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**Agrément
Certificate
No 96/3232**
*Third issue**

Designated by Government
to issue
European Technical
Approvals

DCI AND DCI-S CORROSION INHIBITORS

Inhibiteurs de corrosion

Korrosionshemmstoff

Product



Jamestown Bridge, Jamestown, Rhode Island, USA

• THIS CERTIFICATE RELATES TO DCI AND DCI-S, CALCIUM NITRITE BASED CORROSION INHIBITORS FOR REINFORCED CONCRETE, TO PROVIDE INCREASED PROTECTION AGAINST REINFORCEMENT CORROSION.

• The products are for use in reinforced and prestressed concrete with a free water/cement ratio of 0.45 or lower, and have no known detrimental effects on the properties of the cured concrete.

• The products are for use in reinforced concrete structures, designed in accordance with BS 5400-4 : 1990, BS 8007 : 1987 or BS 8110-1 : 1997. They have particular application in severe or very severe exposure conditions (as defined in BS 5400-4 : 1990, Table 13 or BS 8110-1 : 1997, Table 3.2) such as in marine installations, chemical works, power plants, docks and harbour works, and bridges.

• They are also for use in structures subject to de-icing salts, such as multi-storey car parks.

Regulations

1 The Building Regulations 2000 (as amended) (England and Wales)



In the opinion of the BBA, the use of the products is not subject to these Regulations.

2 The Building (Scotland) Regulations 2004



In the opinion of the BBA, the use of the products is not subject to these Regulations.

3 The Building Regulations (Northern Ireland) 2000



In the opinion of the BBA, the use of the products is not subject to these Regulations.

4 Construction (Design and Management) Regulations 1994 (as amended) Construction (Design and Management) Regulations (Northern Ireland) 1995 (as amended)

Information in this Certificate may assist the client, planning supervisor, designer and contractors to address their obligations under these Regulations.

See sections:

7 Delivery and site handling (7.4 and 7.5)

5 Description

5.1 DCI and DCI-S Corrosion Inhibitors are aqueous solutions of calcium nitrite (minimum 30.2% calcium nitrite), with residual calcium nitrate (up to a maximum of 3%). DCI-S contains, additionally, a calcium naphthalene sulphonate formaldehyde copolymer superplasticiser and a hydroxycarboxylic acid salt retarder to offset the acceleration of set normal with calcium nitrite corrosion inhibitors.

5.2 The products have physical characteristics of:
specific gravity (20°C) 1.275 to 1.320

pH (concentrate)	10 ±1
appearance	DCI light yellow clear liquid DCI-S light brown clear liquid
flammability	non-flammable
odour	no significant odour

6 Manufacture and quality control

The products are manufactured in a batch blending process. Quality control is exercised over raw materials, during manufacture and on the finished product.

7 Delivery and site handling

7.1 The products are supplied in 208 litre drums, 1000 litre transitanks or in bulk. Each container has a label bearing the BBA identification mark, hazard warning, first aid, and discharge and disposal instructions.

7.2 The products have a shelf-life of 12 months and should be stored in a secure area at temperatures above -15°C.

7.3 Calcium nitrite is included in the European Inventory of Existing Chemicals, EINECS No 237-424-2. For shipment and storage, R22 classification is appropriate.

7.4 The products are classified Harmful if swallowed, under the Chemicals (Hazard, Information and Packaging for Supply) Regulations 2002 (CHIP3). Precautions are necessary during handling and use, to minimise contact from spillage or leakage. The normal precautions (use of goggles or visor, gloves, protective clothing and prompt removal of contaminated clothing) should be strictly observed during handling and use. If fluid comes into contact with skin it must be washed off promptly. If it comes into contact with the eyes they should be flushed with cold water for 15 minutes, and medical attention sought.

7.5 Small spillages should be diluted with water and flushed to waste. Large spillages should be absorbed by an inert material and transferred to containers for landfill disposal in accordance with local waste-disposal regulations.

8 General

8.1 DCI and DCI-S Corrosion Inhibitors are satisfactory for use in concrete mixes (with a maximum free water/cement ratio of up to 0.45), to provide increased protection to steel reinforcement and pre-stressed tendons against chloride-induced corrosion.

