Concrete Society Technical Report No. 18

Guide to chemical admixtures for concrete

Report of a Joint Working Party

The Concrete Society
The Cement Admixtures Association

Members of the Working Party

P. M. Usher (Convenor)
Formerly CBP (Holdings) Ltd

J. G. Angles
FEB (Great Britain) Ltd

M. R. Rixom
Cormix Division, Joseph Crosfield & Sons Ltd

R. Ryle
RMC Technical Services Ltd

R. Kenny
John Laing Research & Development Ltd

Additional advice has been given by L. H. McCurrich
Fosroc Construction Chemicals Ltd

Concrete Society Technical Report No. 18

First published 1980

ISBN 0 7210 1193 4

Published by The Concrete Society
Devon House, 12-15 Dartmouth Street, London SW1H 9BL

Designed and printed by the Cement and Concrete Association
Wexham Springs, Slough SL3 6PL

Further copies may be obtained from:
Publications Distribution, Cement and Concrete Association
Wexham Springs, Slough SL3 6PL
quoting reference number 52.032

Concrete Society Technical Report No. 18
August 1980

Guide to chemical admixtures for concrete

Report of a Joint Working Party of
The Concrete Society
The Cement Admixtures Association

Summary

This report is a fully revised version of TRCS 1, *Admixtures for concrete,* which was first published in 1968. It is intended as a non-technical introduction and guide to admixtures for site engineers, consulting engineers, architects and ready-mix and precast personnel who are not necessarily materials specialists.

Contents

Classification and specification

Definition

An admixture is defined as a material, other than water, aggregate or Portland cement, which is added to a batch of concrete, mortar or grout during or immediately before mixing, in order to extend the properties of the concrete and/or make it more economical.

The term 'additive' is normally reserved for materials used by cement manufacturers to modify the properties of cement.

Although pozzolans, ground granulated slag and finely divided mineral powders fall within the above definition of admixtures they are generally treated separately and are not included in this publication.

Type of admixture	UK	USA	Germany
Accelerating	BS 5075: Part 1	ASTM C.494-C ASTM D.98 (Calcium chloride)	IB Type BE
Retarding	BS 5075: Part 1	ASTM C.494-B	IB Type VZ
Normal water-reducing	BS 5075: Part 1	ASTM C.494-A	IB Type BV
Accelerating water-reducing	BS 5075: Part 1	ASTM C.494-E	IB Type BE
Retarding water-reducing	BS 5075: Part 1	ASTM C.494-D	IB Type VZ
Air entraining	BS 5075: Part 2*	ASTM C.260 AASHO M.154 CRD-C 13	IB Type LP
Superplasticizers	BS 5075: Part 1	ASTM C.494-F & G	IB Type BV
Pigments	BS 1014		

* Not yet published
BS British Standards Institution
ASTM American Society for Testing & Materials
AASHTO American Association of State Highway Transport Officials
CRD US Army Engineer Waterways Experiment Station
IB Institut für Bautechnik

Classification and standards

Admixtures for concrete are commonly classified by function and the main types are covered by the standards listed above.

Uses

The properties of concrete which can be modified by the use of admixtures and the types of admixture used in each case are shown in the following table.

Throughout the guide the term 'setting' has been used to indicate the point at which hydration takes effect and early strength develops. It must not be confused with setting times in cement standards which are based on particular quality control test methods.

Desired property	Admixture type					
	Water reducer	Accelerator	Retarder	Super-plasticizer	AEA	Other special admixtures
Setting and hardening						
Accelerate rate of gain of early strength	**	*		*		
Accelerate set		*				
Retard set			*			
Workability and other plastic properties						
Increase workability without loss of strength	*			*		
Increase frost resistance during setting		*				
Reduce temperature rise	**		**	**		
Reduce bleeding					*	*
Reduce segregation					*	*
Improve pumpability	*			**	*	*
Hardened properties						
Increase final strength without increasing cement content or reducing workability	*			*		
Improve durability and freeze-thaw resistance	**			*	*	
Improve water-resistance	*			*	**	*
Alter colour						*
Improve bond						*

* Main application ** Secondary application

Specification

Most countries have regulations and standards governing the use of admixtures in concrete.

In the United Kingdom, CP 110, *The structural use of concrete,* and BS 5328, *Methods for specifying concrete,* require admixtures to conform to the appropriate British Standard or, where none exists, to be specified by type and/or proprietary brand.

CP 110 defines structural concrete which contains an admixture as 'special structural concrete' and as such requires that the use of the admixture should have prior approval of the Engineer.

Where suitable standards do not exist, the specifier should satisfy himself on the following points:

Long and short term effects of the admixture

Main chemical ingredients

Effects of over or under dosage

Chloride ion content

Whether the admixture entrains air

Storage life and special storage requirements

Safety handling precautions

Compatibility with cement types and other admixtures.

Sampling and testing

Testing of laboratory produced samples may be useful for mix design purposes or for checking uniformity of the admixture but, where the ongoing use of an admixture is likely to be substantial, testing of the concrete produced under normal site or works operating conditions is recommended.

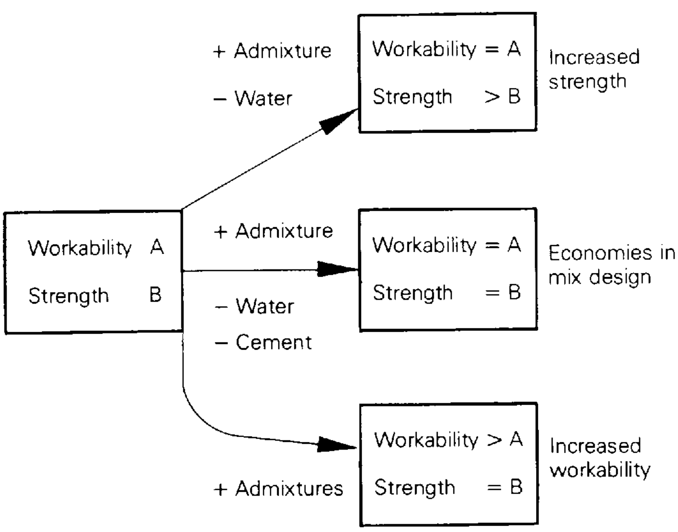
Acceptance and uniformity testing in the UK should be carried out in accordance with BS 5075.

