the determination of DC Class and APM between the three categories of concrete element dealt with in Parts D, E and F.

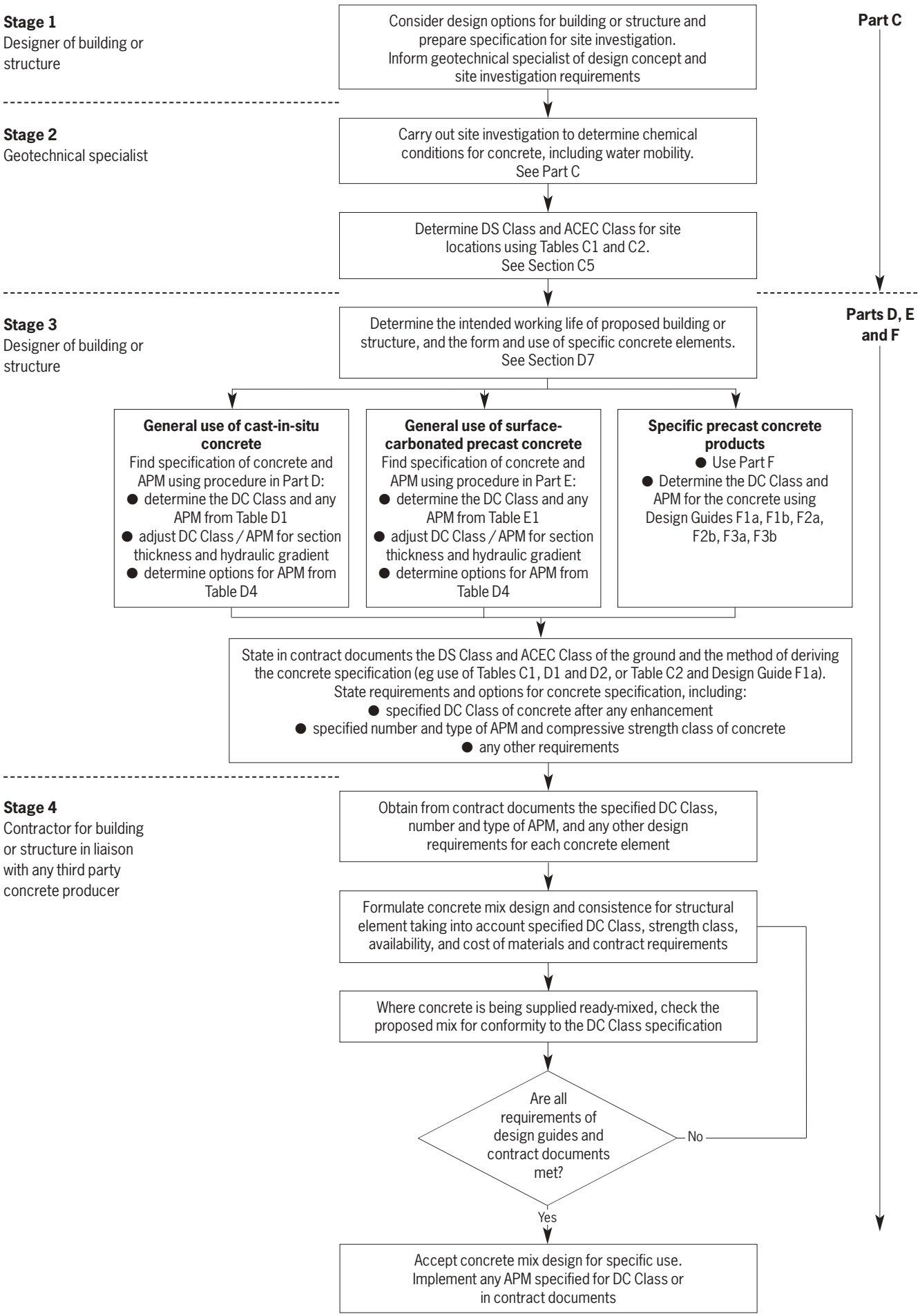

Figure A2 Procedure for design of buried concrete for use in an aggressive chemical environment