8.2 The products have particular application, where steel would be at risk of chloride-induced corrosion, in severe or very severe corrosion conditions (as defined in Table 13 of BS 5400-4 : 1990 or in Table 3.2 of BS 8110-1 : 1997), such as in marine installations, chemical works, power plants, dock and harbour works, bridges, and multi-storey car parks, where chlorides from the sea or from de-icing salts are present. They may be used also as a precaution to resist corrosion from contamination by chlorides present on reinforcing bars or unintentionally in concrete mix materials.

8.3 The structure should be designed in accordance with BS 5400-4 : 1990, BS 8007 : 1987 or BS 8110-1 : 1997, using the appropriate dosage rate depending on the chloride exposure conditions (see Table 1).

Table 1 Addition rates

DCI/DCI-S (l m ⁻³)	Chloride level ⁽¹⁾ (kg m ⁻³)
10	3.6
15	5.9
20	7.7
25	8.9
30	9.5

(1) Calculated level at reinforcing bars.

8.4 The products may be used where sulphates are present, but a sulphate-resistant concrete mix will be necessary to avoid sulphate attack on the concrete.

9 Mix design

9.1 The products have been assessed for use in concrete mixes with a maximum free water/cement ratio of 0.45.

9.2 Test results indicate that the products are compatible with all cements complying with BS EN 197-1 : 2000 and BS 8500-1 : 2002 including pozzolanic blends of Portland cements with pulverized-fuel ash, ground granulated blast-furnace slag or silica fume, blended at the mixer.

9.3 Advice on specification (including use with other liquid admixtures) is available from Grace Construction Products Ltd.

10 Fresh concrete properties

10.1 Test results indicate that the workability of concrete mixes with the products is similar to that of a control concrete.

10.2 Test results indicate that the presence of the products decreases the air content of concrete mixes, and a moderate increase in dosage rate of air entraining agent may be required to attain the specified air content.

11 Stiffening times

11.1 Penetration-resistance measurements conducted in accordance with BS 5075-1 : 1982 show that the presence of the products in the concrete mix decreases the initial and final set times.

11.2 The slight reduction in the initial and final setting times should be considered when scheduling concrete construction operations, especially the mixing, placing, compaction and presence of cold joints.

12 Water absorption

Results of Initial Surface Absorption Tests (ISAT), conducted in accordance with BS 1881-5 : 1970, indicate that the presence of the products does not affect the water absorption characteristics of concrete.

13 Strength characteristics

13.1 Results of compressive strength cube tests conducted in accordance with BS 1881-116 : 1983, after 28 days and after heat ageing, indicate that the presence of the products has no significant effect on the concrete's compressive strength.

13.2 The products have no significant effect on the flexural strength of concrete and all normal reinforcement is still required as for conventional concrete.

13.3 Results of steel to concrete bond strength tests indicated a 13% increase in bond strength.

14 Resistance to leaching

14.1 Results of test data and visits to inspected sites show no evidence of the products leaching out from within the concrete.

14.2 The products have not been assessed for use in potable water systems.

15 Durability

15.1 The use of calcium-nitrite-based corrosion inhibitors has been studied since the early 1970s, and DCI Corrosion Inhibitor has been used in reinforced concrete structures in the USA since 1980. Visits to these early applications confirmed that there were no visible signs of corrosion in the structures, and that they are continuing to perform satisfactorily.

15.2 Test data confirm that the use of the products has no adverse effects on the fresh and hardened properties of concrete.

15.3 When chlorides are present (see section 8.2) the life of a reinforced concrete structure is determined by the corrosion which takes place at the reinforcement. The use of the products in these situations provides increased corrosion protection to the reinforcement and extends the life of the structure.

Installation

16 General

When installing DCI and DCI-S Corrosion Inhibitors, basic workmanship should comply with the relevant requirements of BS 8000-2.1 : 1990 and BS 8000-2.2 : 1990.

17 Mixing

The products are added to conventional concrete mixes with the mix water, at the appropriate dosage rate (see section 8.3 and Table 1).

18 Placing

18.1 Concrete mixes containing the products can be transported by normal conveying methods.

18.2 Special precautions are not necessary when pouring into moulds or shutters.

18.3 Concrete mixes containing the products may be vibrated by conventional means to provide full compaction.

18.4 Where concrete containing the products is delivered by a supplier of ready mixed concrete, DCI or DCI-S should be clearly marked on the delivery ticket, together with the actual addition rate in lm^{-3} .

