NZRMCA Technical Note 1

Alkali Silica Reaction Precautions for Normal Concrete

THE NEW ZEALAND READY MIXED CONCRETE ASSOCIATION INC.

Published by the Technical Committee, NZRMCA, May 2004

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Contents

INTRODUCTION

Several changes have taken place in respect to specifying concrete and the relationships between NZS 3104 - Concrete Production, NZS 3109 - Concrete Construction Amendment 1, 2003 and a revised TR 3 - Alkali Silica Reaction.

The revised version of TR 3, some 90 pages, has been posted on the CCANZ website – www.cca.org.nz, where it can be downloaded.

This Technical Note takes primary abstracts from TR 3 to demonstrate how the Concrete Producer needs to deal with the alkali aggregate reaction risk for Normal Concrete.

NZS 3104 - Concrete Production requires action by the Concrete Producer in respect of AAR risk matters.

> ***"Clause 2.4.2:***
>
> ***Where sand or aggregate are potentially reactive as defined in TR 3:***
>
> ***For Normal concrete, the concrete producer shall certify that the total alkali content in the concrete will not exceed 2.5 kg/m^3 from all sources. If not the concrete shall be designated as Special Concrete."***

The primary difference in those latest revisions to the Standard is that:

(a) The Concrete Producer is fully responsible for all Normal Concrete mixes, i.e. mixes that have been specified by 28 day strength and workability only.

(b) The Specifier becomes responsible for specifying any Special features and the means of demonstrating compliance for Special Concrete. The Concrete Producer still has the responsibility of designing the concrete mix to meet the special requirements set out by the Specifier.

Section 2.2.1 – Specification, is abstracted from TR 3.

2.2.1 Specification

The heading and clauses (a) to (c) below are provided as model specification clauses. Dialogue between specifier and supplier is implicit in the nature of Special Concrete, and therefore this procedure assumes that where necessary such discussions will include the measures to be taken to minimise the risk of ASR damage.

"Precautions for minimising the risk of ASR.

(a) The reactivity of the fine and coarse aggregates proposed for use in a particular concrete shall be determined by petrographic examination, accelerated laboratory testing or field experience as described in section 6.1 of TR3 (2003).

(b) If the aggregate supplier and/or concrete producer can confirm that the proposed aggregates are non-reactive as defined in clause 6.1 of TR3 (2003) then no further precautions need be applied.

(c) If the aggregate supplier and/or concrete producer cannot confirm that the proposed aggregates are non-reactive as defined in clause 6.1 of TR3 (2003) then the following precautions shall be taken:

