Concrete resistant to chemical attack

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INTRODUCTION

This publication gives guidance on the specification of concrete when sulfate and acid ground conditions will be encountered. Requirements for concrete in ground containing waste materials or in structures exposed to chemicals are not given in this publication; see **Special cases**.

BS EN 206–1: 2000, *Concrete. Part 1: Specification, performance, production and conformity* is a framework standard. This is a standard where some of the detailed requirements are given in national provisions, i.e. the details of what to specify and certain rules of application are given in a complementary British Standard, BS 8500, *Concrete - complementary British Standard to BS EN 206–1* (to be published in 2002). To help specifiers, producers and users, a derived publication, *Standards for fresh concrete*, is being produced that contains the text of both standards woven together, plus guidance on its use.

This publication should be read in conjunction with the complementary publication in this series, *Concrete for normal uses* (to be published) and BRE Special Digest 1, *Concrete in aggressive ground* (2001). This Special Digest introduces several new concepts including structural performance level. This takes account of the structural performance factors such as the consequence of serious erosion of the concrete by chemical attack and the ease of repair.

A summary of the procedure for determining the concrete quality and the additional protective measures (APMs) where necessary is given in Figure 1.

Concrete may be specified as either designed concrete or prescribed concrete, each with its respective sub-set of designated and standardized prescribed concrete. The use of prescribed concrete for structural applications is rare and consequently this publication covers only designed and designated concrete.

BRE Special Digest 1, *Concrete in aggressive ground,* is available from www.brebookshop.com

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Association of Concrete Industrial Flooring Contractors
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British Cement Association
British Standards Institution
Building Research Establishment
Cement Admixtures Association
Cementitious Slag Makers Association
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RMC Readymix
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United Kingdom Quality Ash Association

A full list of the publications in this series is given on the back page.

Figure 1: Stages in determining the appropriate concrete specification

Stage		Outputs
Stage1 • Using Table 1, classify the soil on the basis of the type and quantity of sulfate and other aggressive chemicals	→	• Design sulfate class (DS-class)
Stage 2 • Determine the type of ground (natural or brownfield) • Determine the acidity (pH) and mobility (static or mobile) of the groundwater • Using Table 1 and the DS-class, type of ground, acidity and mobility of the groundwater, determine the aggressive chemical environment for concrete classification (ACEC class)	→	• ACEC classification of the ground conditions
Stage 3 • Select from Table 2 the structural performance level (low, normal or high) • Determine the section thickness • Determine the hydrostatic head • Use Table 3 and this information with the ACEC-class to give the basic design chemical class (DC-class) and the number of additional protective measures (APMs)	→	• Basic design chemical class • Number of additional protective measures
Stage 4 • Check local availability of aggregate carbonate ranges B or C • Consider suitability and applicability of the different APMs given in Table 4. • Select the APMs and where applicable, modify the basic DC-class	→	• Modified or confirmed DC class • The type of APMs to be applied to the structure
Stage 5 • Convert the modified or confirmed DC-class to a designated concrete (Table 5) or complete the designed concrete specification (strength class, maximum nominal upper aggregate size, consistence class)	→	• Specification of a designated or designed concrete • Specification of the APMs to be applied to the structure

CHEMICAL ATTACK

Deterioration of concrete caused by chemical attack can be the result of contact with gases or solutions of many chemicals, but in the ground it is generally due to exposure to solutions of sulfate salts or to acidic solutions. Solutions of naturally occurring sulfates of sodium, potassium, calcium or magnesium, which may be present in some soils or groundwaters, can cause expansion and disruption of concrete.

The most abundant naturally occurring sulfates are:

- calcium sulfate (gypsum or selenite);
- magnesium sulfate (Epsom salt);
- sodium sulfate (Glauber's salt).

Although no significant amounts of ammonium sulfate have been found occurring naturally in the UK, this sulfate is the most damaging to concrete. Pyrite (iron sulfide) or other sulfides can occur naturally or arise from industrial wastes and, if slowly oxidized in the soil, give rise to sulfuric acid and sulfate ions in acid solution. Other acids frequently found, especially in moorland waters or peaty soils, are humic and carbonic acids.