Normal water-reducing admixtures

Description

Function

Water-reducing admixtures are water soluble organic materials which reduce the amount of water needed to achieve a given workability in plastic concrete without significantly affecting the air content or setting characteristics of the concrete. This effect can be utilized in three ways:



Materials

The principal chemicals are:

Salts of lignosulphonic acids

Salts of hydroxycarboxylic acids

Low molecular weight polysaccharides (hydroxylated polymers)

Mechanism

The water-reducing chemical is adsorbed on to the cement particles and thereby lowers the inter-particles attraction and produces a more uniform dispersion of cement grains. This reduces the amount of water needed to achieve a given paste viscosity.

Effects on properties of concrete

The effect of water-reducing admixtures is dependent on

Dosage

Cement type

Aggregate type and grading

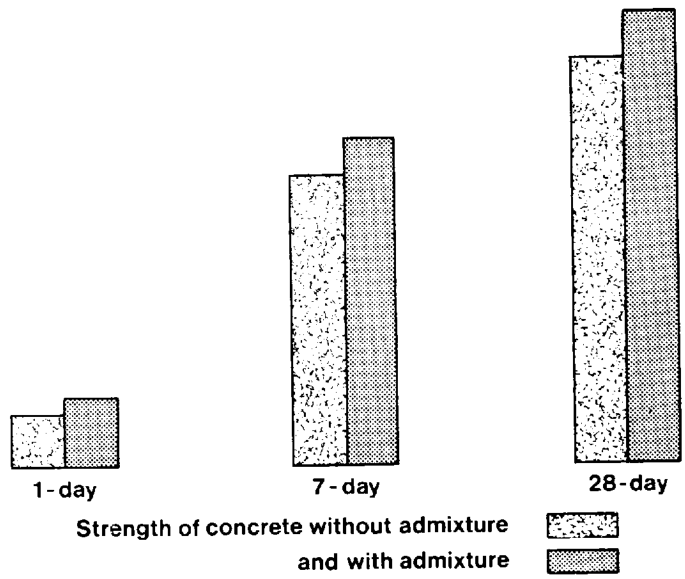
Mix proportions

Temperature

At normal dosage of admixture water reductions for constant workability of 8–12% can typically be obtained.

Strength

The compressive strength of concrete is increased by using water-reducing admixtures to reduce water content while maintaining workability. The increase in strength is a direct result of the lower water/cement ratio. BS 5075: Part 1, requires an increase in compressive strength over the equivalent plain concrete mix of at least 10% after 7 and 28 days.



Normal water-reducing admixture – strength gain.

The relationship between tensile or flexural strength and compressive strength is not altered by a normal water-reducing admixture.

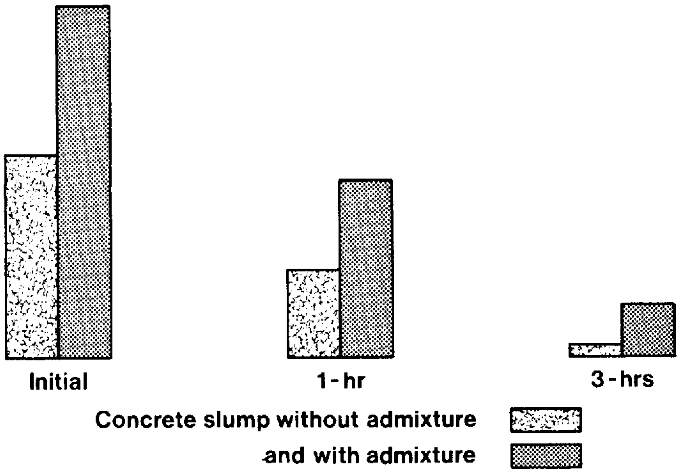
Because water-reducing admixtures increase strength at all ages of the concrete they can be used in certain instances for early strength gain as an alternative to an accelerator. A normal water-reducing admixture can typically achieve an increase in 1-day strength of about 10–15%.

Setting time

The setting of concrete as defined by the stiffening times in BS 5075: Part 1 for concrete containing these admixtures must be within 1 hour of the equivalent plain concrete mix. In practical terms normal water-reducing admixtures can be regarded as not affecting the setting characteristics of the concrete.

Workability

Where no change is made to the water/cement ratio, water-reducing admixtures increase workability. Typically an initial slump in the range 25–75 mm can be increased by 50–60 mm.



Normal water-reducing admixture – workability.

Slump loss

The rate of slump loss of concrete containing a normal water-reducing admixture is generally similar to or greater than that of the equivalent plain concrete mix depending on whether the admixture is being used to increase workability or reduce water.

Where a water-reducing admixture is used to obtain increased workability, the allowable time between mixing and placing is extended.

Air entrainment

Lignosulphonate-based materials tend to increase air entrainment but BS 5075: Part 1 requires that any increase in air content shall not be more than 2% by volume.

Salts of hydroxycarboxylic acids and the low molecular weight polysaccharides do not entrain additional air and often result in reduced air content.

Air-entraining agents may be used in conjunction with water-reducing admixtures either as an integral admixture or separately. Where used separately compatibility must be assured by reference to the manufacturer.

Bleeding

Salts of hydroxycarboxylic acids and low molecular weight polysaccharides can cause an increase in bleeding of those concrete mixes which exhibit a tendency to water movement.

Lignosulphonates normally result in decreased bleeding due to the slight air entrainment.

Heat of hydration

The maximum rise in temperature of concrete is unaffected by the presence of a normal water-reducing admixture when no other mix design changes are made.

If the cement content is reduced the maximum temperature rise is reduced in direct relation to the cement reduction made.

Volume deformation

Creep and drying shrinkage are not generally altered significantly from that of plain concrete designed to have the same workability and 28-day compressive strength.

Cohesion

For a given workability a concrete containing a lignosulphonate or hydroxylated polymer water-reducing admixture is likely to be more cohesive than one which does not.

Durability

There is no theoretical or practical evidence to show that water-reducing admixtures contribute in any way to the corrosion of reinforcement or other embedded metals or have any adverse effect on properties which are relevant to the long-term durability of concrete.

When used to reduce the water content of the mix normal water-reducing admixtures enhance the durability of the concrete by improving both density and impermeability.

Lignosulphonate based water-reducers have been in commercial use since the mid-1930s without any reported adverse effects on long-term durability.

Applications

High strength concrete

Water-reducing admixtures are used to obtain a higher strength concrete without the addition of further cement which may cause problems of temperature rise and shrinkage cracking.

