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An Initial Survey on the Occurrence of Alkali Aggregate Reaction in Finland

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Report's title	
An Initial Survey on the Occurrence of Alkali Aggregate Reaction in Finland	
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Summary

Alkali-aggregate reaction (AAR) in concrete is one of the least dealt with concrete degradation mechanism in Finland. It is a common belief that Finland does not have AAR due to the exceptional quality of its rock. However, several cases of AAR in concrete structures have been identified in recent years at VTT/Expert Services resulting in uncertainty in this claim and raising concern about the occurrence and extent of AAR in Finland.

This project was linked to larger work funded by the Finnish Transport Agency year 2011 Concrete Technological Engineering Structures projects (BTT, Betoniteknilliset taitorakenteet). The work has been financed by the Finnish Transport Agency, where a preliminary study on the occurrence of alkali-aggregate reaction in concrete infrastructure in Finland was undertaken. This report is mainly based on the results of a survey conducted among the Finnish laboratories with thin section microscopy analysis capabilities.

The main goals of the study were to: Clarify phenomenologically AAR; Identify the locations and extent of occurrence in Finland; Show the approach other Nordic countries have adopted for AAR; Identify the needs to proactively address AAR in Finland.

The results show that over 50 Finnish concrete cases were confirmed to have shown obvious signs of AAR in studies conducted over the past 15 years. These structures have come from a wide range of geographic areas of Finland and from various types of structures, though AAR has been most evident in bridges and houses. Some susceptible types of Finnish aggregates have been identified based on thin-section studies of structural concretes.

Although there are many structures surveyed as being affected by AAR in Finland, this figure is expected to increase rapidly as a result of geological constraints, the non-application and in some cases, inadequate or insufficient national regulatory norms on the topic of AAR.

This report present recommendation for further actions to be taken with regards to identifying the extent and causes of the problem in Finland, and measure to mitigate the occurrence of AAR in future concrete structures. This report is also provided in Finnish (VTT-CR-00554-12/FI, 31.1.2012).

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Abstract

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Keywords: alkali, aggregate, silica, reaction, concrete, degradation, AAR, ASR, cracking, durability

Tiivistelmä

Betonin rapautumista aiheuttavista tekijöistä alkalikiviainesreaktio (AKR) tunnetaan Suomessa varsin huonosti. Yleisesti uskotaan, että Suomessa ei alkalikiviainesreaktiota esiinny ja että kiviaines on fysikaalisesti, mekaanisesti ja kemiallisesti lujaa ja kestävää. VTT Expert Services Oy:n tutkimuksissa on viime vuosina kuitenkin todettu useita AKR-tapauksia. Havaintojen takia epävarmuus kiviaineksen yleisesti erinomaista laatua kohtaan on kasvanut ja AKR:n esiintymisestä ja ilmiön laajuudesta Suomessa on noussut huoli.

Tämä tutkimus liittyy suurempaan Liikenneviraston vuonna 2011 rahoittamaan tutkimuskokonaisuuteen ”Betoniteknilliset taitorakenteet, BTT”. Tutkimuksen rahoitti kokonaisuudessaan Liikennevirasto. Tutkimus oli ensimmäinen Suomessa tehty AKR:n esiintymistä ja laajuutta käsittelevä tutkimus ja sen keskeinen elementti oli eri laboratorioista kerätty AKR:ää koskeva havaintoaineisto, joka laboratorioissa oltiin kerätty ohuthietutkimusten yhteydessä.

Tutkimuksen tavoitteet olivat:
• Selvittää AKR:n yleisiä syntymekanismeja
• Selvittää AKR:n esiintymistä ja laajuutta Suomessa
• Selvittää muiden Pohjoismaiden lähestymistapa AKR:oon
• Määrittää AKR:oon liittyvät testaus- ja tutkimustarpeet Suomessa.

Tulokset osoittavat, että viimeisen 15 vuoden aikana Suomessa tehdyissä tutkimuksissa on löytynyt yli 50 betonivauriotapausta, joissa AKR:sta on selviä merkkejä. Suuri osa tapauksista on raportoitu Etelä-Suomesta, mikä on hyvin ymmärrettävää, koska myös tehtyjen tutkimusten määrä Etelä-Suomessa on suuri. Vastaavasti Lapista raportoitujen tapausten määrä on pieni, samoin kuin myös tehtyjen tutkimusten määrä. Tutkimusten määrään suhteutettuna voidaan Pohjanmaalta raportoitujen AKR-tapausten määrää pitää pienenä. AKR:ää on todettu erilaisissa rakenteissa, mutta tyypillisimmät kohteet ovat olleet sillat ja julkisivut. Ohuthietutkimuksissa on tiettyjen kiviainestyyppien todettu olevan muita yleisemmin AKR:n aiheuttajana.

