Chemical Admixtures for Concrete

SECOND EDITION

M.R. Rixom and N.P. Mailvaganam

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Second Edition

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In addition, those readers who attended the Concrete International meeting in 1980 will recognize Chapter Six as an updated version of the excellent paper presented by Mr T. Tipler of the Cement and Concrete Association. We are grateful to him and to the Concrete Society for permission to use his paper as the basis of this chapter.

Finally we would like to thank our companies Cormix Ltd and Sternson Ltd for allowing us to publish the book and acknowledge the contribution made by friends and colleagues within our companies.

Foreword to second edition

Since the first edition was published in 1978, several changes have occurred which the original author considered necessitated a reappraisal of the book's contents leading to an enlarged and revised edition. Apart from a general updating of the literature, and rectifying minor errors and deficiencies, the following observations influenced the decision to produce a further edition:

(a) The use of admixtures, as expected, has gained greater acceptance so that the amount of concrete which contains admixtures has increased. This has led to a better understanding of the properties of admixtures by the concrete engineer and technologist, so that he is less dependent on the reliability of the advice of the admixture supplier and has become a more discerning specifier and user. On the other hand, the widespread problems of concrete damage caused by earlier indiscriminate use of calcium chloride, sometimes in flake form at high concentrations, has not lessened the awareness of potential dangers that could exist.
Co-operation between industry and governmental agencies has produced new or modified standard testing methods allowing limits to be set for minimum levels of acceptability, and providing a means by which products can be fairly evaluated on a comparative basis. In certain countries this has been further developed to certification of a product's fitness for use, without which sale of such materials is not allowed.
In view of this it has been decided to include a chapter on the standards and controls that exist in various countries. This has replaced the original Chapter 6 which has been omitted from this edition (see [d] below).

(b) The construction industry has continued to become more international; as the economic climate of the construction industry has declined in most western countries, so has the need to be involved in overseas contracts become more important. Many more engineers are finding themselves grappling with products, standards, and specifications which emanate from other countries, and working in climatic conditions which make admixtures not only desirable, but necessary. In view of this, apart from the chapter on standards etc., more information has been given on the influence of high temperatures on concrete which contains admixtures.

(c) At the time of writing the first edition, the majority of the applicational information was based on UK practice and experience. The international response to the book has been such that it was felt desirable to introduce a more international flavour to the applications chapter. In addition, it could not be forgotten that the USA represents the largest single market for chemical admixtures and the efforts of the American admixture industry, the construction industry, and the ASTM have contributed more to the present state of the art than any other single nation. It was considered timely, therefore, to introduce a co-author, Noel Mailvaganam, who has experience of the situation in America. This was particularly welcomed by the original author, Roger Rixom, who has known Noel Mailvaganam over many years, and has resulted in an expansion of Chapter 5 leading, it is believed, to a much more authoritative and useful section.

(d) It was felt that neither of the authors of the revised edition could contribute further to the chapter on the analysis of concrete for admixture content as this lay outside the field of their experiences. On the other hand, the information presented in the original edition is now largely out of date; for this reason this chapter has been omitted from the new edition. It is to be hoped that those qualified in this field could be persuaded to produce a book on this important topic, or perhaps to contribute a chapter in a subsequent edition of this book.

The authors hope that the additions and changes described above will result in a book both gaining a wider readership and finding a greater usefulness to the individual reader. Finally, the authors would like to thank all those who have constructively criticised the original edition.

Introduction

Since the publication of the first edition of this book, most major industrial countries have seen recessional trends in their construction industries, the hardest hit being the large civil engineering contracts. Against this background, the chemical admixture business has shown remarkable growth worldwide and has become a major chemical business with an annual turnover in the region of US $600 million.

A typical example of the resilience of the industry to withstand a declining or stagnating construction industry is shown in Fig. 0.1 where the cement use and admixture production in Western Germany over the period 1978 - 1981 are compared.

It is appreciated that the admixture production figures contain an export element but, nevertheless, the health of the admixture business in comparison to the industrial climate within which it works is apparent. The reasons for this apparent depression-proof nature of the admixture business are believed to be:

(a) In those countries where the use of admixtures falls well below the potential use, there is considerable opportunity for the degree of penetration to be increased, resulting in a net growth. Indeed, in recessionary times with reduced concrete volumes, there is commercial pressure to improve margins and the use of admixtures is often part of a cost-saving strategy.