19 Curing

It is essential that all normal good curing procedures for conventional concrete in accordance with BS 8110-1 : 1997 are strictly followed.

20 Finishing

Placed concrete mixes may be floated and trowelled using all normal hand or power tools.

21 Miscellaneous

The presence of the products in the fresh concrete mix can be verified by use of the Hach Test⁽¹⁾.

- (1) Components for this test are available from Grace Construction Products Ltd, as is an analytical test service to determine the amount of corrosion inhibitor present in fresh or hardened concrete.

Technical Investigations

The following is a summary of the technical investigations carried out on DCI and DCI-S Corrosion Inhibitors.

22 Tests

22.1 Tests carried out by the BBA to verify DCI-S concrete's early age properties were conducted using the mix design given in Table 2.

22.2 Results of the plastic and hardened concrete state tests conducted by the BBA are summarised in Tables 3 and 4.

22.3 The results of the characterisation tests conducted on the products are detailed in Table 5.

22.4 The Hach test was used to verify the presence of the calcium nitrite corrosion inhibitor in the fresh concrete mix detailed in Table 2 (see also section 20.1).

22.5 An examination was made of long-term data conducted by Grace Construction Products, USA (see Table 6).

22.6 An examination was made of test reports relating to the mechanism of protection and the selection of addition rate.

22.7 An examination was made of independent test data relating to the products' classification to ASTM C 494 and ASTM G 109.

Table 2 Mix design

Component	Quantity (kgm ⁻³)	
	DCI-S concrete	Control concrete
Cement (CAA reference)	400	400
20 mm aggregate (Thames Valley Flint, Kingsmead Quarry) ⁽¹⁾	705	705
10 mm aggregate (Thames Valley Flint, Kingsmead Quarry) ⁽¹⁾	470	470
Sand (Thames Valley Flint, Chertsey Quarry) ⁽¹⁾	630	630
DCI-S	19.5 ⁽²⁾	0
Free water (including that in DCI-S)	180	180

(1) Water absorption of total aggregate — 33 kgm⁻³.

(2) Equivalent to 15.0 l m⁻³.

Table 3 Plastic concrete state tests

Test (units)	Method	Results	
		DCI-S concrete	Control concrete
Air content (%)	BS 1881-106	0.50	0.84
Slump (mm)	BS 1881-102	90	70
Density (kgm ⁻³)	BS 1881-107	2355	2350
Setting time (resistance to penetration)	BS 5075-1	4 hrs 30 mins	5 hrs 18 mins

Table 4 Hardened concrete state tests

Test (units)	Method	Conditions	Results	
			DCI-S concrete	Control concrete
Initial surface absorption (ISAT) (mm ⁻² s ⁻¹)	BS 1881-5	10 mins	0.32	0.32
		30 mins	0.22	0.21
		1 hr	0.16	0.17
		2 hrs	0.13	0.14
Compressive strength (Nmm ⁻²) — equivalent cube method	BS 1881-116	28 days water cure	56.5	56.6
		28 days water cure	} 48.5	49.5
		28 days at 60°C		
		24 hrs water soak		
Flexural strength (Nmm ⁻²)	BS 1881-118	28 days	4.40	4.72
Bond strength to steel (N)	BBA test specification	28 days	6750	5950

Table 5 Characterisation tests

Test	Method	Results
		DCI and DCI-S
Colour	BBA test specification	DCI-light yellow clear liquid DCI-S light brown clear liquid
Odour	BBA test specification	Insignificant
Specific gravity	BS 3900-A12	1.30

Table 6 Summary of long-term test data

Test	Comments
Compatibility	Compatible with all common cement type silica fume, slag cement and pulverized-fuel ash.
Reinforcement compatibility	Compatible with plain, galvanized and epoxy-coated steel with no loss of bond strength.
Use with chloride accelerators	Protects steel in the presence of chlorides.
Effectiveness in marine environments (ASTM G 109)	After one year control samples showed significant signs of corrosion, whilst DCI/DCI-S concrete showed no signs of corrosion.
Nitrite stability and leaching	Field analysis of sites 18 years old indicate that calcium nitrite is still stable in the concrete with no decrease in concentration.
Cyclic polarisation (ASTM G 61)	Test results indicate that the presence of calcium nitrite significantly increases the pitting potential of concrete. (Note: a higher pitting potential indicates an increased corrosion resistance).
Concrete crack testing Field testing Concrete quality testing Large-scale slab testing	The results of these tests indicate that the presence of calcium nitrite does not have a detrimental effect on the properties of the cured concrete.
Modulus of elasticity	

23 Investigations

23.1 The manufacturing process was examined, including the methods adopted for quality control and composition of the materials used.