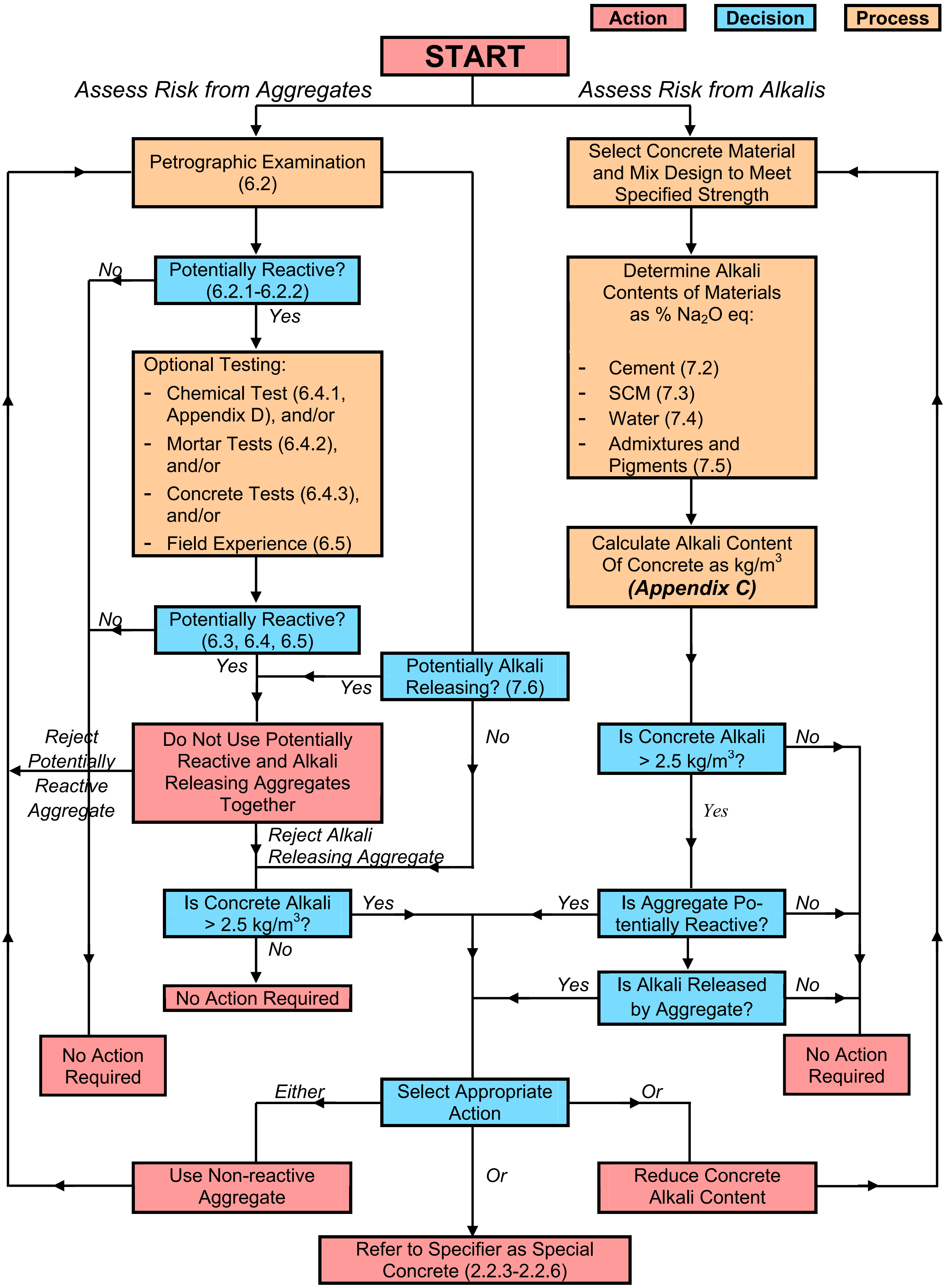
(i) For Normal Concrete as defined by NZS 3104:2003 the concrete producer shall certify that the total alkali content in the concrete shall not exceed 2.5 kg/m^3 from all sources.

(ii) Where the concrete producer cannot certify that the total alkali content is less than 2.5 kg/m^3 then the concrete shall be designated as Special Concrete. The specifier must be informed of the change in designation, and must take appropriate action.

(iii) For Special Concrete, the specifier shall evaluate and specify the risks associated with ASR according to clauses 2.2.3 and 2.2.4 of TR3 (2003), and shall specify the appropriate level of precaution required to minimise the risk of ASR damage according to clause 2.2.5 of TR3 (2003). The supplier shall then select appropriate preventive measures according to clause 2.2.6 of TR3 (2003), and shall provide supporting evidence such as calculations and/or test results to demonstrate to the specifier that the selected preventive measures will be effective."

One other issue that may arise is that if it is identified that your aggregate is one that can release alkali then you must not use reactive aggregates in the mix even if the 2.5 kg/m^3 can be met. Typical aggregates displaying this characteristic are Nepheline Basanite and Phonolite.

Figure 1: Procedure for Assessment of ASR Risk – Normal Concrete



PROCEDURE FOR ASSESSMENT

STEP 1:

In order to comply with (a) and (b) of the specification TR 3, 2.2.1, you need to check the petrographical definitions of the sand and aggregate by referring to the Aggregate Supplier. You need a statement that identifies that you are being supplied with material that is listed in either Table 6, TR 3 or Table 7, TR 3.

Table 6: New Zealand aggregates believed to be non-expansionary from field experience (with low alkali cement) or laboratory testing.

Greywacke	Limestone	Rhyolitic pumice
Basalt <50% SiO_2	Schist	Perlite
Phonolite	Quartz Sands	Vermiculite
Granite	Quartz-feldspar sands	

If the Aggregate Supplier confirms that all sands and aggregates comply with Table 6, then you need not check any further and need not take any special precautions to limit alkali levels.