The most common form of sulfate attack involves formation of the reaction products ettringite (a calcium aluminate sulfate hydrate) and gypsum, and may lead to expansion and cracking of concrete. However, recent evidence from a small number of cases has shown that concrete exposed to cold, very wet conditions and containing a source of carbonate may suffer a different type of sulfate attack. This involves the formation of the mineral thaumasite (a calcium silicate carbonate sulfate hydrate) and may lead to weakening of the concrete.

The following guidance incorporates recommendations for minimizing the risk of the thaumasite form of sulfate attack (TSA) given in the BRE Special Digest 1.

EXPOSURE CLASSIFICATION

The limiting values for some of the exposure classes for chemical attack and some of the test methods that are given in Table 2 of BS EN 206–1: 2000 vary significantly from current UK practice. BRE Special Digest 1 covers a wider range of exposure conditions including mobile ground water, acids and brownfield sites and consequently this approach to exposure classification and concrete selection is recommended.

Sites are divided into exposure classifications of increasing severity based on the sulfate and magnesium content of the soil or groundwater. The soil is then classified as being natural or brownfield (sites that contain chemical wastes remaining from previous industrial use or from imported wastes). Further divisions by the pH and mobility of the groundwater complete the classification of the site. Unless proven otherwise, the groundwater should be classified as mobile. The resulting classification is known as the aggressive chemical environment for concrete class (ACEC class) (see Table 1). In some cases, also see Table 1, the designer should also be given the design sulfate class (DS class) as this has implications for the concrete specification.

A summary of the ground classification is given in Table 1. More detailed guidance is given in BRE Special Digest 1.

ASSESSMENT OF MEASURES REQUIRED FOR IN-SITU CONCRETE

Using the procedures and techniques described in BRE Special Digest 1: *Concrete in aggressive ground, Part 1. Assessing the aggressive chemical environment* determine the following:

- sulfate and magnesium content of the ground;
- pH of the groundwater;
- mobility of the groundwater;
- whether the site contains natural soil or is a brownfield site;
- if a brownfield site, concentrations of other materials aggressive to concrete.

With this information, enter the left hand side of Table 1 and select the appropriate design sulfate class (DS class). Select the type of ground conditions (natural or brownfield), then the mobility of the ground water (static or mobile) and finally the row with the appropriate acidity (pH). The right hand column of this row will give the aggressive chemical environment for concrete class (ACEC class) and, where it is necessary to pass this information to the designer, the design sulfate class (DS class)

For the structure to be built, select:

- structural performance level from Table 2;
- section thickness from the preliminary design.

and determine whether the element will be subjected to a hydrostatic head of groundwater greater than five times the section thickness.

Enter Table 3 on the appropriate ACEC class row and select the column for the appropriate structural performance level and section width to give the cell containing the basic design chemical class of the concrete and the recommended number of additional protective measures (APMs). Read all the Notes carefully as they indicate what additional conditions apply.

Where the design chemical class is DC-3, DC-4 or DC-4m, the number of APMs may be reduced (see Notes 1 and 2 to Table 3), if an enhanced concrete quality and Range B or C aggregates are specified by using the appropriate starred or double starred design chemical classes (see Notes 1 and 2 to Table 3). Before using this option, check that Range B or C aggregates are economically available. It should be noted that these options do not apply to the DC-3z and DC-4z classes.

An example procedure is given on page 5.

