SA HB 79:2015

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Handbook

Alkali Aggregate Reaction—Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia

STANDARDS Australia

CEMENT CONCRETE & AGGREGATES AUSTRALIA

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Alkali Aggregate Reaction—Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia

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PREFACE

This Handbook revises and supersedes SAA HB 79—1996.

In 1994, a National Working Group was established by the Cement and Concrete Association of Australia (C&CA) to consider the phenomenon of alkali aggregate reaction (AAR) in concrete and make recommendations for its practical management in Australia, and in particular to provide guidance for the specification of future work. The Working Group comprised representatives of designers, specifiers, asset owners, materials suppliers, researchers and scientists. The resulting document was published jointly by C&CA and Standards Australia (then SAA) as *Alkali Aggregate Reaction—Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia* (T47/HB 79) in 1996 and covered the then current state of knowledge of AAR in Australia.

In 2012, in light of the significant amount of Australian and overseas research that had been published in the previous 16 years, and anticipating the publication of a revised edition of AS 2758.1, a second edition of the Handbook was commissioned by Cement, Concrete and Aggregates Australia (CCAA). The draft document was prepared by a team of Australian and New Zealand researchers, engineers, scientists and concrete practitioners, with significant knowledge of the AAR phenomenon. The draft document was reviewed and approved for publication by Standards Committee CE-012, Aggregates and Rock for Engineering Purposes.

This Handbook focuses on providing advice on the assessment of risk of damage due to AAR and the appropriate strategies to minimise that risk. It also presents an overview of AAR in concrete, to promote understanding and discussion allowing potentially harmful reactions to be identified and appropriately dealt with.

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INTRODUCTION

Purpose and scope of the document

Reports of problems in a small number of significant concrete structures in Australia over the past 50 years have raised the awareness and interest in alkali aggregate reaction (AAR). With the increasing trend to higher strength and higher performance concrete with increased cementitious material content, it is now necessary that the risk associated with AAR be evaluated when designing future work. The increasing number of cases of AAR creates a need for guidance on appropriate management of AAR damage in existing structures.

This Handbook provides asset managers, specifiers, designers, suppliers, and contractors with guidelines for—

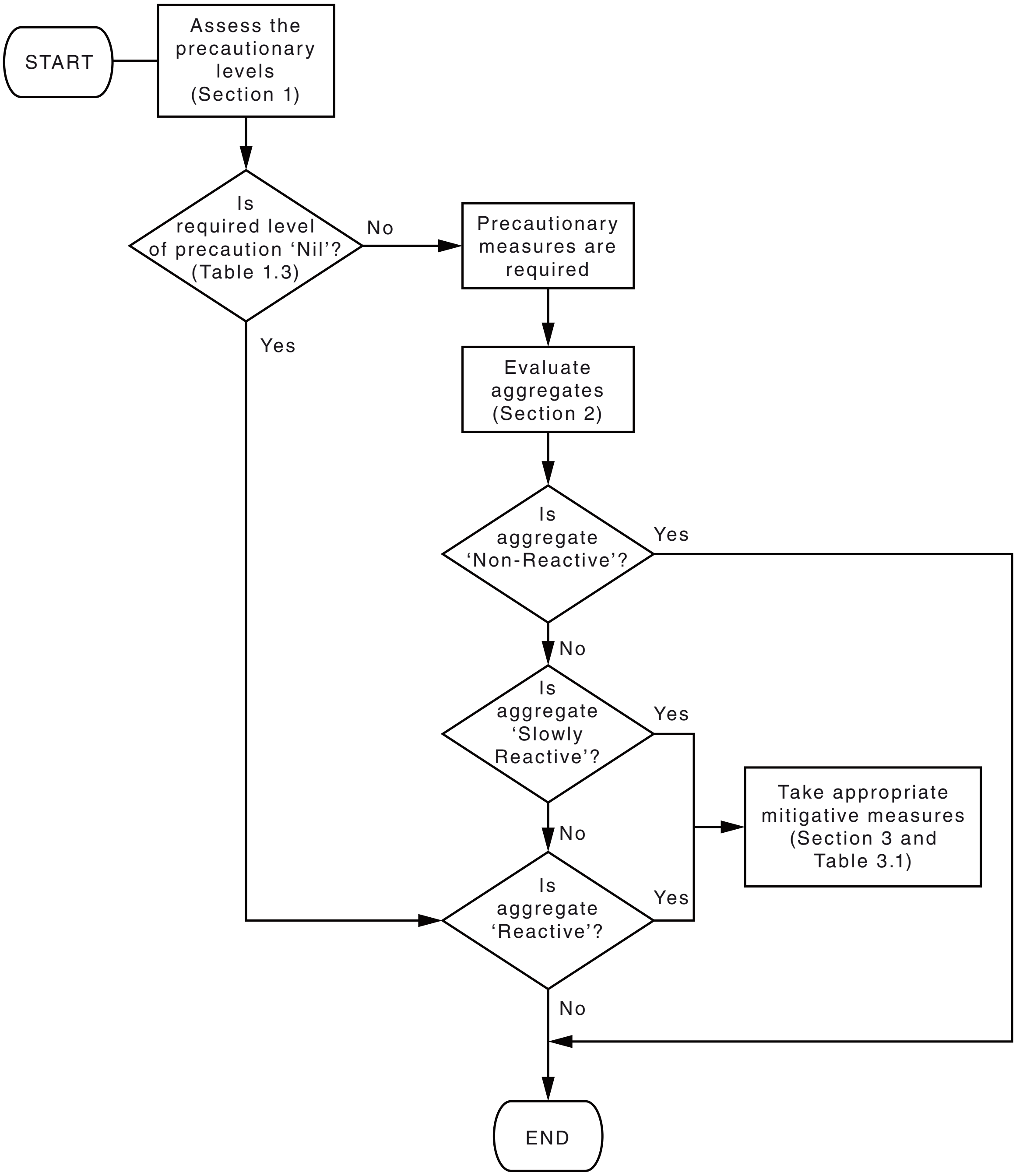
(a) the assessment of risk of damage due to AAR based on the type of structure, the environment and their interaction;

(b) the assessment of aggregates for potential reactivity; and

(c) appropriate precautions which can be adopted to minimise the risk of damage due to AAR in future work and management of concrete structures already affected by AAR.