23.2 A visit was made to Grace Construction Products research facilities in Cambridge, USA, to verify the quality of test data listed in section 22.5.

23.3 An examination was made of the products' approval in the USA by:

- Federal Highways Administration
- Corps of Engineers
- US Navy
- State Departments of Transport.

23.4 Visits were made to sites in progress and existing sites in the USA to assess DCI/DCI-S concrete's ease of use, practicability of installation, and performance in service (see Table 7).

23.5 Assessment was made of the products' scope of use and durability.

23.6 User surveys of specifiers, engineers and contractors in the USA and the Middle East were conducted to establish the products' performance in use and in service.

23.7 A literature search was conducted to investigate the use of calcium nitrite in reinforced concrete.

Table 7 Details of visits⁽¹⁾ to sites in progress and existing sites

Site details	Comments
Beverley — Salem Bridge, Massachusetts, USA	Cast in-situ reinforced concrete, bridge over salt water. DCI dosage rate of 10 lm^{-3} , w/c ratio ⁽²⁾ 0.40, in conjunction with epoxy-coated reinforcing bars.
Green Airport, Rhode Island, USA	Cast in situ reinforced concrete roadway. DCI dosage rate of 20 lm^{-3} , w/c ratio 0.40, both on uncoated and epoxy-coated reinforcing bars.
East Boston Pier 4, Massachusetts, USA	Pier and waterfront project, both precast and cast in-situ units. DCI dosage rate of 15 lm^{-3} , w/c ratios 0.38 (precast), 0.42 and 0.44 (in situ).
Lafayette Place Garage, Boston, Massachusetts, USA	Underground car park, cast in-situ prestressed concrete, 1983. DCI dosage rate 18 lm^{-3} . No evidence of reinforcement corrosion, although concrete cracked due to other influences.
Boston Common Garage, Massachusetts, USA	Refurbishment underground garage project, 1994.
Black Falcon Terminal, Boston, Massachusetts, USA	Refurbishment of quayside docks, cast in-situ concrete, 1995. DCI-S dosage rate 25 lm^{-3} . 0.40 w/c ratio.
Marine Industrial Park Parking, Boston, Massachusetts, USA	Multi-storey car park. Precast concrete with DCI, 1993.
Portsmouth Naval Hospital, Virginia, USA	Multi-storey car park, 1992. Cast in-situ/post-tensioned. DCI-S dosage rate 15 lm^{-3} . 0.40 w/c ratio.
Main Street Garage, Norfolk, Virginia, USA	Multi-storey car park 1991. Cast in-situ/post-tensioned concrete. DCI-S dosage rate 15 lm^{-3} . 0.40 w/c ratio.
City Hall Avenue Parking, Norfolk, Virginia, USA	Multi-storey car park 1992. Cast in-situ concrete. DCI-S dosage rate 15 lm^{-3} . 0.40 w/c ratio.
Old Dominion University Norfolk, Virginia, USA	Multi-storey car park 1993. Cast in-situ. DCI-S dosage rates 10 lm^{-3} and 15 lm^{-3} .

(1) September 1995.

(2) Water/cement ratio.