Tässä raportissa esitetään suosituksia tarvittavista toimenpiteistä AKR:n aiheuttamien ongelmien laajuuden ja syiden selvittämiseksi, ja AKR:n esiintymistä tulevaisuuden betonirakenteissa lieventävien toimenpiteiden arvioimiseksi Suomessa.

Avainsanat: alkali, kiviaines, piidioksidi, reaktio, betoni, rapautuminen, AKR, ASR, halkeilu, säilyvyys

1. Introduction

Alkali-aggregate reaction (AAR) in concrete is one of the least dealt with concrete degradation mechanism in Finland. It is a common belief that Finland does not have AAR due to the exceptional quality of its rock. However, several cases of AAR in concrete structures have been identified in recent years at VTT/Expert Services resulting in uncertainty in this claim and raising concern about the occurrence and extent of AAR in Finland.

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The main goals of the study were to:

- Clarify phenomenologically AAR;
- Identify the locations and extent of occurrence in Finland;
- Show the approach other Nordic countries have adopted for AAR;
- Identify the needs to proactively address AAR in Finland.

2. Background

2.1 Terminologies and mechanisms

Alkali-aggregate reactions, commonly known as AAR, are chemical reactions that occur between certain types of mineral of aggregates and the alkaline (Na+ and K+) and hydroxyl (OH-) ions present in the interstitial solution of cement paste in concrete. These dissolution reactions occur due to the high solubility of certain amorphous, disordered or poorly crystallized forms silica present in very alkaline solutions. This reaction leads to formation of a hygroscopic alkaline gel [Silva, 2005].

In general, these reactions are expansive in nature, resulting in internal stresses in concrete and consequently cracking. It is often accompanied by the appearance of efflorescence and exudations on the surface of the concrete [Silva, 2005]. These reactions are not normally the primary cause of collapse of a structure, however they significantly decrease the durability of concrete as a result of cracking favouring other processes of deterioration, particularly in the cases of carbonation or chloride penetration resulting in reinforcement corrosion.
There are three distinct types of AAR: alkali-silica reaction, alkali-silicate reaction, and alkali-carbonate reactions.

Alkali-silica reaction (ASR): was the first to be identified. In general it proceeds at a relatively high rate. It is most common type of AAR being the subject of intense research, of which there is still no general consensus on the mechanisms and the development of the expansive forces. ASR corresponds essentially to an attack on certain forms of reactive silica with a more or less disordered structure (opal, chalcedony, chert, certain types of quartz - proving to be unstable in an alkaline environment of high pH), by alkaline and hydroxyl ions of the interstitial solution of the concrete, producing an alkaline silicate gel. The speed of this attack depends on the concentration of alkali hydroxides in the interstitial solution and the structure of silica. From the hydration reactions of cement, calcium hydroxide ($Ca(OH)_2$) is the main source of calcium ions (Ca +) which penetrate the gel formed. A gel of calcium silicate, sodium and potassium of varying composition is formed in the concrete around the aggregates. This gel, due to its ability to absorb water, generates expansive forces. The composition of alkali-silica gel varies as follows: SiO_2 28 to 86%, K_2O 0.4 to 19%, Na_2O 0 to 20% and CaO from 0.1 to 60% [Silva, 2005]. Calcium hydroxide has been identified as a primary source of hydroxyl ions, thus allowing the reaction between the alkali ions with the reactive silica, and mobilizing expansive forces.

Alkali-silicate reaction: also called delayed/slow expansion alkali-silica reaction, is similar to the reaction described above, except that the reactive constituent of the aggregate is not free silica, but silica present as a constituent of siliceous rocks (eg. granite, shale, greywacke) [Silva, 2005]. The reaction mechanism is analogous to the expansive alkali-silica reaction, but there are some differences in the physical and chemical behaviour of gels and other reaction products formed. The reaction time is actually the slowest of the three types presented. The coexistence of this type of reaction with the ASR is possible because usually in rock containing phyllosilicates there is microcrystalline quartz present.

Alkali-carbonate reaction: involves the reaction between hydroxyl and alkaline ions with clayey dolomitic stone. This reaction results in dedolomitization, i.e., the decomposition of the double carbonate of calcium and magnesium in the alkaline solution of the concrete. The expansion takes place very rapidly and with intense cracking of the concrete and is not associated with formation of expansive gels, but the dedolomitization, largely as a result of absorption of water by clay minerals that are exposed in the process [Silva , 2005]. These reactions can result in zones which can reach 2 mm in width around the particles of the aggregates. The cracks develop extensively within this ring, both parallel to the interface as well as in the radial direction. The radial cracks extend slowly, joining other cracks in the cement paste, resulting in a network of cracks, loss of adhesion between aggregate and paste and the deterioration of the concrete [Silva , 2005]. However, it is noted that this reaction is not common, affecting particularly Canada and China.