A description of AAR is provided in Appendix A. The flow chart in Figure 0.1 outlines how to minimise ASR in new structures.

This Handbook does not include or constitute a specification for managing the risk of AAR in future or existing structures.



NOTE: For aggregate classification terminology see Table 2.1.

FIGURE 0.1 MINIMISING THE RISK OF ASR IN NEW STRUCTURES

Background

A small proportion of concrete throughout the world has suffered from deterioration caused by reaction with chemicals in the in-service environment. A small proportion also suffers deterioration associated with chemical reactions within the concrete itself. AAR is one such internal chemical reaction. AAR can induce expansion and cracking in concrete, particularly in concrete elements containing high levels of alkali and with sufficient moisture, either available internally in large elements or entering the concrete from external sources. In other cases, AAR may occur without causing physical damage, for example, if the extent of reaction is very limited or expansion is physically restrained, or if the reaction runs out of moisture or alkali.

The understanding of AAR in concrete structures is largely based on visual observations of physical damage, i.e. AAR that has had deleterious effects. Consequently, measures taken to ‘prevent’ AAR in structures implicitly aim to prevent AAR causing unacceptable damage, rather than preventing the reaction altogether. The approaches taken in this Handbook and international guidelines thus provide means to manage the risk of unacceptable damage. Unless explicitly stated otherwise, in this Handbook ‘AAR’ refers to AAR having deleterious effects.

While cracking caused by AAR can be visually severe and may affect the long-term durability of a concrete structure, thus requiring more maintenance interventions over its service life, the structural consequences of the reaction require careful analysis to determine their severity. Although the number of concrete structures deleteriously affected by AAR may be small, a number of these are critical structures (e.g. dams, retaining structures, bridges) with long design lives. This follows from the fact that some of these structures are more sensitive to deformation while others were more likely to have been built with high cement contents, resulting in greater amounts of available alkalis in the concrete.

AAR was first recognised as a problem in North America in 1940 when Stanton[(1)] reported that the expansion and cracking of concrete in some structures in California was related to a chemical reaction between alkalis in the cement and certain mineral constituents of the aggregate. As a result of Stanton’s work, in 1941 the US Bureau of Reclamation, after establishing that damage in two concrete dams was due to AAR, placed an upper limit of 0.60% by mass on the alkali content of cement used in its more important projects. However, many of the concrete structures that had cracked in the 1930s, including the two dams, were still reported as performing satisfactorily some 60 years later[(2)].

After the problem was first reported in North America in 1940, cases of AAR were reported in other countries: in Denmark (early 1950s), in Germany (early 1960s) in the UK (mid 1970s) and in Japan (early 1980s). In addition, significant cases of damage due to AAR have been reported in Canada, France, New Zealand and South Africa. Since 1974, 14 international conferences on AAR (including the 10th in Melbourne in 1996) have been held. The increased number of papers presented during more-recent conferences indicates that despite half a century of research, the various aspects of AAR in terms of testing, assessment, monitoring, suitable preventative and remedial measures, lessons learned and overall management are still being investigated and discussed around the world.

In Australia, research work on AAR was conducted by CSIRO in the 1940s and 1950s by Alderman, Vivian and others[(3,4)]. Their work showed that delayed reaction occurred between cement and cryptocrystalline quartz and that rocks containing opaline silica were highly reactive. It was also concluded that the use of low-alkali cement may not solve the problem if the aggregate is highly reactive. No work was reported in the 1960s or 1970s.

Extensive research and investigative work, including the development of new test methods, examination and diagnosis of AAR in field structures and the recommendation of mitigative measures, was conducted by Shayan and others at CSIRO and later at ARRB from the 1980s until the present. Carse and others at Department of Transport and Main Roads, Queensland were also active in research and field studies from the 1980s to 2000.

Incidences of significant damage due to ASR in Australia

A number of Australian concrete structures including dams and bridges have been identified as suffering from various levels of AAR. It has been identified in some dam structures[5,6] and several bridges in New South Wales, Victoria[7], Western Australia[8], Queensland[9,10,11] and Tasmania. Approximately one million concrete railway sleepers in Western Australia were also affected. Some of these structures are listed in Table 0.1 of the Introduction.

This table is indicative only and is by no means complete. Neither all structures under investigation or showing signs of AAR, nor the specific concrete details are included. Structures listed in the table in many cases require further attention which may include aesthetic repairs, further investigation and increased monitoring, or remedial measures. A number of the structures listed have been repaired, in some instances extensively, and some structures have been replaced. Repairs usually commenced within a few years of AAR being identified.

Since the 1996 edition of this Handbook, 12 dams, four bridges in Western Australia, three Rail bridges in Victoria, one bridge in Tasmania and four bridges in New South Wales have been identified as having damage due to AAR in unpublished reports. Only cases reported in published documents are detailed in Table 0.1.

Supplementary cementitious materials (SCMs) were not widely used in Australia to mitigate AAR until the mid 1990s. It is unlikely that many, if any, of the structures reported in Table 0.1 incorporated SCMs specifically to control ASR.