Easier placing and compaction

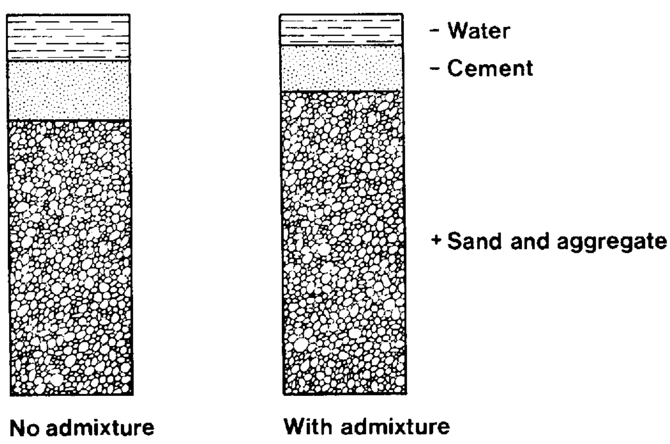
By adding a water-reducing admixture to the mix and maintaining the same water/cement, ratio workability is increased thereby allowing easier placing and compaction.

Improved quality

By a combination of water reduction and improved workability, water-reducing admixtures can be used to improve the quality and durability of concrete. A significant improvement can be achieved at very little or even, where a cement reduction is possible, at no extra cost.

Economies in mix design

Use of a water-reducing admixture to reduce water content



Normal water-reducing admixture – cement saving same strength, same workability.

without loss of workability at the same time maintaining the original water/cement ratio, will allow cement savings of up to 10% to be achieved.

creted, the reduced cement content will result in lower maximum temperatures with consequent reduced risk of shrinkage cracking.

Precautions

Overdosing
The amount of water-reduction or gain in workability will be increased by overdosing. Overdosing can also, in certain instances, result in retardation and/or a degree of air entrainment. Where there is no air entrainment the gain in strength, and other properties will develop normally after the initial retardation period.

Yield
Where water-reduction is used to reduce cement content there will be a reduction in the volume of cement paste and hence in the yield. This must be taken into account in calculating potential economies.

Accelerating and accelerating water-reducing admixtures

Description

Function
Accelerating admixtures are water soluble inorganic chemicals which increase the rate of reaction between cement and water and thereby accelerate the setting and early strength development of concrete.

Accelerating water-reducing admixtures also incorporate water-reducing properties.

Materials
Most accelerators are based on one of the following chemicals:

Calcium chloride

Calcium formate

Calcium formate is sometimes blended with sodium nitrite or other materials to obtain enhanced properties.

The use of calcium chloride is restricted in the UK and many other countries to unreinforced concrete due to its potentially corrosive influence on embedded metal.

Mechanism
The early strength of concrete is the result of hydration of tricalcium silicate(C_3S) and tricalcium aluminate (C_3A) phases of Portland cement. When mixed with water C_3S hardens rapidly and both C_3S and C_3A release heat.

Accelerators increase the rate of hydration thereby providing earlier heat evolution and strength development.

Accelerators do not depress the freezing point of water significantly and should not, therefore, be referred to as antifreezes.

Effects on properties of concrete
The effect of accelerating admixtures is dependent on:

Dosage

Cement type

Mix proportions

Accelerating water-reducing admixtures are also dependent on aggregate type and grading.

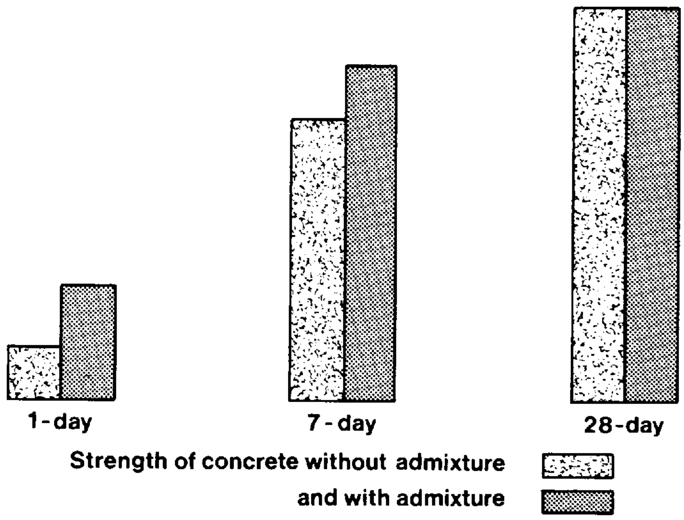
Strength
While accelerators can achieve significant increases in early strength of concrete, the effect on long-term strength is generally negligible.

Where a water-reducing agent is incorporated with the accelerator, the long-term strength gain will be directly related to the reduction in water/cement ratio.

For accelerating admixtures BS 5075: Part 1 requires an increase in compressive strength over the equivalent plain concrete mix of at least 25% at one day and no strength reduction at 7 or 28 days. For accelerating water-reducing admixtures BS 5075 requires in addition an increase in compressive strength of 10% at 7 and 28 days.

Many accelerators can achieve 1-day strength gains of up to 100% over the equivalent plain concrete mix. The cost of achieving this with a calcium formate based accelerator is likely to be several times that of using calcium chloride.

The accelerating effect is most pronounced at lower temperatures of the order to 5–10°C.



Accelerating admixture – strength gain.

Setting time
The setting time of concrete containing an accelerator will be shorter than that of the equivalent plain concrete containing no accelerator. The effect of calcium chloride on setting time is generally greater than that of calcium formate.

Workability
Both calcium chloride and calcium formate give a slight improvement in workability.

A more significant improvement in workability may be obtained by combining the accelerator with a water-reducing agent.

Air entrainment
Most accelerators do not entrain air to any significant degree.

Bleeding
Accelerating admixtures do not normally have any effect on bleeding.

Heat of hydration
Accelerators increase the rate of heat release and may therefore give a greater temperature rise than the equivalent plain concrete mix. The total heat of hydration is unaffected.

Volume deformation
Calcium chloride increases both drying shrinkage and creep.
Calcium formate slightly increases drying shrinkage but there is little published data available on its effect on creep.

Durability
Calcium chloride has the ability to break down the natural passivity provided by Portland cement concrete and thereby encourage the corrosion of reinforcement or other embedded metal.
While calcium chloride tends to decrease permeability of concrete, its corrosive influence and ability to increase shrinkage make it a potential hazard to long-term durability in reinforced concrete.
There is less published data on the influence of calcium formate on durability but electro-potential tests of a blended calcium formate/sodium nitrite based accelerator have shown no corrosive influence.
Calcium formate based accelerators have been in use in the UK without reported harmful effects since the mid-1960s.

Applications

Early demoulding
Accelerators are used primarily to increase the rate of early strength gain and allow earlier demoulding.

Cold weather concreting
Accelerators are also used to reduce the risk of damage to concrete by freezing when concreting in cold weather and to allow the removal of formwork near to more normal striking times. The exposed faces of struck concrete must still be protected.

Precautions

Evolution of heat
High dosage rates or, occasionally, normal dosage rates with high cement content mixes may cause rapid stiffening and considerable heat evolution with consequent risk of thermal and shrinkage cracking. Calcium chloride in particular should be used with care in hot weather.

Corrosion of embedded metal
CP 110 restricts the use of calcium chloride or admixtures containing calcium chloride in structural concrete which contains embedded metal.

Dispensing
Calcium chloride can be obtained as a solution or in flake form. In the case of flake it is essential that the flake is completely dissolved in water before addition to the concrete mix.
Calcium formate may also be supplied in powder form and in such cases should be added to the dry batch before mixing. Liquid admixtures are generally considered easier to dispense accurately and are more readily dispersable evenly through the mix.

Settlement
Some settlement of solids may occur from calcium chloride solutions after prolonged storage.
Settlement from calcium formate solutions can occur after only a relatively short period of storage and facilities for agitation may be necessary.

Retarding and retarding water-reducing admixtures

Description

Function
Retarding admixtures are water soluble chemicals which delay the setting of cement.
Retarding water-reducing admixtures also incorporate water-reducing properties and most commercially available retarders are of this type.

Materials
The main types of chemical used for retarding admixtures are:

Salts of lignosulphonic acids

Salts of hydroxycarboxylic acids

Low molecular weight polysaccharides

Salts of boric acid

Salts of phosphoric acid.
Several of the chemicals are the same as those used for normal water-reducing admixtures, but for retarding purposes they are used at higher dosages.

Mechanism
As with normal water-reducing admixtures the chemical is adsorbed onto the surface of the cement particles, but the altered properties of the film slow the rate of water penetration to the cement and the chemical in solution slows down the growth of hydration products.

Effects on properties of concrete
The effect of retarding admixtures is dependent on:

Dosage

Cement type

Mix proportions

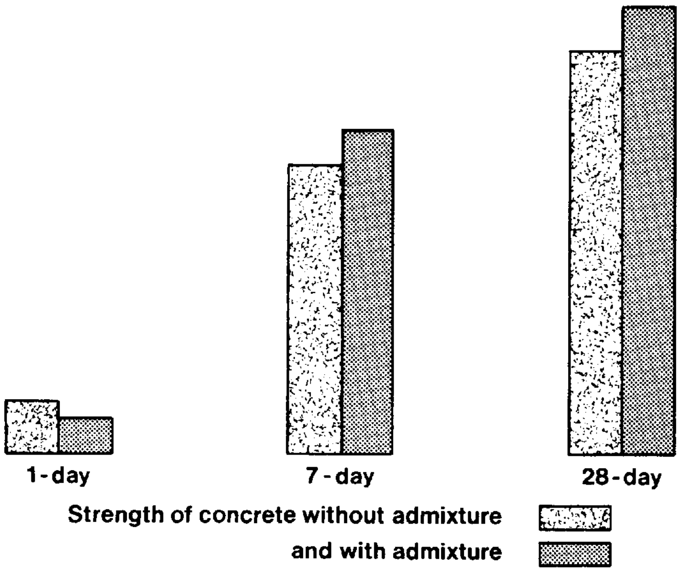
Temperature

Timing of addition

Retarding water-reducing admixtures are also dependent on aggregate type and grading.

Strength
Early compressive strength of concrete is reduced by using a retarder. The delay in strength gain corresponds to the delay in setting time and is normally one–three hours. By the time the concrete is two–three days' old the strength will be approximately the same as the equivalent plain concrete mix. When using retarding water-reducing admixtures the 28-day strength may be up to 10% higher than the equivalent plain concrete mix.
For retarding admixtures BS 5075: Part 1 allows a reduction in

compressive strength against the equivalent plain concrete mix of 10% at 7 days and 5% at 28 days. For retarding water-reducing admixtures the requirement is an increase of 10% at 7 and 28 days as for normal water-reducers.



Retarding water-reducing admixture – strength gain.

The relationship between tensile or flexural strength and compressive strength is not altered by a retarder.

Setting time
Retarders delay the setting time of concrete. Delays of from one–three hours are normally sought but longer delays for special purposes of up to two or more days can be obtained.

Workability
A pure retarder does not in itself noticeably affect the workability of concrete but most retarders incorporate water-reducing properties which may be used to increase workability.

Slump loss
The rate of slump loss of concrete containing a retarder is similar to that of the equivalent plain concrete mix. Where a water-reducing retarder is used to increase initial workability the time for which the concrete remains workable is extended.

Air entrainment
As for *Normal water-reducing admixtures.*

Bleeding
Any tendency to bleed will have more significance in retarded concrete due to the longer period for which the concrete remains fluid.

Head of hydration
The use of a retarder does not significantly alter the amount of heat of hydration but its onset is delayed to the extent of the retardation.

Where a water-reducing retarder is used to reduce cement content the maximum temperature rise is reduced in direct relation to the cement reduction made.

Volume deformation/durability
As for *Normal water-reducing admixtures.*

Applications

Large pours
Retarders enable setting time to be extended thereby preventing the formation of cold joints in large pours. Additionally, water-reducing retarders allow a reduction in cement content with a consequent reduction in maximum temperature rise.

Sliding formwork
Retarders enable the rate of advance of sliding formwork to be reduced to allow time for steel-fixing and sometimes for overnight stopping.

Hot weather concreting
The use of water-reducing retarders assist hot-weather concreting by: (a) delaying setting time and hence compensating for the accelerating effect of the high ambient temperature, and (b) permitting a higher initial workability which therefore extends the period during which the concrete remains workable.

Ready-mixed concrete
The delay in setting time and higher initial workability obtainable through use of a water-reducing retarder compensate for the time lost in transit of ready-mixed concrete.

Precautions

Overdosing
Overdosing will result in excessive retardation but strength will develop normally after the period of retardation provided that curing is adequate and that the formwork is not disturbed.

Timing of addition
To obtain consistent results the retarder should be added with the gauging water. A delay in the addition of the retarder to the concrete mix increases the degree of retardation obtained but may lead to poor dispersion.