2.2 Factors influencing AAR

For alkali-silica reaction to occur, three conditions must be present: aggregate with reactive forms of silica, high-alkali (pH) pore solution, and sufficient moisture.

Reactive aggregate. Experience has proven that several types of natural aggregate materials are capable of interaction with the alkaline solutions which are present in cement paste. The reactivity is a function of the type and form of constituents comprising the aggregate. Silica minerals in aggregates are generally stable if crystalline and generally reactive if amorphous, but there are exceptions. Aggregates that present large surface areas for reaction – poorly crystalline, many lattice defects, amorphous, glassy, microporous – are susceptible to reaction.

The following list of rock types contain critical amounts of potentially reactive forms of silica: chert and flint containing chalcedony; acidic and intermediate volcanic rocks, such as rhyolite, dacite, latite, and andesite, and the associated porphyries and tuffs; shale and slate; sandstone, siltstone, and quartzite; siliceous carbonate rocks; graywackes; argillites; phyllites; granites and granodiorites; and granodiorite gneisses [Wigum, 1995; Wigum, 2006; Pyy, 2010; Silva, 2005; Farny, 1997].

High-alkali content. Alkali hydroxides in solution will react readily with reactive forms of silica in aggregate. As the aggregate reactivity increases, gel reaction products can be formed with lesser concentrations of alkali. That is why use of low-alkali cements alone may not be sufficient to control ASR with highly reactive aggregates. As the alkalinity of the pore solution increases, potential for the ASR increases. At higher concentrations of alkali hydroxides, even the more stable forms of silica are susceptible to attack. If the alkali concentration is great enough, the alkali hydroxides break stronger silicon bonds found in less reactive aggregates to form the gel reaction product. This explains why aggregates thought to be nonreactive sometimes exhibit ASR [Wigum, 2006].

Ideally, the concept of total alkali loading should include the alkalis from all of the constituents of concrete. However, usually only the alkalis from the cementitious materials are included in the determination because alkali contribution from other constituents is usually small. Typically, low-alkali cement is defined as having an equivalent sodium oxide content (Na_2O_{EQ}.) of no more than 0.60% [SS 134204, 2001]. However, concrete made with low-alkali cement can still exhibit expansive ASR if moisture movement concentrates the alkalis in one location, if the aggregate is extremely reactive, if alkalis are provided by other constituents of concrete in addition to the binders.

When potential for ASR exists, the accepted allowable limit of alkali content used in some European countries and Canada is 3 kg/m^3 of concrete. [LNEC 461, 2004; CAN/CSA-A23.1, 1994].

Alkalis from external sources may increase expansion caused by ASR, especially when concrete is cracked or is highly permeable. Common sources of external alkalis are deicing salts, seawater, groundwater, and water from industrial processes. Sodium chloride deicing salt solutions and seawater can provide unlimited amounts of alkali. Immersing concrete prisms containing reactive aggregates in a sodium chloride solution has demonstrated increases in expansion and deterioration of the concrete, especially at elevated temperatures [Swamy, 1987].

Moisture. Moisture allows migration of alkali and hydroxyl ions to reaction sites and the resulting gel absorbs moisture, leading to expansion. For this reason, deleterious ASR does not occur in concretes that are dry in service. Research has shown that expansive ASR can occur in concrete having a relative humidity above 80 % [Stark, 1991]. It is possible for well-cured concrete in arid regions to have a relative humidity at or above 80% just beneath its surface, even after many decades. Any reduction in permeability, by using a low water-cement ratio, supplementary cementing materials or other means, reduces movement of moisture and alkalis into and within the concrete.

Temperature. Structures in warmer climates are more susceptible to ASR than those in colder climates because the reaction rate usually increases with increasing temperature. For the majority of aggregates, higher temperatures also mean larger ultimate expansions. However, there are studies showing that lower temperatures resulted in significantly larger ultimate expansions with certain aggregates. The effect of high or low temperatures on ultimate expansion is aggregate-dependent, with most aggregates reacting more at higher temperatures [Wigum, 2006].

2.3 Field diagnostics

AAR expansion is heterogeneous and varies from one element to another with respect to several parameters: temperature, moisture level, reinforcement and external stress, exposure to sun/rain, etc. Furthermore, it is recognized that AAR has a greater effect on surface concrete. This would be attributed to a slower expansion at the surface – mainly due to the decrease of the pH pore solution caused by alkali leaching and carbonation – that generates tensile stress (and therefore cracking), and also to environmental agents, such as frost action or wetting/drying cycles that are only active in the surface zone. Regarding the inner damage, it appears that the effect of confinement by the surrounding concrete body – as well as the protection against environmental agents – limit the damage [Rivard, 2009]. Freeze-thaw cracking may also be combined with or start after AAR. However, in contrast to surface scaling, the AAR cracking starts in the interior and initially may not be visible on the surface [Rønning, 2001].