If you change sand or aggregate supplier then the check must be carried out again.

Table 7: New Zealand aggregates or minerals known to be potentially reactive either from field experience or laboratory testing.

Basalt >50% SiO_2	Rhyolite	Cristobalite
Andesite	Volcanic glass	Tridymite
Dacite	Quartzite	
Amorphous and cryptocrystalline silicas including opal and chalcedony		

STEP 2:

If the Aggregate Producer confirms that some sands and/or aggregate are defined as in Table 7, then you will need to check whether the total alkali in the concrete from all sources does not exceed 2.5 kg/m^3.

If the alkali content is calculated to be below 2.5 kg/m^3 then no further action is needed. If you change the ingredients of the concrete mix then the calculation needs to be rechecked.

CALCULATION OF ALKALI CONTENT

To be able to calculate the alkali content the following information is required:

1. Cement Alkali level expressed as % Na_2O Equivalent. This value is contained on Standard Cement Test Certificates. Currently values between 0.4% and 0.6% are typical for cements used in New Zealand. Clearly cement contents of 400 kg/m^3 and the higher of the range figure 0.6% will give a figure of 2.4 kg/m^3, i.e. very close to the limit.

2. **Supplementary Cementitious Materials**

   Alkali content per kg. This will need to be supplied by the SCM supplier if it is being included in the Normal Concrete.

3. **Alkalis from Sodium Chloride Contamination of Aggregates**

   Alkali content per kg mass of aggregates. This information needs to be supplied by the Aggregate Producer.

4. **Mixing Water**

   The Sodium and Potassium contents of the mixing water needs to be analysed as mg/L by the Concrete Producer. If potable water is being used there is not need to obtain an analysis.

   If wash water/slurry is being used then analysis needs to be carried out. Samples need to be taken over an operational period of time, e.g. one week, in order to capture a realistic range of values.

   In all instances where recycled wash water is used it will be necessary to calculate the total (soluble and insoluble) alkali level of the recycled wash water. (Measurements taken from some plants have produced total alkali levels from grey water as high as 0.5 to 0.6 kg / m^3.) Note that clear washwater (with the sediment settled out of suspension) will give lower levels of total alkalis.

   To do this calculation it will be necessary to measure the sodium and potassium levels present in the recycled mixing water, with the results expressed as mg or g/L. This analytical work is done in chemistry test laboratories, which are located in all of the main centres throughout New Zealand.

In instances where potable water is used exclusively, this test programme is not necessary.

Samples for analysis need to be taken over a period of time such as one "typical" week, in order to capture realistic results.

Where there is a high cement content mix being produced with admixtures containing alkalis (e.g. some superplasticisers) and recycled washwaters, it is possible that over 1 kg of the total allowance of 2.5 kg will be accounted for by these two materials, before allowing for the alkalis present in the cement.

In cases such as this, it may be necessary for the producer to either reduce the amount of recycled wash water used, or completely substitute it with potable water to ensure that the maximum limit of 2.5 kg is not exceeded.

If the concrete is being used in a low risk environment as defined in Table 2 of TR3, the total alkali limit can be raised to 3 kg / m^3, but this mix is then classed as a "Special Concrete" in terms of NZS 3104 if it is designed to minimise the risk of ASR.

5. Chemical Admixtures and Pigments

The alkali contents of admixtures need to be supplied by the Supplier. The levels can vary quite considerably depending on the admixture type. A typical range is shown in Table 9, TR 3. However, values for your Admixture supplier need to be supplied.

Table 9: Alkali contents of concrete admixtures.

Admixture type [1]	Na_2O (%) [2]
Water reducing	< 0.1 – 5.0
Air entraining	< 0.2 – 0.5
Superplasticising	1.8 – 5.0
High early strength superplasticising	~ 11.0
Set accelerating	< 0.1 – 1.8
Set retarding	~ 5.3
Pump aid	< 0.1
Shrinkage reducing	< 0.1

1. These data represent products from one manufacturer only. They ***must not*** be used to calculate alkali contents of proposed concretes.

2. These values are analyses for sodium only. They do not include K_2O so are not alkali equivalents. Sodium is often the prevalent alkali.

TR 3, Appendix C – Sample Calculations, is included.

