EFFECTS OF ALKALI-REACTIVE CRUSHED FILLERS ON EXPANSIONS DUE TO ASR

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ABSTRACT

Investigations of alkali-reactive fillers by the Concrete Prism Test (CPT) have shown diversities in the effects between the different fillers. Crushed bottle glass and fillers from Icelandic rhyolite have shown pronounced inhibiting effects on expansions due to ASR. On the other hand, addition of fillers of Norwegian alkali reactive cataclastic rocks (mylonite, cataclasite) caused no effect or resulted in small increases in expansions. The fillers that inhibited the expansion have been proven to be highly pozzolanic tested by thermo gravimetric analysis (TGA). This is not the case for cataclastic rocks, which have a very low pozzolanic reactivity at 38°C but relatively high at 80°C. The reactivity of the different fillers has been examined by micro-structural analyses.
Studies of the fillers using the accelerated mortar bar test (AMBT) suggest that this method does not always give reliable predictions on the effects of cataclastic rock fillers. The inhibiting effect of these fillers predicted by the AMBT was turned to no effect or a small increase in expansion when tested by the CPT. The AMBT seems to give reliable predictions on the behaviour of real pozzolans like silica fume and fly ash as well as crushed bottle glass and Icelandic rhyolite. The explanation for the different behaviour between the CPT and AMBT for cataclastic rocks might be the insignificant pozzolanic reactivity at lower tempatures (38°C) and the increased pozzolanic reactivity at higher temperatures (80°C) proven by TGA. Testing of cataclastic materials (and probably other crystalline reactive materials) by methods using elevated temperature (e.g. AMBT) aiming to accelerate the ASR may therefore give unreliable predictions of the behaviour in field. This is because the "balance" between the ASR and the desired pozzolanic reaction may be changed by elevated temperature in the laboratory compared to the true situations in field.

Keywords: Alkali Silica Reaction, filler, pozzolanic reactivity, concrete prism test. accelerated mortar bar test

1 INTRODUCTION

It is a well-known fact from the literature that the particle size of alkali-reactive rock particles has a large influence on the expansion characteristics. A recent Norwegian research project Lindgård & Wigum [1] has indicated that the coarse aggregate fractions (> 8 mm) are more deleterious in field structures than the fine fractions (< 4 mm). This is valid for Norwegian slowly reacting aggregates, but should not be generalized. French [2] has reported that for chert and volcanic glass the particles sizes from 3 to 7 mm appears to be the most damaging. Further, he reported that for aggregate types such as recrystallized sandstone, meta-quarzite, greywacke and argillite, the coarser sizes appear to be most deleterious.

There are conflicting reports in the literature regarding the effects of very fine particles in the order of 125 μm and smaller. There are some documented cases indicating that particles below a certain limit show pozzolanic behaviour, thus being able to inhibit the expansive reactions caused by the alkali silica reaction. Shao et al. [3] have shown that fillers of crushed bottle glass smaller than 38 μm are able to reduce the expansion relative to the control mortar containing no glass filler. The coarser filler fractions were reported to have less effect. The experiments were performed using the accelerated mortar bar test. Hudec & Chamari [4] have reported a similar set of experiments, where glass fractions below 75 μm reduced the expansions due to ASR. On the other hand, fractions larger than 75 μm gave a tendency of increased expansions of the mortar bars.

Vivian found in 1951 (reported in Diamond & Thaulow) [5]) that siliceous magnesium limestone containing opal and chalcedony, yielded significant rapid expansions for all sizes down to about 70 μm. Particles in the range between 50 and 70 μm gave expansions after six months delay, while particles smaller than approximately 50 μm caused no expansions at all. When testing different sizes of opal, Vivian generally found the expansions to increase with falling particle size. Again, the particles smaller than 50 μm gave no expansions at all.