It was common belief that only structures in constant contact with water, such as dams, harbours and bridges, were in danger of such damages but in 1978 it was proven that AAR was also a widespread problem in exterior walls of houses [Einarsdóttir, 2008].
No exhaustive catalogue exists of features suggestive of ASR that could be visualized during a routine site inspection. Certain features are sometimes the result of ASR and the most important of these are given below [BCA, 1993]:

Cracking. In unloaded sections of plain concrete, cracks caused by ASR will often form individual three-armed star shapes that join up to produce a pattern of cracks. Any other abnormal shrinkage or expansion may cause very similar crack patterns. This pattern can be altered or prevented by stress or reinforcement. In reinforced concrete the cracks often reflect the pattern of the underlying steel. In heavily reinforced or prestressed beams and columns, or where there is a moderate longitudinal compressive stress in the member, cracks will not form perpendicular to the direction of the major stress. They will tend to form parallel to the line of stress, i.e. along the length of the member and may be short cracks or may extend the whole length of the member. On occasion, a distinct step in the surface may be seen across a crack.

Discoloration, efflorescence and exudations. Distinctive surface discoloration is sometimes a feature of ASR and often occurs along the line of cracks, but it may also appear as surface patches. The extent and quantity of efflorescence and exudations should be recorded, and the colour, texture, dampness and hardness of the deposit described.

Pop-outs. Expansion of individual aggregate particles, or of gel close to an exposed concrete surface, can sometimes detach a conical portion of the surface, leaving a small pit or 'pop-out'.

Movements, displacements and deformation. Significant movements in the structure can sometimes occur. These commonly occur at the closing of joints, the relative displacement of adjacent concrete sections, excessive deflection, and the twisting or bulging of originally flat surfaces. The correspondence of this movement with other features, such as concrete of different composition, unusually wet or exposed locations, or less restrained parts of the structure, should be noted.

2.4 Laboratory test methods

Although tests for the reactivity of aggregates have been developed and published, these do not directly assess the susceptibility to alkali reactions of the particular concrete mixes to be used in a structure. There are generally no test methods, with a possible exception for the concrete prism test, which are able to predict the field behaviour of aggregates. They do not take into account the mitigating effect of supplementary materials, or the specification of low alkali levels in the mix. By using such mitigation measures, a much wider selection of aggregates can be used safely. However, at present there are no reliable performance tests by which the actual concrete mix to be used can be tested. Although such performance tests have been proposed, they have not been validated against actual performance in structures or field tests. [Rilem TC-219] Different national practices on mix design, prism sizes and storing of the specimens also make it difficult to compare test results.

Whatever their limitations, laboratory testing is the starting point in the evaluation of aggregates and concretes for their susceptibility to AAR, supplemented by known field experience and practical performance of these aggregates in concrete. Thorough petrographic examination together with other instrument techniques such as X-ray diffraction and infra-red spectroscopy is the first step in the evaluation of the suitability of aggregates for concrete. The limitations of petrographic studies are highlighted, and these tests should not therefore be assumed to guarantee information on the development or absence of ASR [Swamy 1992].

There are more than a dozen test methods currently in use to assess AAR. The laboratory test methods have two, somewhat contradictory, objectives: to determine the alkali reactivity of an aggregate in a reasonable short time, and to evaluate and set acceptable expansion limits, due to the AAR, of a reactive aggregate - cement combination (performance criteria). Most test methods can be described as being either a mortar bar method (ex:ASTM C227), an accelerated mortar bar method (ex: NBRI, 1987 or ASTM C1260), a concrete prism method (ex: ASTM C1260, RILEM AAR-3), or an accelerated concrete prism method (ex: RILEM AAR-4). The general conclusion to be derived from all of these tests is that it is inherent in the nature of AAR, and the numerous factors that influence the reaction, that no single test, wherever its nature, can be completely relied upon. It is important to assess the role of laboratory testing, its aims and objectives, and bear these in mind when specifying acceptable limits of expansion for practical design.

From an engineering point of view a combination of petrographic analysis, knowledge of field performance and a mortar bar or concrete prism test is likely to give the best information required to avoid deleterious expansions in concrete construction. In terms of accuracy, the concrete prism test is in general to be preferred to a mortar bar test, since only in such a test can all the numerous factors which influence AAR, such as the mix constituents, mix proportions and the effects of external environment on the porosity and permeability of the material, be realistically modelled. A petrographic analysis is usually the first test and the fastest, while the mortar bar is a relatively quick test, the concrete prism test is very slow. Usually the time constraint is the controlling factor for selection. It should be borne in mind that, notwithstanding the effects of all the factors that influence ASR, the environment is the most critical parameter, and this is precisely the one factor that is beyond the control of human beings [Swamy 1992].