Yield
As for *Normal water-reducing admixtures.*

Curing
A retarded mix must be adequately cured in order to prevent plastic cracking, which can arise if the concrete is allowed to dry out before sufficient strength has developed.

Superplasticizers

Description

Function
Superplasticizers are chemicals, usually long-chain molecules, which when added to normal concrete allow a large reduction in water needed to achieve a given workability or, alternatively, impart extreme workability beyond that achieveable with normal water-reducing admixtures.

Materials
The principal chemicals used are:

Sulphonated melamine formaldehyde condensates

Sulphonated napthalene formaldehyde condensates

Modified lignosulphonates.

Mechanism

The superplasticizer is adsorbed onto the cement particles, thereby lowering inter-particle attraction and producing a more uniform dispersion of cement grains as with a normal water-reducer.

Effects on properties of concrete

The effect of a superplasticizer is dependent on:

Dosage

Cement type

Aggregate type and grading

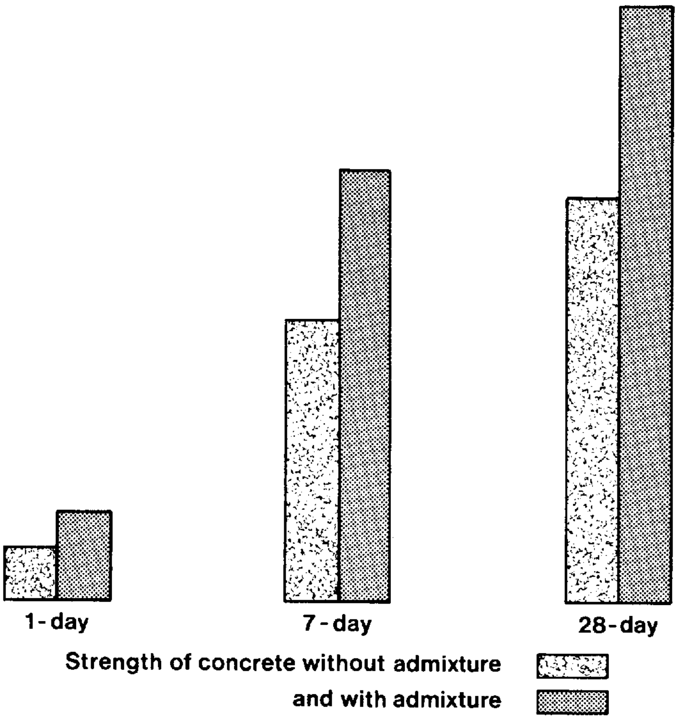
Mix proportions

Temperature.

By the addition of a superplasticizer the water content of concrete can be reduced by 20–30% without loss of workability.

Strength

The compressive strength of concrete is increased by the use of a superplasticizer to reduce the water content while maintaining workability. The increase in strength is, as with a normal water-reducer, a direct result of the lower water/cement ratio. The increase in strength will follow the strength/water–cement relationship for the particular cement.



Superplasticizer – strength gain (when used to reduce water content).

The relationship between tensile and flexural strength and compressive strength is unaltered.

Superplasticizers can be used to achieve early strength gain as an alternative to an accelerator and can typically achieve an increase in 1-day strength of the order of 50% or more.

Setting time

Superplasticizers may cause slight retardation when used at high dosages.

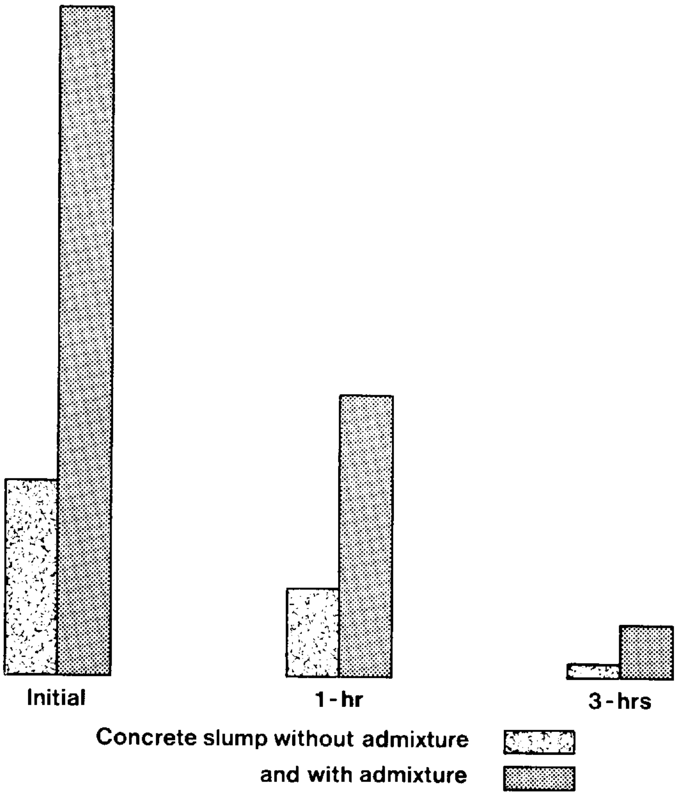
Workability

Where no change is made to the water/cement ratio, superplasticizers can achieve a major increase in workability. Typically, a slump of 75 mm will increase to a collapse slump.

Superplasticized concrete with a very high workability is normally referred to as flowing concrete.

Because of the difficulty of measuring very high slumps reliably, it is common to use the flow table test specified in DIN 1048 (1972: Section 1: Clause 3.1.2) for measuring workability of flowing concrete. Flowing concrete is defined as having a flow table spread of 51–62 cm.

The extreme workability imparted by a superplasticizer is retained for a limited period and flowing properties are normally retained for no more than 30–45 minutes after the addition of the superplasticizer.



Superplasticizer – flowing concrete.

Slump loss

The rate of slump loss for superplasticized concrete is generally similar to that of the equivalent plain concrete mix. Where the superplasticizer is used for water reduction the rate of slump loss will increase.

Air content

Sulphonated melamine formaldehyde based superplasticizers tend to reduce air content when used to produce flowing concrete.

Sulphonated napthalene formaldehyde and lignosulphonate based materials usually increase air content.

Bleeding

Bleeding and segregation can occur in flowing concrete if the mix design and concrete production are not properly controlled. In particular the proportion of fines in the mix is important and, as a general guide, the mix should be designed as for pumpable concrete. (For example at least 450 kg/m³ of cement plus aggregates passing 300 μm.)