Diamond & Thaulow [5] carried out an investigation with opal of α-cristobalite type, which was crushed and sieved into fractions down to 20-30 μm. Standardised non-reactive sand was used as reference aggregate, while 5 or 10 % crushed opal of different sizes was added to the mortars. The specimens (cylinders with a diameter of 10 mm and a length of 20 mm) were stored above water at a temperature of 20° C. The results showed that 10 % opal gave significantly higher expansions than 5 %. However, the results did not give evidence to any significant effect of particle size, as all particle sizes were capable of producing large expansions. The smaller sizes gave rapid expansion up to 2.5 %. The coarser sizes gave slower expansion, but still in the same order as the finest fractions. If there exist any critical size limit where no expansion would appear below this limit, the limit is lower than 20-30 μm for this particular aggregate.

At present, the effect of the particle size appears to be confusing and is still far from being fully understood. Obviously, the effect o f fillers may vary from causing rapid harmful expansions, to acting as effective inhibitors due to pozzolanic behaviour. It is a paradox that a) the reactive component in the alkali silica reaction, disordered or amorphous silica, is generally the same component that reacts with calcium hydroxide in the pozzolanic reaction, and b) pozzolanic materials have shown to be very effective in reducing cracking and expansion due to ASR. The similarity between the pozzolanic reaction and the alkali-silica reaction has been pointed out by several scientists, e.g. Urhan [6] , Wang & Gillot [7] and Xu et al. [8] .

2 SCOPE OF WORK

The work presented here is part of a recent doctoral project by Pedersen [9] , aiming to further develop knowledge related to utilization of crushed concrete aggregates. A central part of this project has been to clarify the possibilities and limitations of using alkali-reactive crushed rock fines in concrete, with special attention to mylonite filler from Tau located in the Southwestern part of Norway. The doctoral work has included studies on the effect of fillers on rheological properties of fresh concrete, compressive strength as well as studies on expansive reactions due to ASR. The part presented here has focused on the following:

- Examine the possibilities and limitations of using crushed alkali-reactive fines in concrete
- Examine if the accelerated mortar bar test gives reliable predictions of the long-term behaviour in concrete
- Examine the relationship between pozzolanic reactivity of fillers and their potential of being deleterious or beneficial in concrete

Some important findings of the doctoral study of Pedersen [9] are presented in the following, while the full documentation is found in the doctoral thesis.

3 EXPERIMENTAL DETAILS

3.1 Experimental work

A variety of fillers (see description in Section 3.3) have been tested with respect to pozzolanic reactivity and expansive behaviour. Most of the fillers have been split into different fractions using an air classifier, giving the opportunity to study the effect of particle size distributions of the fillers.

The AMBT was used as a screening method prior to testing by the CPT, which is believed to give the most reliable prediction of the long-term effects of alkali-reactive rocks as well as evaluation of mix design parameters. An important matter of the testing was to evaluate to what extent the AMBT is useful to predict the long-term effects of alkali-reactive fillers.

To investigate to what extent alkali-reactive fillers have a potential to react pozzolanic, the direct pozzolanic reactivity was tested for 0-20 μm fractions of the fillers. The effect of high curing temperatures (80°) was tested for some fillers to investigate the effect of such high temperatures as used by the AMBT. Details of the test method are given in Section 3.2, while descriptions of the materials are given in Sections 3.3.

3.2 Test methods

3.2.1 Concrete prism test

The effect on expansive reactions was tested using a Norwegian version of the concrete prism test (CPT) described by Lindgård et al. [10]. In all the experiments presented here, the fine aggregate (< 5 mm) consisted of non-reactive glacio-fluvial granite/gneiss, while the coarse aggregate was alkali-reactive crushed mylonite. The tested fillers replaced the non-reactive sand by volume, meaning that the amount of reactive coarse mylonite was constant in all mixes. The w/c ratio and the amount of cement was constant for all mixes (0.45 and 400 kg/m^3, respectively), the alkali level was adjusted to Na_2O-equivalent of 5 kg/m^3 by addition of NaOH. The prism sizes were 100 x 100 x 450 mm.

3.2.2 Accelerated mortar bar test

The Norwegian practice of the accelerated mortar bar test (AMBT) is described by Lindgård et al. [10]. The reference sand used in the present study was used as the 0-4 mm fraction submitted from the manufacturer, while the particles smaller than 0.125 mm was removed by sieving. A comparison has shown that this 0.125-4 mm grading gives the same expansion as the standard 0.15-4.8 mm grading as specified in the original procedure (0.16 % after 14 days). The w/c ratio and the amount of cement were kept constant for all mixes (0.47 and 600 kg/m^3, respectively), and the tested fillers replaced the mylonite sand by volume. The size of the mortar bars was 40 x 40 x 160 mm.

3.2.3 Pozzolanity by thermo gravimetric analysis

The pozzolanic reaction reduces the content of calcium hydroxide (CH) in a cement-based system. The kinetics of the pozzolanic reaction may then be observed by monitoring the CH content as a function of time. Calcium hydroxide decomposes according to Equation 1 in a temperature range of approximately 450-550°C:

$$Ca(OH)_2 \rightarrow CaO + H_2O \qquad (1)$$

By using thermo gravimetric analysis (TGA), the pronounced weight loss due to the decomposition of CH may qualify as a measure of the pozzolanic reactivity.

In the present study, the fillers were mixed with calcium hydroxide (CH) and artificial pore water in a weight proportion of 50:35:15 of filler, water and CH, respectively. (The amount of water had to be adjusted to 40 for rhyolite to reach a workable mix.) All mixes were left for sealed curing in small glasses at varying temperatures. A small quantity of water was added, carefully without disturbing the mix, at the top layer of the mixture in each glass at 2 days of curing. This was done to secure that the reactions not stopped due to lack of water. At the specified curing time, each sample was ground and dispersed in ethanol, followed by filtering and drying at 105°C. The thermal analyses were carried out on a NETZSCH 409 STA, with a heating rate of 10°C/min, using nitrogen as a purge gas and aluminium powder as a reference. The weight of the samples was 150 mg.

As described by Justnes [11], the pozzolanic reaction involves the alkalis normally present in a Portland cement system. In the absence of a natural source of alkalis, alkalis should then be added to the mix in order to accelerate the reaction speed. Artificial pore water simulating the chemistry of the actual pore water obtained when using the CEM I, Norcem Standardsement, was therefore used as mixing water. This particular cement has a K/Na molar ratio of 2, and gives a pH of approximately 13.5. The artificial pore water was made by mixing 11.83 g of KOH and 4.22 g of NaOH per litre of water, thus giving the K/Na molar ratio of 2, and a OH^- concentration of 0.3162 moles/l, equivalent to a pH of 13.5. The use of this artificial pore water intended to simulate the chemistry of the pore water in real concrete.

Similar methodology to determine the pozzolanic reactivity as used in the present study has recently been reported by Justnes & Østnor [12] and by Biernacki et al. [13].

3.2.4 Micro structural analysis

Micro structural analysis is a method using different microscope techniques. In Norway the combination of polished fluorescence impregnated polished core slabs and fluorescence impregnated thin sections are always used. Core slabs are examined by use of a binocular microscope and visual observations e.g. reaction sites and reaction products can be investigated. Examined under UV-light cracks and porosities (as gel) are easily identified. Thin sections are examined under a petrographic microscope mounted with polarising filters and UV-filters. Here aggregate, cement paste and reaction products can be assessed. Micro structural analysis is the only secure method for documentation of ASR in concrete.

3.3 Materials

3.3.1 Cement

Norcem Standard, CEM I – 42.5 R, with Na_2O-equivalent of 1.02 %

3.3.2 Fine and coarse aggregate

Granite/gneiss:

Non-reactive glacio-fluvial reference aggregate.

Mylonite:

Crushed alkali-reactive rock. Petrographic description as given by Jensen & Fournier [14]: "*Grey-greenish, foliated and fine grained. Cataclasts or clusters with grain sizes ~0.4 mm dominate the rock and consist of altered feldspar, sericite, amphibole and carbonate minerals. Irregular bonds and linsoids of elongated re-crystallized quartz, have individual crystals on 0.01-0.05 mm. The rock was formerly classified as quartz mylonite but is more correctly classified as blastomylonite*"

Mylonite is considered reactive, and has given the following performance by the CPT and the AMBT:

- 0.16 % expansion at 14 days (AMBT)
- 0.093 % expansion at 1 year (CPT, coarse mylonite aggregate > 5 mm tested in combination with fine non-reactive granite/gneiss)

3.3.3 Fillers

Mylonite:

Crushed rock filler, petrographic description given in the previous section.

Cataclasite:

Crushed rock filler, petrographic description as given by Jensen & Fournier [14]: "*Greenish, homogenous and fine-grained. The major constituents are feldspar particles in a matrix of quartz, "crushed" feldspar, dark minerals and mica. Average grain size of the matrix is 0.01-0.03 mm. The feldspar crystals are max. 0.7 mm and the quartz crystals are mostly about 0.05 to 0.3 mm.*"

Cataclasite has given the following performance in the AMBT and CPT:

- 0.24 % at 14 days (AMBT)
- 0.28 % at 1 year (CPT, coarse cataclasite aggregate > 5 mm tested in combination with fine non-reactive granite/gneiss)

Rhyolite (Hvalfjörður, Iceland)

Crushed Icelandic alkali-reactive rock filler, petrographic description as given by Hólmgeirsdóttir [15]: "*The rhyolite has a glassy texture with concoidal fractures and flow structures. Phenocrystals are feldspars, mainly plagioclase but also microcline, and to a lesser extent pyroxene. The groundmass mineral assembly is hard to establish because of small crystal size, however, this is mainly feldspars and quartz. Opaque minerals are also existent in the more crystallised particles. The particles are altered to various extents, ranging from almost no alteration evident to almost completely alteration (rare). The alteration mineral assembly consists of zeolites, clay minerals (possibly including smectite), quartz minerals, and high temperature minerals like epidote and possibly some more.*"

Ground rhyolite from this source has earlier proven to be pozzolanic according to Gudmundsson [16]. The material is considered highly reactive, expansion data from testing by the ASTM C 227 are 0.245 % and 0.351 % at 26 and 52 weeks, respectively according to Helgason [17]. However, testing of rhyolite sand of standard grading according to the Norwegian version of the AMBT method has given an expansion at 14 days of only 0.06 %. The expansion at 56 days was 0.59 %.

Fly ash

Danish fly ash, delivered from Norcem AS. This specific fly ash is utilized in the fly ash cement produced by Norcem, and is documented to reduce expansion caused by ASR significantly (Kjellsen et al. [18].

Limestone :

Filler from crushed pure calcite.

Glass filler:

Commercial Swedish filler (Microfiller) of crushed recycled glass. Mixture of white and coloured glass.

The fillers were divided into different fractions using an air classifier giving the opportunity to study the effect of the particle size.

The workability of the mortar and concrete mixes was adjusted by adding the low-alkali (< 2 % Na_2O equivalent) superplasticizer Scancem SSP-2000, which is a polycarboxylic co-polymer with 25 % active content.

4 RESULTS

4.1 CPT results

The effects of the different fillers were tested by adding fillers to concrete with non reactive fine aggregate and reactive coarse mylonite aggregate. All mixes had constant w/c-ratios (0.45) and 400 kg cement/m^3 concrete. The alkali-level was adjusted to 5 kg Na_2O-equivalent/ m^3 concrete for all mixes. Expansion results after two years of storing are given in Table 1.

Table 1. Two years expansion results

	CPT			
	Expansion after 2 years (%)			
Filler type / amount	Ref. (0 %)	2.00 %	5.15 %	10.30 %
Mylonite 0-20	0.179	-	0.210	-
Mylonite 10-30		-	0.193	-
Mylonite 0-125		0.203	0.202	0.183
Rhyolite 0-20		-	0.028	-
Rhylite 0-125		-	0.041	-
Glas 0-125		-	0.043	-
Cataclasite 0-125		-	0.191	-
Fly ash		-	0.020	-

Some expansion results as a function of time are plotted in Figure 1.