3. International Experiences

Alkali-aggregate reaction was first explicitly described in the literature by Stanton in the United States in 1940 [CCANZ, 2003]. At that time, he was able to demonstrate that severe cracking in a number of concrete structures in California, going back to the 1920s and 1930s, was basically a consequence of the characteristics of the cements and the aggregates. The high-alkali cements in combination with opaline aggregates were responsible for the observed deleterious reactions [Pedersen 2004].

Since then, a great number of articles on this topic have been published, and thirteen international conferences on AAR have been arranged. According to Diamond [1997], there were approximately 1300 papers published on AAR up to 1991, and Figure 1 gives a rough estimate on the growth of AAR scientific publications since then.

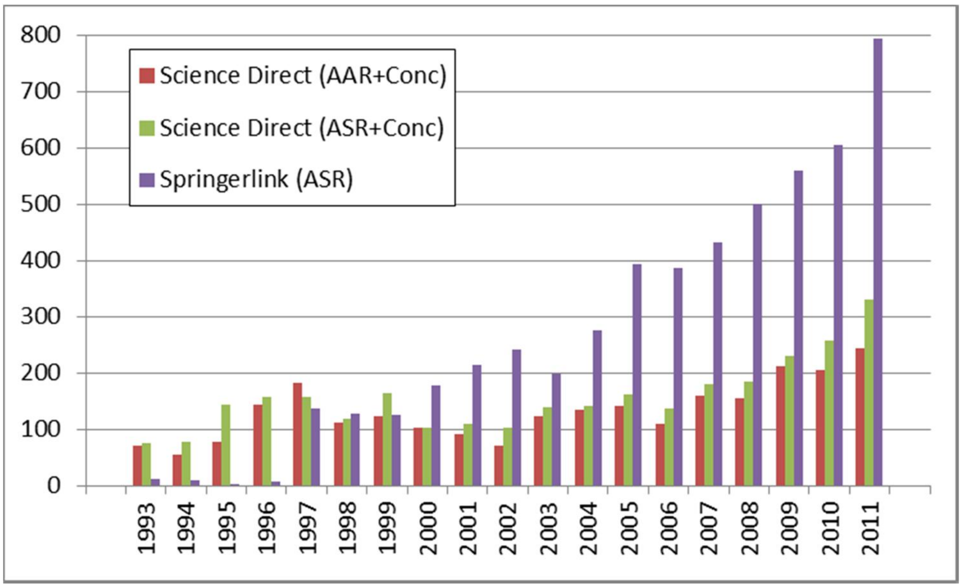

Figure 1. Evolution of scientific articles dedicated to ASR or AAR, from Science Direct and SpringerLink.

AAR has been identified in over 50 countries worldwide. About the only country in Europe that has not officially recognized AAR is Finland. Among the Nordic countries, the topic of AAR has been discussed for some decades. Denmark established that AAR was a concern in the 1950s [Nerenst 1957] followed by Iceland in the 1960-70s [Gudmundsson 1975]. Sweden and Norway also started AAR investigations afterwards, with research building momentum through the 1980-90s [Lagerblad 1992, Jensen 1993]. A couple of these countries are detailed here, as examples of the development steps that have been taken.

It should be noted that aggregate types of Denmark and Iceland are totally different from those in Finland. For this reason examples of reactive aggregate types from these countries are not relevant. Danish aggregate is young sedimentary rocks and Icelandic aggregates are young volcanic rocks whereas in Finland, Sweden and Norway the primary aggregate sources are old crystalline rocks.

In Sweden the scientific study on ASR started in 1980, when a research project started addressing pop-outs in concrete floors in Skåne. In this study a highly reactive opal-flint from Scania was found to be the reason for ASR (Nilsson & Peterson, 1983). Shortly after this ASR was found when studying deterioration of bridges in the Stockholm area. In Stockholm the reactive aggregate was a mylonitic rock and the alkalis came from de-icing salts (Lagerblad & Nieman, 1992). Since then AAR has been found in most locations around Sweden and there are many different reactive rock types in Sweden. The most reactive are those from Scania, as mentioned above.