Heat of hydration

The maximum rise in temperature of concrete is unaffected by the presence of a superplasticizer if no other mix design changes are made.

If the cement content is reduced, the maximum temperature rise is reduced in direct relation to the cement reduction made.

Volume deformation

Such work as has been published indicates that superplasticizers do not adversely affect either creep or drying shrinkage with the possible exception that with flowing concrete early age shrinkage cracking may be increased under drying conditions, unless adequate curing precautions are taken.

Durability

There is no theoretical or practical evidence to show that superplasticizers contribute in any way to the corrosion of reinforcement or other embedded metals or have any adverse effect on properties which are relevant to the long-term durability of concrete.

When used to reduce water-content of the mix, superplasticizers improve both density and impermeability.

Superplasticizers have been in commercial use in Japan since the late 1960s, and in Germany and the UK since the early 1970s.

Applications

Congested reinforcing

Superplasticizers used to produce high workability enable concrete to be placed more easily in congested and inaccessible sections.

Floor slabs

Flowing concrete enables floor and pavement slabs which are not laid to falls to be placed quickly, with little or no vibration and with very low labour content.

Improved quality

By a combination of water-reduction and improved workability superplasticizers can be used to improve the quality and durability of concrete.

Early demoulding

By using superplasticizers to reduce water content and lower the water/cement ratio, it is possible to increase early strength and allow earlier demoulding.

This is an alternative to using an accelerator or heat curing.

Precautions

Mix design

For high workability or flowing concrete it is important to pay attention to the mix design so that the concrete will not bleed or segregate significantly and so that only the minimum quantity of superplasticizer is required. In particular, it may be necessary to increase the proportion of fines by perhaps 5%. A trial mix is desirable. (See *Bleeding* above.)

For reduced water/cement ratio mixes a higher dose level is used but no special considerations are required other than those appropriate to a plain concrete mix of the same water/cement ratio.

Dispensing

To obtain the full benefit of the effect of most types of superplasticizer, they are usually added to the concrete just prior to discharge and mixed at full speed for about two minutes.

In the case of ready-mixed concrete this means that arrangements must be made for adding the superplasticizer after the truck has arrived on site.

The age of the concrete between batching and adding the superplasticizer can affect the fluidity achieved but this can often be offset by increasing the dosage.

Duration of flowing properties

The workability of flowing concrete decreases with time and, with most types of superplasticizer, flowing properties are retained for no more than 30–45 minutes after the addition of the admixture.

Handling

Flowing concrete can be placed by chutes or skips, or may be pumped. If transported in open dumpers or skips, these should not be filled to capacity as spillage is likely to be excessive.

Flowing concrete is more easily moved into position using wooden rakes or 'pushers' than by conventional shovel.

Vibration

Flowing concrete needs little or no vibration. Excessive vibration can cause segregation and bleeding.

Water-reduced high strength concrete should be vibrated in the normal way.

Formwork

The increased fluidity of flowing concrete means that additional pressures are brought to bear on formwork. Formwork should be designed to resist full hydrostatic pressure.

Any initial tendency of flowing concrete to leak through gaps in formwork normally ceases within a matter of minutes.

Air-entraining admixtures

Description

Air-entraining admixtures are organic surfactants which entrain a controlled quantity of air in concrete in uniformly dispersed discrete bubbles of predominately between 0·25–1 mm diameter.

Materials

The principal chemicals used are:

Abietic and primeric acid salt (neutralised wood resins)

Fatty acid and salts of fatty acids

Alkyl aryl sulphonates

Alkyl sulphates

Phenol ethoxylates

Mechanism

Air-entraining agents lower the surface tension of water and facilitate bubble formation. Uniform dispersion and stability are achieved by the mutual repulsion of the negatively charged air-entrainer molecules and the attraction of the air-entrainer molecules for the positive charges on the cement particles.

Effects on properties of concrete

The effect of air-entraining admixtures is dependent on:

Dosage (some air entrainers are less sensitive than others)

Cement type

Aggregate type and grading

Mix proportions (including workability)

Ambient temperature

Type of mixer

Mixing time.

Strength

The effect of air entrainment is to increase yield, improve workability but reduce strength. These three factors are taken into account in mix design such that the strength loss is minimised. A method for doing this is outlined in the DoE publication, *Design of normal concrete mixes.*

Workability

Air entrainment increases workability. Typically 5% air entrainment will increase slump by 10–50 mm.

Setting time

The use of air-entraining admixtures has no significant effect on setting time.

Bleeding

Air entrainment reduces bleeding in concrete. It is not uncommon for bleeding to be halved and where gap-graded sands are used the reduction can be greater.

Volume deformation

Air-entraining admixtures do not affect drying shrinkage. Creep is unaffected at lower levels of air entrainment but may be slightly increased at air contents above 6%.

Cohesion

Cohesion is increased by the use of an air-entraining admixture and this is of particular value where sands and aggregates with poor gradings are used.

Density

Concrete density is reduced in direct proportion to the amount of air entrained.

Air entrainers used to achieve very low densities, say down to 500 kg/m³, for floor screeds and thermal insulation are more usually known as foaming agents.

Durability

Air entrainment generally improves durability by reducing permeability. The resistance of hardened concrete to the action of frost and de-icing salts is considerably improved by the use of air-entraining admixtures. This is achieved by the entrained-air bubbles acting as expansion chambers to accommodate the ice formed within the capillaries. Because the bubbles break up the continuity of the capillaries they also reduce permeability and water adsorption.

Yield

The use of an air entrainer increases the yield of concrete by the volume of the entrained air. This has a significant effect on the apparent cost of using an air-entraining admixture.

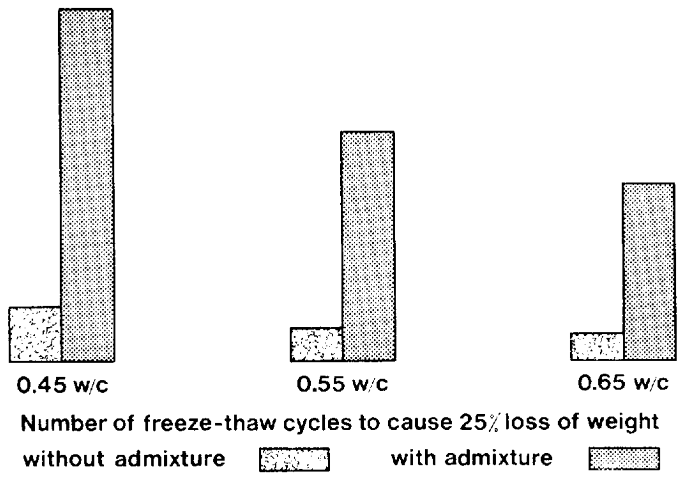
Applications

Freeze-thaw resistance

The major use of air-entraining admixtures is in the production of concrete pavings for roads and airfields where improved resistance to frost and de-icing salts is required. The Department of Transport specification for Road and Bridge Works specifies 4½% ± 1½% air entrainment for the top 50 mm of pavement quality concrete.