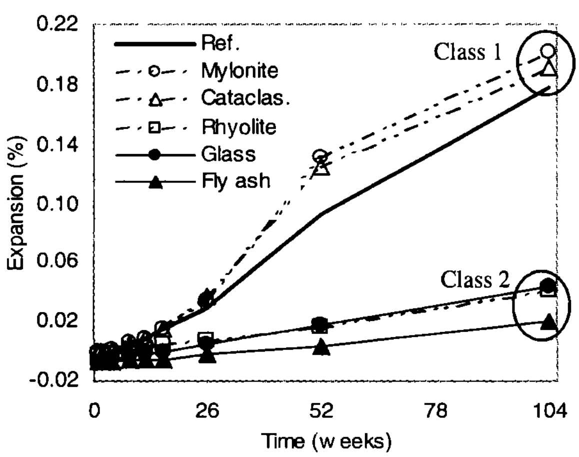

Figure 1. CPT: effect of 5.15 % 0-125 µm fillers on concrete expansions up to two years.

Note that the supplementary materials can be divided into two distinct classes based on their expansion results: 1) The mylonite and cataclasite fillers gave increased expansions compared to the reference concrete. The relative difference was at a maximum after one year of exposure, while the difference was small and barely significant after two years of exposure. 2) The effect of the other fillers (glass, rhyolite and fly ash) was the opposite with respect to expansion, as they all gave a distinct inhibiting effect.

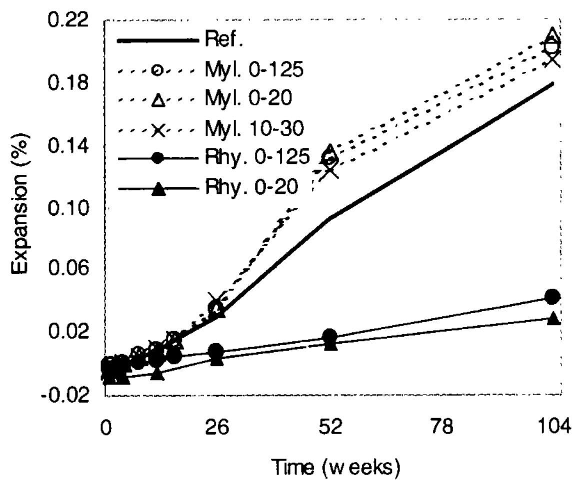

Figure 2 CPT: Effect of particle size on expansions.

The filler/total aggregate ratio was 5.15 % (by volume) for all mixes shown in Figure 2.

4.2 AMBT results

When tested by the AMBT, the fillers replaced reactive mylonite sand, while the amount of cement was kept constant. For all mixes : w/c ratios (0.47) and 600 kg cement /m^3 mortar. Expansion results after 14 days of storing are given in Table 2.

Table 2. Expansion results after 14 days of storing.

	AMBT		
	Expansion after 14 days (%)		
Filler type / amount	Ref. (0 %)	10 %	20 %
Mylonite 0-20	0.16	0.12	0.07
Mylonite 10-30		-	0.09
Mylonite 0-125		0.15	0.11
Rhyolite 0-20		-	0.01
Rhyolite 10-40		-	0.03
Rhylite 0-125		0.07	0.03
Glass 0-20		-	0.06
Glas 0-125		0.16	0.07
Cataclasite 0-20		-	0.07
Cataclasite 0-125		-	-
Fly ash		0.03	-
Limestone 0-30		-	0.15

Note that the filler/total aggregate ratios are generally higher than in the CPT experiments presented earlier. However, addition of 10 % filler in the AMBT gives an equal filler/cement ratio as 5.15 % addition of filler in the CPT. Equally, the 20 % addition level in the AMBT corresponds to the 10.3 % addition level in the CPT with respect to filler/cement ratio.

Mylonite, cataclasite, rhyolite and glass fillers, as well as fly ash, reduced the expansions when they replaced mylonite 0.125-4 mm sand. The inhibiting effect, i.e. the reduced expansion, generally increased with increasing replacement level and with decreasing particle sizes of the fillers. The limestone filler, on the other hand, did not give any significant effect on the expansion.