To the north of this area within Sweden, microcrystalline siliceous rocks (porphyries, metarhyolites) and strongly deformed rocks (cataclasite and mylonites) occur in places and they are reactive if combined with a high alkali cement or alkalis that have been added externally. The third type of rock formation, which has been identified in Sweden to cause ASR are the erogenic metamorphic rocks (greywackes, mylonites and some altered sparagmite sandstone) from the Swedish-Norwegian mountain chain. (Lagerblad & Trägårdh, 1992) (Wigum, 2006).

Norwegian scientific knowledge of ASR was established in two research projects from 1988 to 1992, which are summarised in a doctoral thesis by Jensen [1993]. However, the first publication regarding alkali silica reaction was written as early as 1962 by Musæus, who performed a study on possibly alkali reactivity on phyllite [Jensen 1993]. In 1978 Kjennerud published results from an investigation of a swimming pool as well as turbine foundations in a hydropower plant [Jensen 1993]. He concluded that alkali-aggregate reactions were responsible for the damages in both cases. Yet according to Jensen [1993], ASR was not sufficiently confirmed to become accepted as a degrading mechanism for Norwegian aggregates until 1988. A review of the early Norwegian history of ASR is given in the doctoral thesis of Jensen [1993], while the recent Norwegian history of ASR is summed up in the thesis by Broekmans [2002]. National guidelines regarding ASR were published by the Norwegian concrete association in 1996, providing criteria for the use of potentially alkali-reactive aggregates [Norwegian concrete association 1996]. New guidelines were to be published in 2004 [Pederson, 2004].

Even though it is evident that there has been a tremendous development of knowledge of AAR up to now, and that many of the problems associated with utilization of potentially alkali-reactive aggregates have been solved, some of the more fundamental aspects of the reactions are still not fully understood [Pederson, 2004].

4. Finnish Practice

Historically, is has been taught in Finnish building technology education and material science that alkali-aggregate reactions are not a concern. Finnish aggregate and concrete durability guidelines even state that “According to common belief AAR is not a problem when using Finnish aggregates.” [BY43, 2008]. Finland also has a strong tradition of using mineral by-products, such as fly ash and blast furnace slag, which are known to lower the risk of AAR. Yet closer attention should now be given to the individual material components in Finland, to identify where there may be AAR risks.

As early as 1992, Hannu Pyy identified in a presentation at a Nordic mini-seminar on AAR in Stockholm that “So far AAR has not been reported in Finland. This is a wonder when considering the composition of Finnish bedrock and the fact that AAR has been reported in countries around us. How could it (Finland) be a white spot on the map?” [Pyy 1992]. This was also reinforced by Jouni Punkki and Veli Suominen in their 1994 Betoni lehti article entitled “Alkalikiviainesreaktio Norjassa – ja Suomessa?” (AAR in Norway – and Finland?) [Punkki 1994] where they asked why Finland would be immune to AAR risks.

The following sub-sections identify the primary AAR-related concerns related to Finnish practice.

4.1 Aggregate Types

Finland is known to have strong, non-reactive aggregates. The bedrock is manly made of Precambrian plutonic and metamorphic rocks. The occurrence of sedimentary rocks is marginal and also these rocks are old. The metamorphic rocks include different metavulcanites, gneisses, schists and quartzites and they are often highly metamorphosed and folded. The bedrock is covered by soil from the latest ice age, about 10000 years ago, so there is a wide time gap between these two.

The soil represents well the composition of the underlying bedrock. Granites and granodiorites are the most common rock types in the bedrock and soil. These rock types cover about 60% of the average composition of a sporadic aggregate. The rest is mainly made of gneisses and schists. In Eastern Finland quartzites play a more significant role.

From a geological point of view, there is very much in common between Finland and Sweden. In both countries the bedrock is made mainly of Precambrian rocks (Figure 2). This is, in itself, quite an important aspect because Sweden has acknowledged the existence of AAR already 20 years ago [Nilsson & Peterson, 1983] and has addressed this problem accordingly. On the map it can be seen that the bedrock both in Sweden and Finland represents the same Precambrian association made of metamorphic, cataclastic and mylonitic schists and gneisses, cut by plutonic rocks like granite and gabbro.

The authors' belief is that in Finland AAR is more connected to certain rock types than to certain geographical areas, though this should be further clarified in the future.