Total air content recommended by CP 110 for frost resistance varies with aggregate size:

Maximum aggregate size (mm)	Air content (%)
40	4 ± 1½
20	5 + 1½
10	7 + 1½



Air-entraining admixtures – durability.

Poor aggregates

By reducing bleeding and improving workability and cohesion, air-entraining admixtures enable poorer quality aggregates to be used and are particularly valuable in overcoming harshness.

Concrete pumping

The properties of reduced bleeding, improved workability and improved cohesion also make air-entraining admixtures a useful aid to the pumping of concrete where pumping pressures are below about 5·2 N/mm², say 6 N/mm² or 60 bar. At higher pumping pressures the entrained air is compressed to the point at which it ceases to be effective.

Extruded concrete

Air-entraining admixtures are used to reduce bleeding and improve cohesion, compaction and surface finish in extruded concrete.

Precautions

Mix proportions

An increase in sand content from 35 to 45% will typically increase air content from 4½ to 5%.

An increase in cement content of 90 kg/m³ will typically reduce air content by 1%. Increase in cement fineness will also reduce air content.

Dispensing
The dosage rate for air-entraining admixtures may typically be as low as 30 ml per 50 kg cement and accurate dispensing is therefore essential.

Air content
The air content should be measured frequently using the method specified in BS 1881: Part 2. The DoTr specification requires the determination of air content to be carried out at least six times per day.

Organic impurities
Carbon can substantially reduce the effectiveness of air-entraining admixtures. Care may be needed when using pfa or certain pigments.

Temperature
An increase in temperature will reduce air content. A rise in temperature from 10 to 32°C may halve the amount of air entrained but normal day-to-day temperature fluctuations are much smaller and do not cause significant problems.

Mixing time
The effect of mixing on the amount of entrained air varies with type, loading and condition of the mixer. In general, the air content will increase with mixing time up to about two minutes in stationary mixers, and up to about 15 minutes in transit mixers. Thereafter, the air content is likely to remain constant for a considerable period of time. Severely extended mixing times may decrease air content.

Transportation
When being transported air-entrained concrete can lose up to 0·5% air, although this tends to be in the form of the larger and least effective bubbles.

Admixtures for special purposes

Bonding admixtures

Function
Bonding admixtures are organic polymer emulsions used to enhance the bonding properties of concrete and mortar.

Materials
The principal emulsions used are:

Polyvinyl acetate (PVA)

Styrene butadiene (SBR)

Acrylic

In general, synthetic emulsions are preferred to natural rubber or latex compounds.

Effects
In addition to improving bond strengths, bonding admixtures may affect the following properties of concrete:

Increase abrasion resistance

Increase tensile strength

Decrease drying shrinkage

Decrease modulus of elasticity

Decrease compressive strength

PVA bonding admixtures are sensitive to moisture so that bond strength is impaired in conditions of permanent damp. Both styrene butadiene and acrylic emulsions are less sensitive to moisture but are more expensive. PVA emulsions are less vulnerable to loss of intercoat adhesion due to drying.

Bonding admixtures are particularly useful for patching and remedial work where a feathered edge is required.

Pigments

Function
Pigments in powder form for use in concrete and mortars are formulated from both natural and synthetic materials in order to produce sufficient colour without significantly affecting the physical properties of the mix.

Materials
Pigments for use with concrete in the UK should comply with BS 1014. Carbon black, red, yellow, brown and black iron oxides, black manganese oxide, blue cobalt oxide and green chromium oxide are used.

Certain organic dyestuffs may be used but do not necessarily comply with BS 1014.

Effects
Up to 10% of pigment by weight of cement may be added depending on the depth of colour required. Used with white Portland cement it is possible to produce pastel shades.

Pigmental concrete and mortar will normally have the same physical properties as the unpigmented mix except that certain pigments, e.g., carbon black, may cause slight loss of compressive strength at early ages. Carbon can also diminish the effectiveness of air-entraining admixtures.

Damp-proofing admixtures and integral waterproofers

Function
Damp-proofing admixtures are chemicals which reduce the rate of moisture adsorption into unsaturated concrete. They do not reduce the permeability of saturated concrete and are not suitable for resisting hydrostatic pressure.

Integral waterproofers are normally a combination of a damp-proofer and a water-reducer.

Materials
The principal chemicals used for damp-proofing admixtures are:

Stearates

Oleates

Certain petroleum derivatives.

Effects
Damp-proofing admixtures reduce the rate of adsorption of moisture into the pores of the concrete and retard the rate of transmission of water through unsaturated concrete. When combined with a water reducer such as a lignosulphonate they enable these damp-proofing properties to be combined with the benefits of denser and less permeable concrete achieved by water reduction.

Damp-proofing admixtures and integral water-proofers are a valuable aid to the achievement of watertight concrete but they are not a substitute for good workmanship.

Expanding admixtures

Function
Expanding admixtures are materials which cause a small expansion in grouts, mortars or concrete to compensate for shrinkage.

Materials
The following materials are most commonly used for expanding admixtures:

Granulated iron is oxidised by the water and oxygen in the concrete and expands. This expansion can continue beyond the plastic phase and can therefore, in theory, counteract both settlement and drying shrinkage. In practice, it is difficult to achieve such precise control of the rate and duration of oxidation.

Powdered aluminium normally mixed with find sand because of the low addition rate, reacts with the alkali to produce hydrogen. The expansion is completed during the plastic phase of the concrete and cannot therefore be used to compensate for drying shrinkage.

Expansive cements are available in some countries and may be incorporated in Portland cement mixes to provide expansion which, as with granulated iron, can continue beyond the plastic phase.

Activated carbon can be used to create expansion during the plastic phase of the concrete by the release of air.

Effects
Expanding admixtures are used widely in grouting applications, particularly in the grouting of prestressing tendons and of machine bed-plates and crane rails. The degree of expansion achieved can be affected by cement type, aggregate content and temperature.