The effects of varying fractions of mylonite and rhyolite fillers with time, as well as the effect of limestone filler, are plotted graphically in Figure 3. It is clearly seen from Figure 3 that the limestone filler had no effect on the expansion characteristic at all ages, while the mylonite and rhyolite fillers reduced the expansions significantly. Further, it can be seen that the expansions decreased with decreasing particle size for both mylonite and rhyolite fillers. The very low expansion after 56 days of storing for the mortar containing 0-20 μm rhyolite filler is noteworthy. The filler/total aggregate ratio was 20 % for all the mixes plotted in Figure 3.

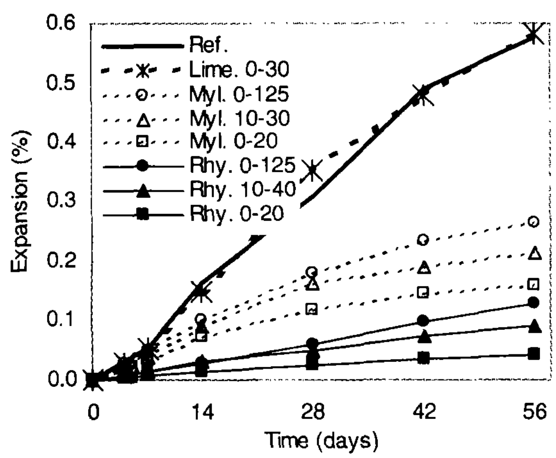

Figure 3 AMBT: effect of replacement with limestone filler and different fractions of mylonite and rhyolite fillers.

It is important to note that the prediction of the effects of mylonite fillers by the AMBT contradicts the effects predicted by the CPT, as shown in Figure 1 and 2.

4.3 Pozzolanic reactivity

In figure 4, the loss of CH as a function of curing time is shown for different 0-20 μm fractions of fillers. The loss of CH is a direct measure of the pozzolanic reactivity. At this curing temperature of 20°C, the pozzolanic reactivity of mylonite and cataclasite filler was insignificant. On the other hand, the pozzolanic reactivity of fly ash, rhyolite and glass filler was marked.

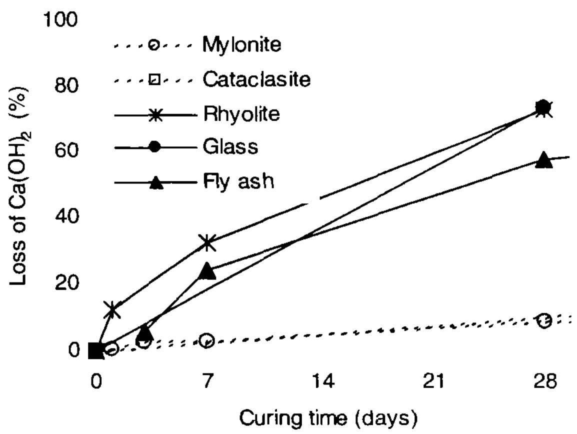

Figure 4. Loss of CH as a function of curing time.

In figure 5, the effect of curing temperature can be seen. It is clear that the pozzolanic reactivity of the mylonite 0-20 μm filler was barely significant at both 20°C and 38°C curing temperature. However, the pozzolanic reactivity of mylonite filler was relatively high at a curing temperature of 80°C. Further, it can be seen that the pozzolanic reactivity of the non-reactive granite/gneiss filler was equal to that of the alkali-reactive mylonite filler. Based on these rather limited tests on the temperature effect, it may be suggested that all rocks containing silica, whether crystalline or amorphous, will be more or less pozzolanic at high temperatures, i.e. 80°C.