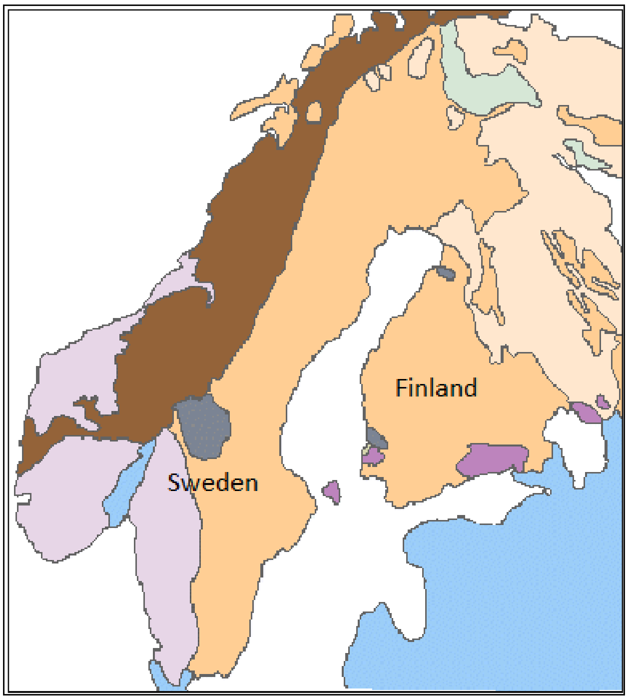

Figure 2. A simplified geological bedrock map of Finland.

4.2 Cement Types

Approximately 80% of the cement used in Finnish construction and products is produced by Finnsementti Oy. On average over the past 5 years, the annual amount of cement produced in Finland is approximately: 45% Yleis cement (CEM II/A-M (S-LL) 42,5N), 35% Rapid cement (CEM II/A-LL 42,5 R), 10% Pika cement (CEM I 52.5R), 5% Plus cement (CEM II B-M (S-LL) 42,5 N), 2% Sulphate resistant cement (CEM I 42,5 N) and 2% white cement (CEM I 52,5 R) [Finnsementti 2012].

When considering the alkali-aggregate reaction risk in concrete products, the cement's total alkali content must be evaluated. The alkali content is composed of the sodium and potassium in the Portland cement clinker, which typically comes from the clay components in the raw materials and coal used during production. The alkali content is often expressed as *Na_2O equivalent* (Na_2O_{EQ}) as a percentage (= % Na_2O + % 0.658 K_2O). Recommendations to limit alkali-aggregate reactions often specify the total equivalent alkali content to be less than 0.60 % [NBN B 12-109, 1993; DIN 1164-10, 2008; BS 4027, 1996]. Alkalis in cement typically vary between 0.2 to 1.5 % Na_2O_{EQ} due to the use heat exchangers in the cement industry leading to increased alkali content in cements today. Depending on the alkali content of cement, the pH of the pore solution varies from 12.5 to 13.5. [Neville, 1997].

The corresponding chemical composition of the Finnish cement types listed above is given in Table 1, according to clinker types. It should be noted from Table 1 that by international practice, all of the Finnish cements (with the exception of Danish White cement) have equivalent alkali contents over the recommended limit of 0.6% to avoid AAR. The Yleis and Rapid cements have values over 1%, which is considered high by international practice.

Table 1. Example chemical composition of cements and blast furnace slag, taken Autumn 2007. (Finnsmetti Oy),

Cement type/ Composition	CEM II/B-S 42,5 N Perus cement	CEM I 42,5 N - SR SR-cement	CEM II/A-M(S-LL) 42,5 N Yleis cement	CEM I 52,5 N White cement	CEM II/A-LL 42,5 R Rapid cement	CEM I 525 R Pika cement	Blast furnace slag - KJ400
CaO	64	63	65	69	65	64	40
SiO_2	21	21	21	25	21	21	34
Al_2O_3	4.3	3.3	5.2	2.1	5.2	4.3	9.3
Fe_2O_3	3.0	4.0	3.1	0.3	3.1	3.0	-
MgO	2.9	2.9	2.6	0.7	2.6	2.9	11
SO_3	3.0	3.1	3.1	2.2	3.7	3.5	-
K_2O	?	0.43	1.2	0.04	1.2	0.53	0.47
Na_2O	?	0.52	0.31	0.19	0.56	0.6	0.47
Free Lime	2.0	2.5	1.8	?	1.8	2.0	-
LOI	-	2.2	-	0.44	-	1.7	-
C_3A	6.5	2.0	8.5	5.0	8.5	6.5	-
$Na_2O_{EQ.}$	**?**	**0.80**	**1.10**	**0.22**	**1.35**	**0.95**	**0.78**

Producing lower-alkali cements may require higher amounts of energy, due to the bypass systems needed to avoid the alkali concentrations in the clinker. Thus as energy efficiency receives more attention in the global economy, there are also recommendations that the requirements for low-alkali cements should be limited to cases where alkali-reactive aggregates are a problem. [FHWA 2012]

4.3 Concrete Products

Concrete products and structures in Finland have a good history of durable performance and long service life. Yet they are often subjected to environmental situations that encourage AAR. Many structures are exposed to wet environments for long time periods of the autumn through spring, where the relative humidity of the concrete is maintained near 100%. Finland’s cooler climate may cause the reaction rate of AAR to be slow, which explains why this degradation may be late in appearing compared to other countries. The harsh environment of Finland also leads to many industries and facilities operating indoors, where the climate can be warm and moist. For instance, concrete within mills and factories associated with pulp and paper production or energy production could be at risk of AAR. Also swimming pool and spa facilities that are maintained at elevated temperatures with a high level of relative humidity could also be susceptible to AAR damage.