Table 1: Classification of the ground conditions

Sulfate and magnesium					Design sulfate class	Natural soil		Brownfield [3]		ACEC class
2:1 water/ soil extract		Groundwater		Total potential sulfate [2]		Static water	Mobile water	Static water	Mobile water	
SO_4 g/l	Mg g/l	SO_4 g/l	Mg g/l	SO_4 %		pH	pH	pH [4]	pH [4]	
< 1.2		< 0.4		< 0.24	**= DS-1**	All values		All values		AC-1s
							> 5.5		> 6.5	AC-1
							≤ 5.5		5.6 - 6.5	AC-2z
									4.5 - 5.5	AC-3z
									< 4.5	AC-4z
1.2 - 2.3		0.4 - 1.4		0.24 - 0.6	**= DS-2**	> 3.5		> 5.5		AC-1s(DS-2)
							> 5.5		> 6.5	AC-2
						≤ 3.5		≤ 5.5		AC-2s
							≤ 5.5		5.6 - 6.5	AC-3z(DS-2)
									4.5 - 5.5	AC-4z(DS-2)
									<4.5	AC-5z
2.4-3.7		1.5-3.0		0.7-1.2	**= DS-3**	> 3.5		> 5.5		AC-2s
							> 5.5		> 6.5	AC-3
						≤ 3.5		≤ 5.5		AC-3s
							≤ 5.5		5.6 - 6.5	AC-4
									< 5.5	AC-5
3.8 - 6.7	≤ 1.2	3.1 - 6.0	≤ 1.0	1.3 - 2.4	**= DS-4**	> 3.5		> 5.5		AC-3s
							> 5.5		> 6.5	AC-4
						≤ 3.5		≤ 5.5		AC-4s
							≤ 5.5		≤ 6.5	AC-5
3.8 - 6.7	> 1.2[1]	3.1 - 6.0	> 1.0[1]	1.3 - 2.4	**= DS-4m**	> 3.5		> 5.5		AC-3s
							> 5.5		> 6.5	AC-4m
						≤ 3.5		≤ 5.5		AC-4ms
							≤ 5.5		≤ 6.5	AC-5m
> 6.7	≤ 1.2	> 6.0	≤ 1.0	> 2.4	**= DS-5**	> 3.5		> 5.5		AC-4s
						≤ 3.5	All values	≤ 5.5	All values	AC-5
> 6.7	>1.2 [1]	>6.0	>1.0 [1]	>2.4	**= DS-5m**	>3.5		> 5.5		AC-4ms
						≤3.5	All values	≤ 5.5	All values	AC-5m

Notes

[1] The limit on water-soluble magnesium does not apply to brackish groundwater (chloride content between 12 g/l and 18 g/l). This allows these sites to be classified in the row above.

[2] Applies only to sites where concrete will be exposed to sulfate ions (SO_4) which may result from the oxidation of sulfides such as pyrite, following ground disturbance.

[3] 'Brownfield' is defined as sites that may contain chemical wastes remaining from previous industrial use or from imported wastes.

[4] An additional account is taken of hydrochloric and nitric acids by adjustment to sulfate content - see BRE Special Digest 1: Part 1.

Table 2: Guidance on the selection of the structural performance level

Structural performance level	Typical attributes/uses
Low	Short service life structures, < 30 years; Unreinforced concrete Non-critical structural details Temporary structures Long service life structures, but with associated low stress levels eg. house foundations (unreinforced).
Normal	Intermediate service life (30 to 100 years) Not falling in either high or low category.
High	Long service life structures > 100 years eg. transport structure foundations Vulnerable critical details such as slender structural elements, hinges, joints etc Structures retaining hazardous materials.

Example of procedure

For an aggressive chemical environment for concrete class of AC-3; with a structural section width of over 450 mm required for a high structural performance; where the hydrostatic head is less than five times the section thickness.

*From Table 3, the recommendation is DC-2/3. No increase for hydrostatic head is necessary. Apply APM – enhanced concrete quality (from Table 4) – once to give DC-3/2. As the local aggregates are range C, apply Note 2 to Table 3 to give DC-3** with no APMs. Specify to the concrete producer DC-3** as part of a designed concrete specification or, if using a designated concrete, specify FND3** (Table 5).*

However, if the local aggregates were range B, an option would be to apply APM1 again and apply Note 1 of Table 2 to give DC-4 with no APMs. In this case specify DC-4* as part of a designed concrete specification or FND4* as part of a designated concrete specification.*

Where the section will be subjected to a hydrostatic head of groundwater greater than five times the section thickness, consider the practicality of installing drainage to avoid this pressure (APM5 in Table 4). If this is not practical, either increase the concrete quality given in Table 3 by one design chemical class (APM1 in Table 4) or apply surface protection (APM3 in Table 4).