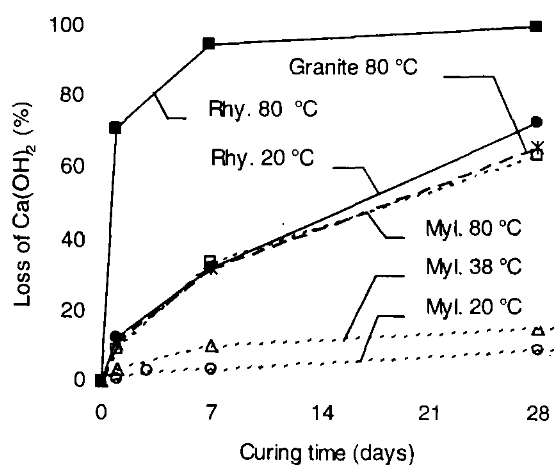

Figure 5 Loss of CH as a function of curing time and temperature

4.4 Micro structural analyses

Micro-structural analyses of specimens stored one year according to conditions of the CPT have been carried out. Examinations of thin-sections have confirmed that the reference concrete as well as the concrete containing mylonite filler was seriously damaged by alkali-silica reactions. Extensive cracking as well as alkali-silica gel was observed on these specimens. On the other hand, no or very few signs of damage were found in the concretes with glass and rhyolite filler. Figure 6 shows a micrograph (thin section photographed in fluorescence light) of a reacted mylonite particle in the CPT after one year exposure. Arrows show a crack in the reacted aggregate running out into the cement past where gel occurs.

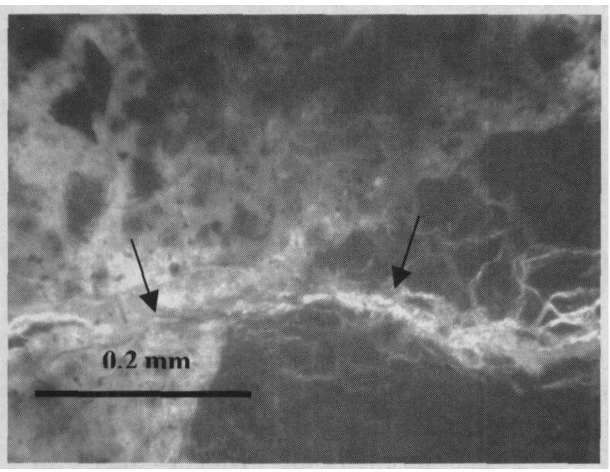

Figure 6. Reacted mylonite particle after one year in CPT

Figure 7 shows a backscatter SEM-micrograph of glass-filler concrete.

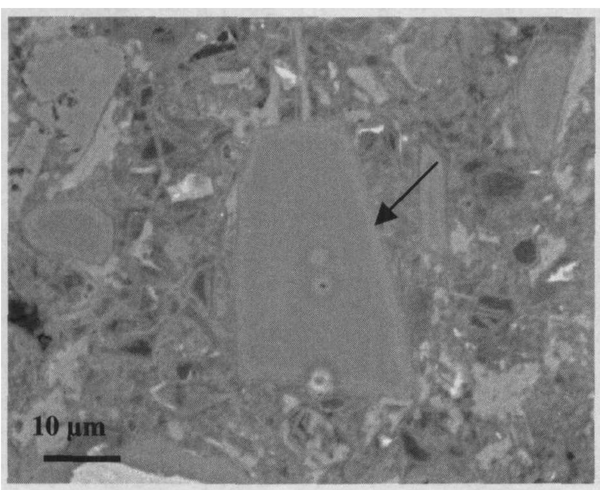

Figure 7. Glass – filler particles after one year in CPT

Note the zonation of glass particles (arrow) shown as a distinct light grey rim in the contact zone between the glass particle and the cement paste. Analyses by electron probe microanalyzer have shown that most of the glass particles showed clear signs of zonation, indicating some kind of chemical reaction with the cement paste. Element mapping has shown a distinct decrease in Na and Si, and a less distinct increase in Ca in the boundary zone of the glass particles. However, no signs indicating that the glass particles had lead to formation of deleterious ASR, alkali-silica gel or cracking were found.

5 DISCUSSION

The result obtained by testing using the CPT is believed to give a reliable prediction of the effect in real field concrete. It is thus clear that alkali-reactive fillers may give very different effects depending on their origin. The Norwegian mylonite and cataclasite fillers may cause additional expansions when added to concrete with reactive coarse aggregates. This is true even for the finest tested fractions of 0-20 µm, and these fillers should be treated as potentially deleterious when submitted in concrete. The expansion characteristics of these fillers in combination with non-reactive aggregates have not been tested, but it may be assumed that they may cause expansions due to ASR. The addition of such fillers may not necessarily be harmful due to the low amounts of filler normally added, but when utilizing such fillers, normal precautions with respect to alkali loads and the use of effective pozzolans should be taken to eliminate the risk of deleterious behaviour.