Appendix C: Sample Calculations

The **total alkali content of a concrete mix** is calculated as follows:

$$A = Ac + B + H + W + D$$

where A = total alkali content of the concrete mix

Ac = total alkali content of the Portland cement or Portland-Limestone cement (section 7.2)

B = total alkali content of SCM admixture (section 7.3)

H = reactive alkali contribution made by sodium chloride contamination of both the fine and coarse aggregate (section 7.6)

W = total alkali contribution made by the mixing water (section 7.4)

D = total alkali contribution made by chemical admixtures and pigments (7.5)

The **alkali contributed to the concrete mix by the Portland cement or Portland-limestone cement** shall be calculated from:

$$Ac = \frac{C \times a}{100}$$

where Ac = total alkali content of the Portland cement or Portland-limestone cement to the nearest 0.1 kg/m^3

C = the Portland cement or Portland-limestone cement content of the concrete in kg/m^3

a = certified maximum percentage of acid soluble alkali content of the Portland cement or Portland-limestone cement.

The term "acid soluble alkali" shall refer to the alkali metals sodium and potassium expressed as their oxides. The alkali content of Portland cements and Portland-limestone cements shall be defined as the percentage mass of equivalent sodium oxide (Na_2O) calculated from:

$$\%\ Na_2O\ \text{equivalent} = \%\ Na_2O + 0.658 \times \%\ K_2O$$

The method used in determining the acid soluble alkali content of Portland cement and Portland-limestone cement shall comply with the methods given in ASTM C114.

(Appendix C continued)

The **total alkali contributed by supplementary cementitious materials** shall be calculated from:

$$B = \frac{E \times f}{100}$$

where B = average total alkali content contributed by the SCM

E = the SCM content of the concrete in kg/m^3

F = total alkali content of SCM

The method used in determining the total alkali content of SCM shall comply with the methods specified in the relevant standard specification for the SCM(s). Note that for blastfurnace slag and fly ash it may be necessary to include all, some or none of the alkali depending on the quantity of the material used.

The **reactive alkali contributed by sodium chloride contamination of the aggregates** shall be calculated from:

$$H = \frac{0.76 \times [(NF \times MF) + (NC \times MC)]}{100}$$

where H = reactive alkali contribution made to the concrete by the sodium chloride present in the aggregates expressed as kg/m^3 sodium oxide equivalent

NF = chloride ion content of the fine aggregates as a percentage by mass of dry aggregates

MF = fine aggregate content in kg/m^3

NC = chloride ion content of the coarse aggregate as a percentage by mass of dry aggregates

MC = coarse aggregate content in kg/m^3

The factor 0.76 is derived from the conversion of chloride ion to sodium oxide equivalent and the composition of seawater.

The chloride ion content of the coarse and fine aggregates used in the concrete shall be determined at agreed intervals in accordance with BS 812: Part 117. When the total chloride ion level in the aggregates is less than 0.005% it shall be regarded as nil.

(Appendix C continued)

The **alkali contributed by the mixing water** to the concrete shall be calculated from:

$$W = \frac{(Na \times 1.35 + 0.658 \times K \times 1.20) \times C \times W/C}{1{,}000{,}000}$$

where W = equivalent alkali contributions made to the concrete by the alkali ions sodium and potassium present in the water in kg/m^3

Na = sodium ion content present in the water as parts per million (mg/L)

K = potassium ion content present in the water as parts per million (mg/L)

C = Portland cement or Portland-limestone cement content of the concrete in kg/m^3

W/C = the water cement ratio

The water shall be analysed for sodium and potassium ions by recognised methods such as those published by the American Public Health Association. Where the equivalent alkali (calculated as Na + 0.585K) present in the water is less than 190 mg/L (ppm) it shall be treated as nil

The **alkali contributed to the concrete by chemical admixtures and/or pigments** shall be calculated from:

$$D = \frac{y}{100} \times \frac{C}{100} \times Z, \text{ or}$$

$$D = \frac{y}{100} \times \frac{C}{100} \times \frac{Z_1 d}{100}$$

where D = alkali contribution made to the concrete by chemical admixtures and/or pigments to the concrete in kg/m^3

C = the Portland cement or Portland-limestone cement content of the concrete in kg/m^3

y = sum of the percentage reactive alkali contents of chemical admixtures and/or pigments

Z = weight of solid admixture or pigment added to the concrete per 100kg of cement

Z_1 = volume of liquid admixture or pigment added to the per 100 kg of cement

d = density of liquid admixture or pigment

(Appendix C continued)

The following **example** shows how the alkali content of a concrete containing no SCM might be evaluated. It is based on Appendix 2 of the 1991 edition of this publication, and is not intended to represent a commercial mix design.

