

N/mm<sup>2</sup> when less than 40 previous test results are available. This margin is, however, considered by many to be unduly high and too onerous for most situations.

Further aspects of mix design are covered in the next two chapters, Chapter 5 covering durability aspects and Chapter 6 covering requirements for particular properties and purposes. The author states the factors which influence durability and explains the importance of water/cement ratios and minimum cement contents for different environments.

The beginning of the chapter on mix design for particular properties and purposes comprises a welcome section on flexural and tensile strengths of concrete. This section is short, but very much to the point and includes useful figures relating flexural and indirect tensile strengths to compressive strengths. The chapter goes on to cover many interesting aspects of mix design for special purposes, including appearance, air-entrained concrete, lightweight concrete,

large maximum-size aggregate, low drying shrinkage, lean concrete bases, concrete blocks, and concrete for pumping. For readers wishing to obtain the essential points of information on these subjects, this chapter provides a very good source of reference.

The final chapter describes clearly methods of combining aggregates to give desired gradings, and discusses the implication of results from trial mixes and the factors influencing adjustments to mix proportions during production.

The book, which is of A4 size, contains 102 pages and includes 82 well chosen references at the end. There is a lot more information in the book than appears at first sight and it is presented very clearly. It can be strongly recommended to everyone engaged in the specification and quality control of concrete construction, and in particular, those concerned with designing concrete mixes. At a cost of £3, it represents good value.

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## **Fresh concrete: important properties and their measurement**

**Proceedings of a RILEM Seminar held on 22–24 March 1973 in Leeds, England**

**Editors: A. M. Neville and D. Slater**

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Forty-one invited participants from seventeen countries representing many different points of view attended this Seminar, which was held in Leeds in March last year. They presented 34 papers on the following topics.

- (1) Definitions of workability and allied properties.
- (2) Measurement of workability and allied properties of cement paste and concrete.
- (3) Influence of properties of cement (powder) on workability and segregation.
- (4) Influence of properties of aggregate on properties of fresh concrete.
- (5) General properties of fresh concrete with special reference to homogeneity.
- (6) Segregation in mixing, transporting, placing and under vibration.
- (7) Special problems of ready-mixed concrete. Pumped concrete.

These papers and the written contributions to the discussions on each topic are contained in the Proceedings; the languages of the Seminar were English and French and nine of the papers are in French.

The *raison d'être* of the Seminar is described by Professor Neville in his summary as "a realisation of

the importance of the role of the properties of concrete when still fresh, coupled with an awareness of the inadequacy of the existing published knowledge". The concrete construction engineer is familiar with the important bearing which fresh concrete properties have upon the handling, placing and compaction of concrete and, indeed, upon its final quality. He knows all too well the problems which can arise when unsuitable fresh concrete is used: the occurrence of poor compaction, segregation, blockages during pumping, scouring on surfaces, and so on. He may not be fully conversant with existing published knowledge, but he is aware of the difficulties involved in choosing appropriate levels of consistence and cohesion for special applications, in measuring and controlling these, and in designing satisfactory concrete mixes. There is much in these Proceedings which will increase his understanding of the behaviour of fresh concrete and of the factors affecting its important properties. The papers reflect the divergent interests and views of the authors; evidently they do not constitute a systematic study from which practical procedures can be adopted immediately. They do, however, present the most recent thoughts of the acknowledged experts in this field.

Over the past 40 years there have been many attempts to define workability. The papers and written discussion contributed under Topics 1 and 2 reveal that there is still no universally accepted definition of workability. Nor is any fundamental test for workability likely to be generally available for site use for some time. Useful contributions, however, are made by Tassios and Tattersall in clarifying terminology. Tassios allows a broad use of the term workability and links its components, mobility, stability and compactibility, to certain rheological properties. Tattersall underlines the futility of trying at present to give a satisfactory definition of workability; he suggests that the term should be retained for general use without attempting to quantify it and at the same time restrict its meaning. He deplores the practice of using rigorously defined terms, such as viscosity, to describe results of empirical measurements.

Several authors agree that the behaviour of concrete approximates in practice to that of the Bingham model. Tattersall presents data which support this view and points out that at least two constants must be measured if one wishes to characterize its behaviour. He makes clear the consequent inadequacy of existing single-point tests and describes a test using a food-mixer which may allow Bingham constants for concrete to be measured on site. Murata and Kikukawa, and Morinaga in a later paper, also describe tests which they have devised for the measurement of these constants, Murata and Kikukawa detailing the practical difficulties of designing viscometers for this purpose.

Three of the papers presented under Topic 2 deal with rheological investigations of cement paste using coaxial cylinders and cone-and-plate viscometry. Cusens infers that cone-and-plate viscometry avoids the lubricating layer and the segregation problems which may occur when coaxial cylinders are used.

A thorough understanding of the factors affecting workability, segregation and bleeding is desirable for the adequate design of concrete mixes. These factors receive comprehensive treatment in the papers presented under Topics 3, 4 and 6. Much of Bombled's long report on the influence of cement deals with cement paste; he reviews the relevant characteristics of cement and tells us that the most important are particle geometry and the nature of the surface ions, or the ions which are dissolved in the mixing water. These considerations enable him to explain, for example, why high alumina cement concrete is more workable than Portland cement concrete of the same mix proportions.

The influence of aggregate is dealt with by Ionescu in his general report and by three other authors.

Ionescu discusses, for both natural and artificial aggregates, properties such as void content, porosity, water absorption, fineness modulus and grading, shape and surface texture. He then outlines some of the effects of these upon the principal properties of fresh concrete, giving illustrative examples from his own research and that of others.

Alexandersson and Hughes discuss the influence of cement and aggregates upon workability. Both these papers draw on the mix design data previously published by the authors.

The phenomena of segregation and bleeding of concrete are dealt with by Popovics in his general report and by Mather. In an otherwise comprehensive review of the factors which influence these phenomena, Popovics surprisingly does not refer directly to the important effect which the proportion of sand can have upon bleeding. Mather gives some useful practical views on the causes of segregation and emphasizes the need for correctly proportioned mixtures.

Two contributions of direct practical value are presented under Topic 5 by Johansson and Mather. They deal with homogeneity and mixer efficiency, and detail tests which can be used for the assessment of these.

The last topic is concerned with the special problems of ready-mixed concrete and with pumped concrete. In three informative papers Mather, Petersons and Dewar discuss the workability of ready-mixed concrete in the light of current practice in the United States, Sweden and the U.K. respectively. Limitations related to length of haul, the use of agitation, re-tempering effects and the specification and control of workability are among the topics discussed.

Morinaga reports an extensive investigation into the factors affecting pressure loss in pipelines. Charts are presented from which one may predict root pipeline pressure for a particular layout or the limiting distance through which concrete may be pumped.

It was not to be expected that the Proceedings would answer all outstanding questions about fresh concrete and its behaviour. It is as yet not possible to define workability. The engineer must still content himself with empirical single-point tests to assess consistence and the only certain way of judging the suitability of fresh concrete for a particular application is by full-scale trial. It is clear, too, that the measurement of more fundamental rheological properties in the laboratory is not without its difficulties. Nevertheless, the Proceedings contain a wealth of information which adds to our knowledge and understanding of the behaviour of fresh concrete, its important properties and their measurement.

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