The rhyolite and glass fillers gave on the other hand a totally different effect in concrete, as these fillers were capable of reducing expansions due to ASR, equally to the effect of fly ash. These materials have been documented to be pozzolanic with relatively high reactivity even at temperatures down to 20°C, while the pozzolanic reactivity of mylonite and cataclasite have been shown to be insignificant at low temperatures. The materials being highly pozzolanic have a distinct amorphous silica phase, while the silica phase of the mylonite and cataclasite is well crystalline quartz. The known deformation and sub-grain development due to cataclasis of the tested reactive Norwegian rocks does not seem to increase the pozzolanic reactivity.

The AMBT may give reliable predictions of the long-term effect in concrete for good pozzolans such as glass filler, rhyolite filler and fly ash. This is in agreement with the findings of Bérubé et al. [19], who have reported that the AMBT gives reliable predictions of supplementary materials such as fly ash and silica fume. However, the effect of adding mylonite and cataclasite fillers was not truly predicted by the AMBT. Increasing amount of filler and decreasing particle size gave increasing inhibiting effect. This is believed to be due to the pozzolanic reactivity of the fillers at the elevated temperature of this method as shown in Figure 5. As the true field situation does not involve prolonged elevated temperatures, the pozzolanic reactivity of these fillers is too low to play a dominant role. This has been shown by the testing using the CPT.

The present study has given valuable information concerning the practical implications of using alkali-reactive fillers. However, some of the more fundamental issues concerning the paradox of the alkali-silica reaction and the pozzolanic reaction are still far from being fully understood. It is clear that factors such as temperature, alkalinity and particle size, and off course the structure of the silica, all have a very large effect on the solubility of silica. And solubility has obviously a large influence on both the alkali-silica reaction and the pozzolanic reaction. It seems clear that grinding of alkali-reactive materials to fine powder in many cases favours the pozzolanic reaction. This is presumably due to the much higher surface area, which promotes quicker reactions with the surrounding pore water and cement paste. There is much evidence in the literature that calcium has a crucial influence on the reaction products, and high availability of calcium seems in most cases to favour the desirable pozzolanic reaction. In the cases of very fine powders evenly distributed in the cement paste it is reasonable to assume that calcium ions may come more easily in contact with the dissolving silica and thereby contribute to a "safe" or pozzolanic reaction. This is the case for fillers of such materials as bottle glass and Icelandic rhyolite. However, the opposite effect, i.e. increased expansion with decreasing particle size, both observed within the present study for slowly reacting cataclastic rocks, as well as for highly reactive opal as reported by Diamond & Thaulow [5], makes the picture very complicated. It is clear that more fundamental research on the mechanisms of the alkali-silica reaction is necessary to understand this.

6 CONCLUSIONS

Based on testing by the CPT, the tested fillers could be roughly divided into two distinct classes:

1. Mylonite and cataclasite filler had limited effects or gave increased expansions

2. Rhyolite and bottle glass significantly reduced the expansions due to ASR equally to the effect of fly ash

The class 2 materials being able to inhibit deleterious expansions due to ASR have a distinct amorphous silica phase. They have a relatively high pozzolanic reactivity, presumably due to the high solubility of the amorphous silica. The effects of such materials may be reliably predicted by the AMBT.

The pozzolanic reactivity of the class 1 materials is too low to play a dominant role, at least for temperatures up to 38C°. However, at temperatures as high as 80°C as within the AMBT, the pozzolanic reactivity is significant. Testing of such materials by methods using elevated temperature to accelerate the alkali-silica reactions may therefore give unreliable predictions of the behaviour, as the balance between the harmful alkali-silica reaction and the desired pozzolanic reactions may be altered compared to the true situations in field concrete.

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