For concrete ground floors and concrete oversite to domestic buildings, the guidance given in Table 3 may be relaxed. Provided a damp proof membrane is placed below the slab to provide a barrier to the aggressive chemicals from the soil or hardcore, the concrete quality need only satisfy structural requirements i.e. it is not required to have sulfate resistance. See Part 3 of BRE Special Digest 1 for further information.

SPECIFICATION

As the requirements to resist aggressive chemicals do not include a strength class (see BS 8500), the concrete could be specified as a prescribed concrete provided that structural strength is of no real concern. In practice, strength is likely to be a consideration and therefore the concrete should be specified as either a designed concrete or a designated concrete.

Table 5 may be used to convert the required modified design chemical class to an equivalent designated concrete. Strength is a required specification parameter with both of these methods of specification. For designed concrete, the selection and specification of a suitable strength class should be based upon structural or other considerations. All FND designated concretes have an associated minimum strength class requirement of C28/35. This should be adequate for most applications. Where it is not, a designed concrete should be specified.

Table 3: Selection of the design chemical class and the number of additional protective measures

Design chemical class / number of additional protective measures [1] [2]								
	Low structural performance level			**Normal structural performance level**			**High structural performance level**	
Section width, mm	≤ 140	> 140 – 450	> 450 [3]	≤ 140 [4]	> 140 - 450	> 450 [3]	>140 – 450 [5]	> 450 [3]
ACEC class	**Applies where the hydrostatic head of groundwater is ≤ 5 times the section thickness [6]**							
AC-1s	DC-2/ 0	DC-1/ 0	DC-1/ 0	DC-2/ 0	DC-1/ 0	DC-1/ 0	DC-1/ 0	DC-1/ 0
AC-1s (DS-2)	DC-2/ 0 [7]	DC-1/ 0	DC-1/ 0	DC-2/ 0 [7]	DC-1/ 0	DC-1/ 0	DC-1/ 0	DC-1/ 0
AC-1	DC-2/ 0	DC-1/ 0	DC-1/ 0	DC-2/ 0	DC-1/ 0	DC-1/ 0	DC-1/ 0	DC-1/ 0
AC-2s	DC-3/ 0	DC-2/ 0	DC-1/ 0	DC-3/ 0	DC-2/ 0	DC-1/ 0	DC-2/ 0	DC-1/ 0
AC-2z	DC-3z/ 0	DC-2z/ 0	DC-1/ 0	DC-3z/ 0	DC-2z/ 0	DC-1/ 0	DC-2z/ 0	DC-1/ 0
AC-2	DC-3/ 0	DC-2/ 0	DC-1/ 0	DC-3/ 0	DC-2/ 0	DC-1/ 0	DC-2/ 0	DC-1/ 0
AC-3s	DC-4/ 0	DC-3/ 0	DC-2/ 0	DC-4/ 0	DC-3/ 0	DC-2/ 0	DC-3/ 0	DC-2/ 0
AC-3z	DC-4z/ 0	DC-3z/ 0	DC-2z/ 0	DC-4z/ 0	DC-3z/ 0	DC-2z/ 0	DC-3z/ 0	DC-2z/ 0
AC-3z (DS-2)	DC-4z/ 0 [7]	DC-3z/ 0 [7]	DC-2z/ 0 [7]	DC-4z/ 0 [7]	DC-3z/ 0 [7]	DC-2z/ 0 [7]	DC-3z/ 0 [7]	DC-2z/ 0 [7]
AC-3	DC-3/ 2	DC-3/ 1	DC-2/ 1	DC-3/ 3	DC-3/ 2	DC-2/ 2	DC-3/ 3	DC-2/ 3
AC-4s	DC-4/ 0	DC-4/ 0	DC-3/ 0	DC-4/ 0	DC-4/ 0	DC-3/ 0	DC-4/ 0	DC-3/ 0
AC-4z	DC-4z/ 1 [8]	DC-4z/ 0	DC-3z/ 0	DC-4z/ 1 [8]	DC-4z/ 0	DC-3z/ 0	DC-4z/ 0	DC-3z/ 0
AC-4z (DS-2)	DC-4z/ 1 [7][8]	DC-4z/ 0 [7]	DC-3z/ 0 [7]	DC-4z/1[7] [8]	DC-4z/ 0 [7]	DC-3z/ 0 [7]	DC-4z/ 0[7]	DC-3z/ 0[7]
AC-4	DC-4/ 2 [9]	DC-4/ 1	DC-3/ 1	DC-4/ 3	DC-4/ 2	DC-3/ 2	DC-4/ 3	DC-3/ 3
AC-4ms	DC-4m/ 0	DC-4m/ 0	DC-3/ 0	DC-4m/ 0	DC-4m/ 0	DC-3/ 0	DC-4m/ 0	DC-3/ 0
AC-4m	DC-4m/ 2 [9]	DC-4m/ 1	DC-4m/ 0	DC-4m/ 3	DC-4m/ 2	DC-4m/ 1	DC-4m/ 3	DC-4m/ 2
AC-5z	DC-4z/1 [7] [8]	DC-4z/1 [7] [8]	DC-3z/1 [7][8]	DC-4z/1 [7] [8]	DC-4z/ 1 [7] [8]	DC-3z/ 1 7] [8]	DC-4z/ 1 [7] [8]	DC-4z/ 1 [7] [8]
AC-5	DC- 4/ 1 [8]	DC- 4/ 1 [8]	DC-3/ 1 [8]	DC- 4/ 3 [10]	DC- 4/ 2 [10]	DC-3/ 2 [10]	DC- 4**/ 1 [8]	DC-3**/ 1 [8]
AC-5m	DC-4m/ 1 [8]	DC-4m/ 1 [8]	DC-4m/ 1 [8]	DC-4m/ 3 [10]	DC-4m/ 2 [10]	DC-4m/ 1 [8]	DC-4m**/ 1 [8]	DC-4m**/ 1 [8]

For notes, see page 7

Notes

[1] Where DC-3, DC-4 or DC-4m is given, the number of APMs may be reduced by 1 provided DC-3*, DC-4* or DC-4m*, as appropriate, is specified and that the reduction in APMs does not override the recommendation to use or include APM3. If, in addition, the concrete quality is to be enhanced as a result of the application of APM1, the step in concrete quality is to the next higher * class e.g. DC-3* becomes DC-4*.

[2] Where DC-3, DC-4 or DC-4m is given, the number of APMs may be reduced by 2 provided DC-3**, DC-4** or DC-4m**, as appropriate, is specified and that the reduction in APMs does not override the recommendation to use or include APM3. If, in addition, the concrete quality is to be enhanced as a result of the application of APM1, the step in concrete quality is to the next higher ** class e.g. DC-3** becomes DC-4**.

[3] Where any surface attack is not acceptable e.g. with friction piles, use the requirements given in the 140 – 450 mm column.

[4] Try to avoid these section widths.

[5] Section thickness of less than 140 mm is not recommended.

[6] Where the hydrostatic head of groundwater is greater than 5 times the section thickness this should preferably be eliminated by the application of APM5. If this is not practical, apply either APM1 or APM3.

[7] Excluding Portland-limestone cement and equivalent combinations.

[8] Only APM3 recommended (not applicable to bored piles).

[9] If APM3 is selected, no further APMs are necessary.

[10] To include APM3, where practicable, as one of the APMs.

To ensure best value, the contract specification should contain:

- strength class of the concrete;
- basic design chemical class;
- number of additional protective measures;
- any specific conditions that apply.

The contractor will consider the various options, select the most appropriate APMs and specify the modified design chemical class to the concrete producer.

If using a **designed** concrete, specify to the concrete producer:

- strength class;
- design chemical class (including, if appropriate, the starred class);
- maximum nominal upper aggregate size;
- chloride class;
- consistence class;
- any additional requirements.

If using a **designated** concrete, specify to the concrete producer:

- appropriate designated concrete, see Table 5;
- maximum nominal upper aggregate size when other than 20 (or 22.4) mm;
- consistence class;
- any permitted additional requirements or relaxation of the requirements.

In both cases, the specifier should inform the producer of the intended method of placing and finishing the concrete.

CONCRETE COMPOSITION AND PROPERTIES

For concrete intended for use in aggressive chemical environments, the requirements for concrete composition and properties are given in BS 8500–2 for designed concrete and designated concretes. The concrete will be durable only if it is placed, compacted and cured in accordance with BSI document DD ENV 13670–1, *Execution of concrete structures. Part 1: Common rules*.

As part of the procedure for avoiding the thaumasite form of sulfate attack, the combined aggregate is classified according to its 'calcium carbonate equivalent' content into range A (high), B (medium) or C (low). The requirements given in BS 8500–2 are linked to the classification of the aggregate carbonate range of the combined aggregates.

Guidance on the method for classifying aggregates by their aggregate carbonate range is given in Part 2 of BRE Special Digest 1 and the national annex to BS EN 12620, *Aggregates for concrete*.

ADDITIONAL PROTECTION MEASURES

Table 4: Additional protective measures (APMs)

Code	Additional protective measure
APM1	Enhanced concrete quality
APM2	Use of controlled permeability formwork
APM3	Provide surface protection
APM4	Provide sacrificial layer
APM5	Address drainage of site

In some exposure conditions and for certain structural performance levels, the base level concrete quality (see Table 2) may be insufficient on its own to provide adequate resistance. In these situations, one or more additional protective measures (APMs) are needed. For practical reasons, all the APMs have been treated as being equally effective. However, as shown in Table 3, there are situations where particular APMs are recommended. Although it is not listed as an APM, re-designing the section thickness to the next band in Table 2 will often reduce the required APMs by 1.

In addition, there are a few highly aggressive situations where aggregate carbonate range C is recommended, see Table 3. Where this recommendation is to be followed, it would be prudent to consider at an early stage the availability of range C aggregate combinations. Where this combination of aggregate is not normally stocked by the concrete producer, advanced notice is needed to enable them to source supplies and develop mix designs.

APM1: Enhanced concrete quality

The requirements for concrete quality are transmitted to the producer by citing a design chemical class. The higher the design chemical class, the higher is the concrete quality. The producer then refers to BS 8500–2 to select the specified requirements in terms of maximum water/cement ratio, cement/combination type etc.

APM1 is an increase in concrete quality (expressed as an increase in the design chemical class) above that shown in Table 2. The design chemical class is increased by 1.

Table 5: Selection of a designated concrete from the design chemical class

Design chemical class [1]	Designated concrete [2]
Fully buried foundations without embedded metal requiring design chemical class DC-1 concrete	GEN1
Fully buried reinforced foundations requiring design chemical class DC-1 concrete	RC30
Plain and reinforced foundations requiring design chemical class DC-2 concrete	FND2
Plain and reinforced foundations requiring design chemical class DC-2z concrete	FND2Z
Plain and reinforced foundations requiring design chemical class DC-3 concrete	FND3
Plain and reinforced foundations requiring design chemical class DC-3* concrete	FND3*
Plain and reinforced foundations requiring design chemical class DC-3** concrete	FND3**
Plain and reinforced foundations requiring design chemical class DC-3z concrete	FND3Z
Plain and reinforced foundations requiring design chemical class DC-4 concrete	FND4
Plain and reinforced foundations requiring design chemical class DC-4* concrete	FND4*
Plain and reinforced foundations requiring design chemical class DC-4** concrete	FND4**
Plain and reinforced foundations requiring design chemical class DC-4z concrete	FND4Z
Plain and reinforced foundations requiring design chemical class DC-4m concrete	FND4M
Plain and reinforced foundations requiring design chemical class DC-4m* concrete	FND4M*
Plain and reinforced foundations requiring design chemical class DC-4m** concrete	FND4M**

Notes

[1] Including any modification as the result of applying APM1.