A structure is to be built to a 50 year service life requirement. A compressive strength of 45 MPa is specified, with no other special requirements so the concrete is deemed to be Normal Concrete. Non-reactive aggregate is uneconomic, and the strength can be achieved without an SCM. Hence the concrete needs to have a total alkali content of 2.5 kg/m^3 or less.

The supplier proposes a mix design with Portland cement content of 385 kg/m^3. The cement the supplier proposes to use has a maximum acid soluble alkali content of 0.60% Na_2O equivalent.

The alkali content of the mix constituents is:

Material	Mix Proportions	Alkalis
Portland cement	385 kg/m^3	Na_2O equivalent 0.60%
Coarse aggregates	1,125 kg/m^3	-
Fine aggregates: Source (a) Source (b)	 420 kg/m^3 380 kg/m^3	 - Chloride ion content 0.03%
Case A		
Typical admixture	Manufacturer's recommended dosage	Na_2O equivalent 0.01kg per 100kg Portland cement when used at recommended dosage
Case B		
Superplasticiser	Manufacturer's recommended dosage	Na_2O equivalent 0.1kg per 100kg Portland cement

The total alkali content of the concrete in each case is calculated as shown in the table on the following page.

In case A the total alkali content is 2.4kg/m^3, which is acceptable, but in case B is it is above the 2.5 kg/m^3 limit. The options for case B are to:

(a) Select a superplasticiser with an alkali content that will reduce the concrete alkalis to less than 2.5 kg/m^3; or

(b) Consider the use of an appropriate amount of SCM as part replacement of the Portland cement; or

(c) Specifically request that cement be supplied with an acid soluble alkali level of 0.50% or less.

(Appendix C continued)

The most appropriate option is selected by the supplier. If an SCM is used (option [b]) and the concrete alkali content remains above 2.5 kg/m^3, the concrete becomes Special Concrete. The supplier must then advise the specifier of the change, and must provide evidence such as calculations or test results to demonstrate that this will provide adequate protection against ASR damage in accordance with Section 5.4.1.

	Case A **Alkali content using typical admixture (kg/m^3)**		**Case B** **Alkali content using a superplasticiser (kg/m^3)**	
Portland cement	$\frac{385 \times 0.60}{100}$	= 2.3	$\frac{385 \times 0.60}{100}$	= 2.3
Coarse Aggregate	-		-	
Fine aggregate Source (a) Source (b)	- $\frac{260 \times 0.03 \times 0.76}{100}$	- = 0.06	- $\frac{380 \times 0.03 \times 0.76}{100}$	- = 0.09
Admixture	$\frac{385 \times 0.01}{100}$	= 0.04	$\frac{385 \times 0.1}{100}$	= 0.39
Water	Alkali <190ppm	= 0.00		= 0.00
Total concrete alkali content		**2.40**		**2.78**

STEP 3:

ALKALI CONTENT OVER 2.5 KG/M^3

If the calculations show that some mixes exceed the 2.5 kg/m^3, then this fact must be notified to the Specifier. Typically these situations are likely to be higher strength mixes with higher cement contents combined with a superplasticiser. These concrete mixes are designated Special Concrete.

The Specifier will then check the Special Concrete provisions of TR 3. It may be that alkali values just above the 2.5 kg/m^3 can be accepted by the Specifier after considering the exposure and application of the concrete.

In order to enter into a discussion with the Specifier on these issues, which are not contained in this note, reference must be made back to the full TR 3 document available on www.cca.org.nz.

SUMMARY

1. The Concrete Producer is responsible for ensuring that the 2.5 kg/m^3 limit is not exceeded in Normal Concrete.

2. Where this cannot be achieved the Concrete Producer must notify the Specifier to declare the mix Special Concrete.

3. Special Concretes need to be evaluated by full reference to TR 3.

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