(b) In countries where penetration is already high, growth has come largely from the use of superplasticizers which are added at much higher dosage levels than traditional water-reducing agents. In this

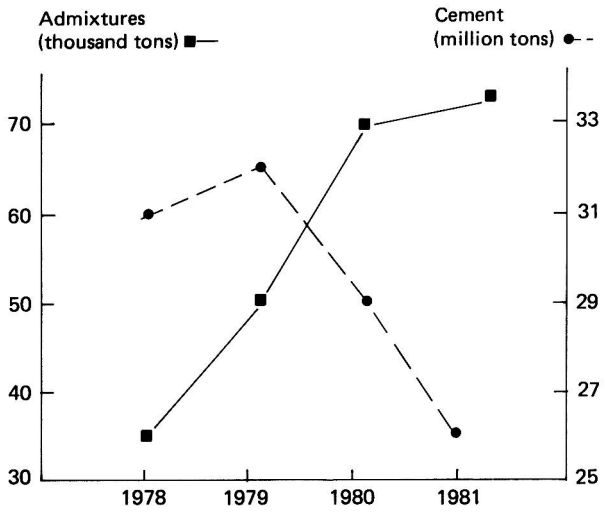

Fig. 0.1

area there has also been much technical development, particularly with regard to products based on polymerized naphthalene sulphonates. It is the view of the authors that future growth over the next five years will come in the main from the area of superplasticizers.

(c) The continued movement of the construction industry to involvement in overseas projects has called for admixtures to assist concreting in extremes of climatic conditions. Concrete oil platforms and Middle East projects are two such examples.

A picture of the global development of cement and admixture usage over the decade 1971 – 1981 is given in Table 0.1.

The increase in the use of admixtures has been reflected in a greater interest in admixture materials and technology from all sectors of the industry. Thus all types and levels of information are demanded, including the simple, but very important, procedures for use on site, the more complex requirements of the design engineer regarding structural characteristics of concrete containing admixtures.

In addition, the cement chemist, the specifier of concrete, the student, the admixture supplier, and many others, require detailed or general information on some aspect of admixtures. The purpose of this book, therefore, is to compile into one volume the available data on admixtures in order to satisfy the demands of all interested parties. It is appreciated that this ambitious objective is unlikely to be achieved to every reader's satisfaction and, to keep the project down to a manageable proportion, it

Table 0.1

Geographical area	Estimated cement consumption (million tons)		Estimated* admixture consumption ('000 tons)	
	1971	1981	1971	1981
USA	70	70	200	250
South America	40	60	40	40
Western Europe	155	160	100	220
Africa	25	40	10	15
Middle East	N/A	35	10	50
Far East	105	140	80	165
Australia	5	6	5	15

*excluding calcium chloride accelerators

has been decided to include only those categories of admixtures which are currently used to any significant degree. Also excluded are those materials, such as pozzolans and pigments, which, although classified by other workers as admixtures, are outside both the normal consideration of those products and the authors' own sphere of interest and knowledge.

The types of admixtures considered in this book are: water-reducing agents (including superplasticizers and retarders), air-entraining agent, waterproofers, and accelerators. Within each product category, the following aspects will be covered: background and definition, chemistry, effects on the cement-water system, effects on plastic concrete, effects on hardened concrete (engineering and durability aspects).

The practical use of admixtures in a variety of applications in the site-batched, ready-mixed, and precast industry is covered in a separate chapter where, apart from *actual examples of use, factors such as storage, safety, and dispensing equipment are discussed.* A short chapter is devoted to international standards and specifications.

It is hoped that in some small way this book will add to an already much improved situation by providing a source of information for those engaged in the manufacture, use and specification of concrete.

Contents

1 Water-reducing agents

1.1 Background and definitions

The water-reducing admixtures are the group of products which possess as their primary function the ability to produce concrete of a given workability, as measured by slump or compacting factor, at a lower water–cement ratio than that of a control concrete containing no admixture.

The earliest known published reference to the use of small amounts of organic materials to increase the fluidity of cement containing compositions, was made in 1932 [1] where polymerized naphthalene formaldehyde sulphonate salts were claimed as useful in this role. This was followed during the mid 1930s to early 1940s by numerous disclosures regarding the use of lignosulphonates and improved compositions [2-9].

The lignosulphonates formed the basis of almost all the available water-reducing admixtures until the 1950s when the hydroxycarboxylic acid salts were developed which have grown to occupy a significant but, nevertheless, still a minority position in this product group. Materials such as glucose and hydroxylated polymers obtained by the partial hydrolysis of polysaccharides have been widely used in North America. The polymers usually have a low molecular weight and contain glycoside units ranging from 3–25. In addition, other chemical and admixture types have been included into the water-reducing admixtures formulations to produce five types within this category.

The *normal* water-reducing admixtures allow a reduction in the water–cement ratio at a given workability without significantly affecting the setting characteristics of the concrete. In practice, this effect can be utilized in three ways: