Wednesday 9 November

2.00- 3.30pm Concurrent Technical Sessions: 4

28. NZI Centre – Design of Multistorey Towers
   – Billings LJ, Thom CW
   Beeca Carter Hollings & Ferner Ltd, Auckland

27. Auckland Trotting Club New Grandstand
   – Brown PB
   Thorburn Davidson Ltd, Auckland

29. Mid City Towers – an Efficient Precast Concrete Framed Building
   – Poole RA, Clendon JE
   Holmes Consulting Group, Christchurch

42. Influence of Cement Paste Flocculation on its Rheological Properties
   – Nawa T., Eguchi H., Fukaya Y.
   Chichibu Cement Co. Ltd, Japan

47. Blended Cements Inhibit AAR Expansion
   – Kennerley RA
   New Zealand Cement Holdings Ltd

48. Alkali-Aggregate Reaction in Concrete – a Problem in New Zealand Too
    –* Rowe G.H., Smith L.M., Freitag S.A., Doyle R.B., St John D.A.
      * Central Laboratories, Works Corporation

49. Strength of Cement-Aggregate Bond
    – Taylor MA
    University of California, Davis, USA

4.00- 5.30pm Concurrent Technical Sessions: 5

19. Structural Walls of Limited Ductility
    – Paulay T, Mestyaneck JM
    Department of Civil Engineering, University of Canterbury

20. Experiments on Vertical Joints of Precast Concrete Wall Panel Structures Considering Restricting Effects of Horizontal Ties
    – Mochizuki S
    Musashi Institute of Technology, Japan

21. A Study on Failure Control and Ductility of Layered Shear Wall Frame System
    – Mochizuki M, Umeda M
    Kogakuin University, Japan

22. Modelling Fire Performance of Concrete Walls
    – Buchanan AH, Carr AJ, Munukutla R
    Department of Civil Engineering, University of Canterbury

50. Development and Commercialisation of Advanced Strength Steel Cement Composites
    – Busck C.J.
    Fibre Cement Technology Ltd, Auckland

51. Ferrocement Applications in Housing
    – Paramasivam P, Lee SL
    National University of Singapore

69. Top-Down Construction – Construction Joints in Underground Concrete Structure
    – Takahei Y.
    Takenaka Technical Research Laboratory, Japan

70. A Top-Down Method of Constructing Permanent and Temporary Concrete Retaining Walls Incorporating Soil Nailing
    –* Ashley A., Bird A.
      * Smith Lecuhrs Ltd, Auckland
BLEND CEMENTS INHIBIT ALKALI AGGREGATE EXPANSION OF CONCRETE

R A Kennerley
Milburn New Zealand Ltd

SUMMARY

The effectiveness of various New Zealand additives in inhibiting alkali aggregate expansion is discussed. Pumice and diatomite both possess the desired properties; local fly ash and melter slag do not and may themselves contribute to expansion. A considerable amount of testing is required before these latter materials can be recommended for use. Blended cements have the advantage, compared with separate batching of additives, that they can be manufactured within close limits and their performance characteristics can be guaranteed.

INTRODUCTION

Blended cements, or composite cements as they are sometimes known, consist of mixtures of inorganic additives and Portland cement produced by the combined grinding and/or blending of finely-ground components. The most commonly used additives are blast-furnace slag, fly ash and, more recently, silica fume (all of which are produced as waste materials), and natural pozzolans. In some countries inert fillers, such as limestone and cement kiln dust, are also used as additives in blended cements; their use is outside the scope of this paper.

In New Zealand the requirements for blended cement are set out in NZS 3123:1974, the New Zealand Standard Specification for Portland Pozzolan Cement. NZS 3123 provides for the use of natural pozzolans, calcined clays and shales and fly ash, but does not cover the use of slag or silica fume. Requirements for slag cements are contained in ASTM Standard Specification C 595-86 for Blended Hydraulic Cements.

One of the properties frequently desired of blended cements is the ability to inhibit or control expansion due to the alkali-aggregate reaction. This property is of special importance in situations where the aggregate to be used is potentially reactive with cement alkalies and where the cement and/or concrete is likely to have a high alkali content.

Not all blended cements inhibit alkali-aggregate expansion. Requirements for expansion control in both of the above specifications are optional and need only be applied where the cement is for use with an alkali-reactive aggregate.

Considerable publicity has been given recently to the increasing number of concrete structures in New Zealand that have developed cracking due to alkali-aggregate reactivity [12]. The first case of such cracking was reported in 1969 [7]; known cases now number 60 [12]. There is thus an
urgent need to ensure that the materials selected for use will not contribute to the expansive cracking of concrete at a later age. One method of providing protection against expansive cracking of concrete containing alkali-reactive aggregate is to use a blended cement which has been shown to inhibit alkali-aggregate expansion. Such a cement, if available in New Zealand, would provide designers with a safe and acceptable alternative to Portland cement.

**ADDITIVE MATERIALS**

Natural Pozzolans

Investigations into the properties of New Zealand pozzolans have shown that diatomite and pumice are the most useful natural materials [6].

These investigations were carried out on a range of materials comprising respectively rhyolite, pumice, diatomite, diatomaceous pumice, ignimbrite, pumice sand, andesitic sand and basaltic tuff using test methods similar to those which were in use at the U.S. Bureau of Reclamation at the time [10]. Results showed that diatomaceous materials possessed superior properties, particularly the ability to inhibit alkali-aggregate expansion. The highest reduction in expansion result recorded was for a sample of andesitic tuff, but this material performed poorly in strength tests. Pumicites tested at 20% cement replacement did not quite achieve a minimum target value of 75% reduction in expansion but they performed very well in strength tests on mortar. An ignimbrite performed poorly, while a pumice sand and a basaltic tuff each showed negative reduction, (i.e. expansion).

A pumicite, a diatomite and two diatomaceous pumicites were subsequently selected for testing in concrete to determine the properties of the resultant pozzolanic concretes [6]. These tests did not consider their effects on alkali-aggregate expansion. The materials chosen were of particular interest because deposits containing them were located reasonably close to hydro development projects on the Waikato River in areas where aggregates available were known to be potentially reactive.

A series of tests was carried out recently using the method of ASTM C441-81 for Effectiveness of Mineral Admixtures in Preventing Excessive Expansion of Concrete due to the Alkali-Aggregate Reaction, on 80-20 blends of Portland cement (alkalies 1.0% as equivalent Na2O) and various additives. Results showed that, with pumicite typical of that found in the Central North Island, a reduction in expansion of 75% is just achieved where the pumicite has a fineness of either 880 m²/kg or 560 m²/kg Blaine. Using a blend of 3 parts pumicite to 1 part finely-ground diatomite (by mass), the reduction in expansion was 93%. The diatomite component thus improved the effectiveness of the pumicite in reducing expansion. Tests on concrete [6] with up to 15% cement replaced by a diatomaceous pumicite have shown that strengths are also improved. This effect is somewhat similar to that reported [9] where the properties of fly ash concrete containing a relatively unreactive Class F fly ash, particularly early strength and durability, are shown to be improved by the addition of silica fume of far greater fineness and reactivity than the fly ash.

Results of laboratory tests (ASTM C227) on mortar bars using Waikato River terrace sand from Atiamuri and Ongaroto basalt aggregate with Portland cement containing respectively 0.97% and 0.70% alkalies as equivalent Na2O are plotted in Figure 1. With the higher alkali cement, the control mortar has expanded appreciably by 6 months; where 25% or 12% respectively of this
cement was replaced by Kopakorahi pumicite (890 m$^2$/kg) or by very finely-
ground Whirinaki diatomaceous pumicite, expansion to 12 months was
inhibited. While the level of expansion of the control is below 0.10% at
6 months which ASTM C33-86 considers to be excessive, it should be noted
that by 12 months the specimens showed extensive cracking. Criteria for
assessing reactivity in use at the time these tests were carried out were
those of the U.S. Bureau of Reclamation, namely 0.04% expansion at
6 months and 0.10% at 12 months. Tests were therefore discontinued at
12 months. Information on possible expansion at later ages which has been
found to occur with cements containing alkali as low as 0.77% [13] or
with low alkali cements [1] was thus lost.

Fly Ash

Fly ash produced by firing pulverized Waikato sub-bituminous coal in power
stations, provided it is sufficiently fine, has been shown to possess weak
pozzolanic properties [8]. The ash is classified Class C according to
ASTM C618, having a relatively high lime content. Huntly fly ash is of
adequate fineness and has low carbon and sulphur contents; but it has a
variable composition and significantly retards the set of cement due to
the presence of varying amounts of soluble borates. It also contains
"available alkali" (ASTM C311) frequently in excess of and occasionally
more than twice the optional ASTM C618 limit of 1.5% maximum.

Tests show that a 30% replacement of a high alkali cement (1.2% as
equivalent Na$_2$O) by Huntly fly ash (zone 1 precipitator, CaO 20%) is
required to achieve a reduction in expansion at 14 days (ASTM C441 test) of
75%. Mortar expansion at 14 days was 0.09%.

For some fly ashes containing high total alkali or excessive "available
alkalies" there is a "pessimum limit" of cement replacement at which
expansions are reduced [3,4]. In some instances more than one "pessimum
limit" has been detected for a given combination of materials.

In view of the variable composition of Huntly fly ash and the recognition
[11] that the role of alkalies in high total alkali fly ash is not
understood, it would be unwise to use this material in concrete containing
reactive aggregates without carrying out extensive tests to determine the
conditions for its safe use.

Slag

Blast-furnace slags have been shown to be very effective in reducing
alkali-aggregate expansion [2,5]. However quenched titaniferous melter
slag from Glenbrook differs in type from blast-furnace slag and contains
a relatively low glass content. Even allowing for the presence of
appreciable crystalline material, the remainder has a hydraulic index
below 1.65 which is the minimum acceptable level for blast-furnace slags
[2]. When subjected to the ASTM C441 test, a blend of 80 parts Portland
cement (1.0% alkalies as Na$_2$O) and 20 parts granulated melter slag gave
an increase rather than a reduction in expansion compared with the control
mix. This property, together with variable composition, suggests that
the melter slag may not be suitable for use as an additive in blended
cement.
Fig 1: Expansion of mortar bars
Test method - ASTM C227
Aggregate - 1 part Waikato River sand
2 parts Ongaroto basalt
BLEND CEMENT USAGE IN NEW ZEALAND

A Portland-pozzolan cement was first manufactured in New Zealand in the 1960s and consisted of a blend of Portland cement from a vertical shaft kiln and Middlemarch diatomite (12% cement replacement). In 1986-7 a blend of sulphate-resisting Portland cement and Ohaaki pumicite (17% cement replacement) was manufactured and used in the Ohaaki geothermal power project to produce a concrete with increased resistance to attack by aggressive geothermal fluids. In each case the pozzolan was interground with cement clinker and gypsum, the composition of the blend being controlled to within quite narrow limits.

BLEND CEMENT VERSUS SEPARATE ADDITION OF ADDITIVE

A blended cement whose composition is closely regulated and whose performance has been thoroughly tested offers distinct advantages to the concrete producer, especially where the aggregate may be alkali-reactive. Such a cement will have had to meet stringent specifications with regard to expansion control, strength and uniformity. Where used it would avoid the necessity of providing for the separate storage and batching of the additive.

Worldwide the use of blended cements is increasing steadily, partly due to the need to utilize waste materials, such as fly ash and slag, and to conserve energy in cement and concrete manufacture; but also in response to the growing recognition by users of the many advantages they offer such as improved workability and ease of placement, and to growing confidence in their performance.

CONCLUSIONS

Blended cements containing additives which, when tested meet the requirements of ASTM C441 and C618, can be used to inhibit expansive cracking of concrete due to the alkali-aggregate reaction. The cements should satisfy NZS 3123:1974; or in the case where the additive is slag, ASTM C595-86.

Diatomite and pumicite are both suitable for use as additives; but Huntly fly ash and Glenbrook melter slag should not be used without exhaustive performance testing to prove their acceptability for use with alkali-reactive aggregates.

REFERENCES


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12. St John, D.A. 1988 Alkali-aggregate reaction and synopsis of other data on AAR, New Zealand Concrete Construction, April 7-14, May 3-11.