Bibliography

BS 1881-5 : 1970 *Testing concrete — Methods of testing hardened concrete for other than strength*
BS 1881-102 : 1983 *Testing concrete — Methods for determination of slump*
BS 1881-106 : 1983 *Testing concrete — Methods for determination of air content of fresh concrete*
BS 1881-107 : 1983 *Testing concrete — Method for determination of density of compacted fresh concrete*
BS 1881-116 : 1983 *Testing concrete — Method for determination of compressive strength of concrete class*
BS 1881-118 : 1983 *Testing concrete — Method for determination of flexural strength*

BS 3900-A12 : 1975 *Methods of test for paints — Tests on liquid paints — Determination of density*

BS 5075-1 : 1982 *Concrete admixtures — Specification for accelerating and retarding water reducing admixtures*

BS 5400-4 : 1990 *Steel, concrete and composite bridges — Code of practice for design of concrete bridges*

BS 8000-2.1 : 1990 *Workmanship on building sites — Code of practice for concrete work — Mixing and transporting concrete*
BS 8000-2.2 : 1990 *Workmanship on building sites — Code of practice for concrete work — Sitework with in-situ and precast concrete*

BS 8007 : 1987 *Code of practice for design of concrete structures for retaining aqueous liquids*

BS 8110-1 : 1997 *Structural use of concrete — Code of practice for design and construction*

BS 8500-1 : 2002 *Concrete — Complementary British Standard to BS EN 206-1 — Method of specifying and guidance for the specifier*

BS EN 197-1 : 2000 *Cement — Composition, specifications and conformity criteria for common cements*

ASTM C 494 *Chemical Admixtures for Concrete*

ASTM G 61 : 1986 *Test Method for Conducting Cyclic Potentiodynamic Polarization Measurements for Localised Corrosion Susceptibility of Iron- Nickel- or Cobalt-based Alloys*

ASTM G 109 : 1999 *Test Method for Determining the Effects of Chemical Admixtures on the Corrosion of Embedded Steel Reinforcement in Concrete Exposed to Chloride Environments*

Conditions of Certification

24 Conditions

24.1 This Certificate:

- (a) relates only to the product that is named, described, installed, used and maintained as set out in this Certificate;
- (b) is granted only to the company, firm or person identified on the front cover — no other company, firm or person may hold or claim any entitlement to this Certificate;
- (c) is valid only within the UK;
- (d) has to be read, considered and used as a whole document — it may be misleading and will be incomplete to be selective;
- (e) is copyright of the BBA;
- (f) is subject to English law.

24.2 References in this Certificate to any Act of Parliament, Regulation made thereunder, Directive or Regulation of the European Union, Statutory Instrument, Code of Practice, British Standard, manufacturers' instructions or similar publication, are references to such publication in the form in which it was current at the date of this Certificate.

24.3 This Certificate will remain valid for an unlimited period provided that the product and the manufacture and/or fabrication including all related and relevant processes thereof:

- (a) are maintained at or above the levels which have been assessed and found to be satisfactory by the BBA;

(b) continue to be checked as and when deemed appropriate by the BBA under arrangements that it will determine; and

(c) are reviewed by the BBA as and when it considers appropriate.

24.4 In granting this Certificate, the BBA is not responsible for:

- (a) the presence or absence of any patent, intellectual property or similar rights subsisting in the product or any other product;
- (b) the right of the Certificate holder to market, supply, install or maintain the product; and
- (c) the actual works in which the product is installed, used and maintained, including the nature, design, methods and workmanship of such works.

24.5 Any recommendations relating to the use or installation of this product which are contained or referred to in this Certificate are the minimum standards required to be met when the product is used. They do not purport in any way to restate the requirements of the Health & Safety at Work etc Act 1974, or of any other statutory, common law or other duty which may exist at the date of this Certificate or in the future; nor is conformity with such recommendations to be taken as satisfying the requirements of the 1974 Act or of any present or future statutory, common law or other duty of care. In granting this Certificate, the BBA does not accept responsibility to any person or body for any loss or damage, including personal injury, arising as a direct or indirect result of the installation and use of this product.



In the opinion of the British Board of Agrément, DCI and DCI-S Corrosion Inhibitors are fit for their intended use provided they are installed, used and maintained as set out in this Certificate. Certificate No 96/3232 is accordingly awarded to Grace Construction Products Ltd.

On behalf of the British Board of Agrément

Date of Third issue: 11th May 2006

A handwritten signature in black ink, appearing to read 'G. A. Cooper'.

Chief Executive

**Original Certificate issued 5th March 1996. The amended version includes change of address of the Certificate holder, revised Building Regulations and new Conditions of Certification.*

Electronic Copy

British Board of Agrément

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For technical or additional information, contact the Certificate holder (see front page).
For information about the Agrément Certificate, including validity and scope, tel: Hotline 01923 665400, or check the BBA website.