Anti-bleed admixtures
Cellulose ether, alginates, polyethylene oxide and other thickening agents have been successfully used as anti-bleed admixtures in concrete, mortar and grouts although in concrete it is more common to use air entrainment for this purpose. Thickening agents are used mainly in situations where there is a strong tendency to water loss.

Fungicidal admixtures
Copper sulphate, pentachlorophenol and other chemicals are sometimes used as admixtures to concrete to prevent fungus growth. Satisfactory results are difficult to guarantee as fungicides tend to wash out and lose effectiveness with time. The toxicity of such materials must also be taken into consideration.

Corrosion inhibitors
Sodium nitrite, sodium benzoate and sodium chromate have been used as admixtures, to inhibit corrosion of steel reinforcement in concrete. Although these chemicals have been shown to be effective in specific situations, there is little general data available on either their effectiveness or disadvantages.

Freezing point depressants
Various forms of alcohol and ethylene glycol have been suggested as anti-freeze admixtures for concrete. Any advantage from depression of the freezing point with these chemicals is generally offset by the high cost and the adverse effects on the setting properties of the cement paste. Freezing point depressants should not be confused with accelerating admixtures. Although most accelerators will in practice depress the freezing point by 2–4°C, their main effect in resisting cold temperatures is the acceleration of setting time and the faster generation of heat.

Dispensing and storage

Storage
Most admixtures are stable products but they may require protection against freezing and they may require to be stirred before use. The manufacturer's instructions should be consulted. Certain admixtures, once subjected to below freezing temperatures, cannot be restored by simple thawing.

Systematic storage to avoid confusion between different types of admixtures is important. Drums are labelled and some manufacturers add a colorising dye to the admixture to aid identification. Such dyes do not affect the colour of the concrete. Smell and relative density can also be used to help identify and distinguish one admixture from another.

Preparation
Most admixtures are supplied as a liquid. Liquid admixtures are generally considered easier to dispense accurately and more readily dispersible evenly through the mix. Where an admixture is supplied in powder form it is normally added to the dry batch prior to mixing but in the case of powder or flake calcium chloride it should be carefully and thoroughly dissolved in water before use.

Addition
With the exception of certain superplasticizers, all liquid admixtures should be added to the mix as part of the gauging water, preferably after the other mix ingredients have been premixed, with an initial quantity of plain gauging water. This is important if consistent results are to be obtained.

Certain types of superplasticizers have to be added to the concrete just prior to discharge. This is necessary to obtain the full benefit of the period of high workability.

Powder admixtures are normally added to the dry batch immediately prior to mixing.

Dispensing equipment
Because the amount of admixture to be added is small in relation to the volume of the concrete mix, accurate dispensing is essential.

Dispensers can be obtained from most admixture suppliers or direct from proprietary dispenser manufacturers.

The type and sophistication of dispenser to be used will depend on:

Volume of concrete handled

Individual batch size

Quality of concrete required

Extent to which admixtures are being used

Type of admixture(s).

Manual dispenser – gravity

Gravity feed from a simple perspex or glass dispenser is foolproof and inexpensive, but accuracy depends on visual sighting of the level in the dispenser by the operator. Admixture tanks or drums have to be located above the level of the batcher operator.

Manual dispenser – pneumatic

Similar to gravity system but feed is by air pressure at 40–120 psi. Accuracy again depends on visual sighting of the level by the operator. Control unit can be located in the batcher operator's cabin. Other advantages are:

Air cleansing of feed lines

Ability to handle more than one admixture.

Automatic dispenser – timed flow

Feed is by electrically driven pump which is controlled by a timer. Dose control is not positive and frequent calibration is necessary to overcome effects of slight blockages by sedimentation, variations in viscosity and variations in power supply. The cheapest automatic system.

Automatic dispenser – pneumatic

Similar to manual pneumatic dispensers but with the addition of an electrical sensing unit in the sight glass tank to cut off automatically the charge at the correct level.

Automatic dispenser – electric

Combination of feed by electrically driven pump with electrical sensing unit in sight glass tank to cut off charge at the correct level. Expensive but has many advantages:

High accuracy

Rapid operation

Low maintenance.

More than one admixture can be handled provided that there is a facility for water flushing the feed lines.

Precautions

Dispensers must be regularly flushed with water, maintained and checked for accuracy.

Not all admixtures are compatible and the advice of the admixture manufacturer should be sought before two or more admixtures are added, either together or separately, to a concrete mix.

Bibliography

AMERICAN SOCIETY FOR TESTING MATERIALS. *Symposium on effect of water-reducing admixtures and set-retarding admixtures on properties of concrete.* ASTM Special Technical Publication No. 266, 1959. pp. 246.

RILEM. *International symposium on admixtures for mortar and concrete* (Two Volumes). Brussels, 1967. pp. 368 and pp. 267.

AMERICAN CONCRETE INSTITUTE. Guide for the use of admixtures in concrete. (Report of ACI Committee 212.) *Journal of the American Concrete Institute,* No. 9, September 1971. pp. 646–676.

UNIVERSITY OF NEW SOUTH WALES. *Proceedings of First Australian Conference on Engineering Materials.* 1974.

UNIVERSITY OF NEW SOUTH WALES. *Proceedings of the Workshop on the use of Chemical Admixtures in Concrete.* 1975.

CEMENT ADMIXTURES ASSOCIATION/CEMENT AND CONCRETE ASSOCIATION. *Superplasticizing admixtures in concrete.* Report of Joint CAA/C&CA Working Party. Cement and Concrete Association, London, 1976. pp. 32. Publication 45.030.

THE CEMENT ADMIXTURES ASSOCIATION. *Concrete admixtures: use and applications.* (Edited by M R Rixom.) The Construction Press, Lancaster, 1977. pp. 87.

QUINION, D. W. *Superplasticizers in concrete – a review of international experience of long-term reliability.* CIRIA Report No. 62, CIRIA, London 1977. pp. 25.

RIXOM, M. R. *Chemical admixtures for concrete.* E & F Spon Ltd, London 1978. pp. 234.

DEPARTMENT OF ENVIRONMENT. *Design of normal concrete mixes.* HMSO, London, 1976.

MINISTRY OF TRANSPORT. *Specification for road and bridge work.* HMSO, London, 1969.

THE CONCRETE SOCIETY. *Proceedings of Concrete International (CI'80).* Volume 2. Construction Press, Lancaster, 1980. pp. 454.

50474