[2] All the FND designated concrete are required to have a minimum strength class of C28/35.

For example:

DC-3 becomes DC-4;

DC-2Z becomes DC-3Z;

DC-3* becomes DC-4*;

DC-3** becomes DC-4**.

This is not an option where the design chemical class in Table 2 is 4 or 4M as these are the highest concrete qualities given.

APM2: Use of controlled permeability formwork (CPF)

Controlled permeability formwork increases the quality of concrete in the surface zone by reducing its water/cement ratio. This provides the additional resistance to chemical attack. The recommendations of the CPF manufacturer should be followed.

APM3: Surface protection

The surface of the concrete can be protected by using either a coating or a waterproof barrier. Common coatings include rubberised bitumen emulsions, bituminous sheet membranes and polymeric-based systems such as epoxy resins. For waterproofing, any of the systems that are resistant to sulfates, any other deleterious chemicals that are present and the level of acidity, will be suitable.

APM4: Sacrificial layer

This involves providing an additional layer of concrete that will absorb all the aggressive chemicals. It is additional to the nominal cover to reinforcement i.e. additional to the minimum cover plus the margin for site workmanship. This is not a viable option where the concrete surface must remain sound to prevent loss of frictional resistance e.g. friction piles. Where the intended working life is at least 120 years, a sacrificial layer of 50 mm is recommended.

APM5: Addressing site drainage

This involves the control of site drainage to minimise contact between the aggressive groundwater and the concrete. Examples are the provision of cut-off barriers or cut-off drains. Any drains will need to be maintained. Consideration should also be given to the possibility that the provision of services to the structure may provide routes by which aggressive chemicals can reach the concrete.

SPECIAL CASES

To determine the concrete quality needed for special conditions, precast concrete elements and concrete masonry, see BRE Special Digest 1.

The specifier may need to refer to other publications to define the requirements for concrete in other conditions. These conditions include:

- Conditions outside the limits of Table 1. No guidance is given in BS 8500–1 for exposure classifications that exceed these limits. In such cases, surface protection should be provided; otherwise specialist advice should be sought. See also BS 8102, *Code of practice for protection of structures against water from the ground*.
- The presence of other aggressive chemicals or media. Examples are:
  i) Milk (lactic acid), silage and slurry. Refer to BS 5502–21, *Buildings and structures for agriculture. Part 21: Code of practice for selection and use of construction materials.*
  ii) Acid spillage in industrial processes. Refer to specialist producers of acid-resistant finishes and to BS 8204–2, *Screeds, bases and in-situ floorings*. Part 2: *Concrete wearing surfaces – Code of Practice*
  iii) Ammonium sulfate. Refer to Part 1 of BRE Special Digest 1.
- Flowing water in combination with aggressive carbon dioxide. Refer to Part 1 of BRE Special Digest 1.
- Seawater. Refer to BS 8500–1 and BS 6349–1, Code of practice for maritime structures. Part 1: General criteria.

FURTHER READING

The other publications from this series will be helpful. Visit www.cementindustry.co.uk and click ‘information’/‘library’/‘BCA publications’ to check availability and for free download

Standards for fresh concrete – a composite of BS EN 206-1 and BS 8500

Specifying concrete to BS EN 206–1/BS 8500:
- *Concrete for normal uses*
- *Concrete resistant to chemical attack*
- *Guide to the selection of concrete quality and cover for reinforcement for normal concrete structures*

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