5. Current AAR knowledge in Finland

5.1 Initial Interest

In the past few years more damage possibly associated with AAR has been noted. Therefore two summary articles were written to provide background about the AAR phenomena for the Finnish concrete industry and international colleagues [Pyy & Holt 2010, Pyy & Holt 2011]. An initial proposal suggesting further studies about Finnish AAR potential was presented to the BTT (Betonitekniset taitorakennetutkimukset) steering committee in 2009. The initial project work reported here was financed by The Finnish Transport Agency (Tiehallinto) in 2011. The results of this work have culminated in a Finnish AAR Workshop, held at VTT January 24, 2012 (details given in Appendix C).

5.2 Survey Results

A survey was sent by email to 10 companies in November 2011 and follow up was made again in January 2012 (see Appendix A contact list). 7 companies responded to the survey while other information was also received that additional cases exist but were not reported here. The survey summary is presented in table format in Appendix B. Some of the key trends from the survey are presented here.

The 2011 Finland survey documented a total of 56 cases of obvious AAR damage in Finnish concrete structures that have been investigated over the past 15 years. An obvious AAR case meant that gel could be detected in the cracks and/or aggregates. It must be emphasized that the survey *did not* include cases where AAR *might* have been a cause of cracking or deterioration but was inconclusive due to a lack of gel product. All of these confirmed AAR cases were listed to be in confidential reports, and thus the full disclosure of information is not provided here.

When core samples were taken for studies of concrete performance, thin-sections were always made. The AAR was not evident in all of the thin-sections for the surveyed structures. Within the 56 structural cases, there were a total of 331 thin-section studied and AAR was evident in 33% of the thin-sections (111 of 331 thin sections). Yet it should be noted that these were not evenly distributed. In the worst case 4 of 4 thin-sections showed AAR damage, but in other cases it might have been only 1 of 24 or 1 of 12 thin-sections showing signs of AAR. It is known that in at least two cases AAR was the primary damage mechanism of the structure, i.e. resulting in maintenance or replacement actions being taken.

Of the 56 structural cases of AAR, researchers indicated that most companies still had the initial reports on file detailing the AAR damage. They also noted that over 75% of the petrographic thin-sections were still available for future study, if there is interest or a need for more detailed investigations.

The regions where AAR was found in Finland are shown in Figure 3. It must be noted that the survey sampling was not complete to cover the whole geographic map, and thus it may be that additional AAR structures exist in areas still not yet identified on this map.

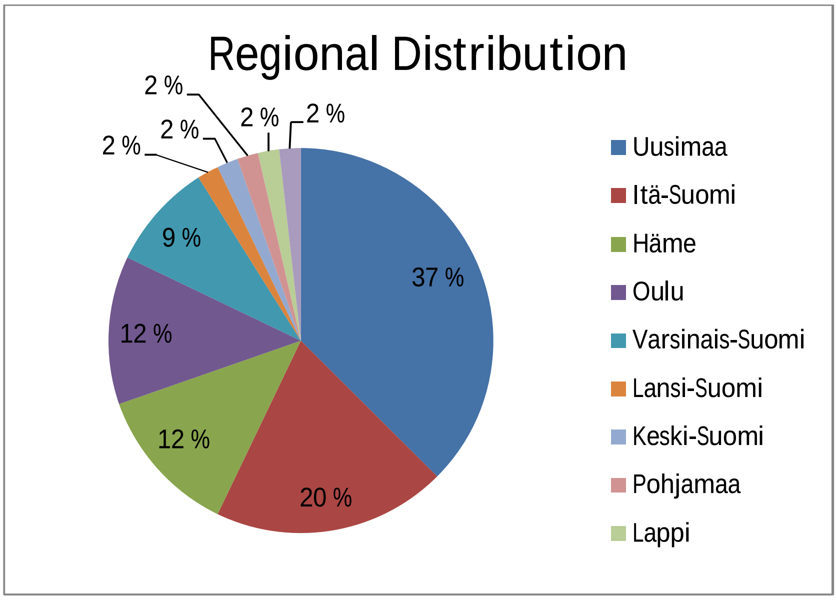

Figure 3. Areas of Finland where AAR in concrete structures has been found based on survey results.

The types of structures where the AAR was reported are shown in Figure 4. The figure shows that the majority of cases were in bridges (39%) and houses (34%).

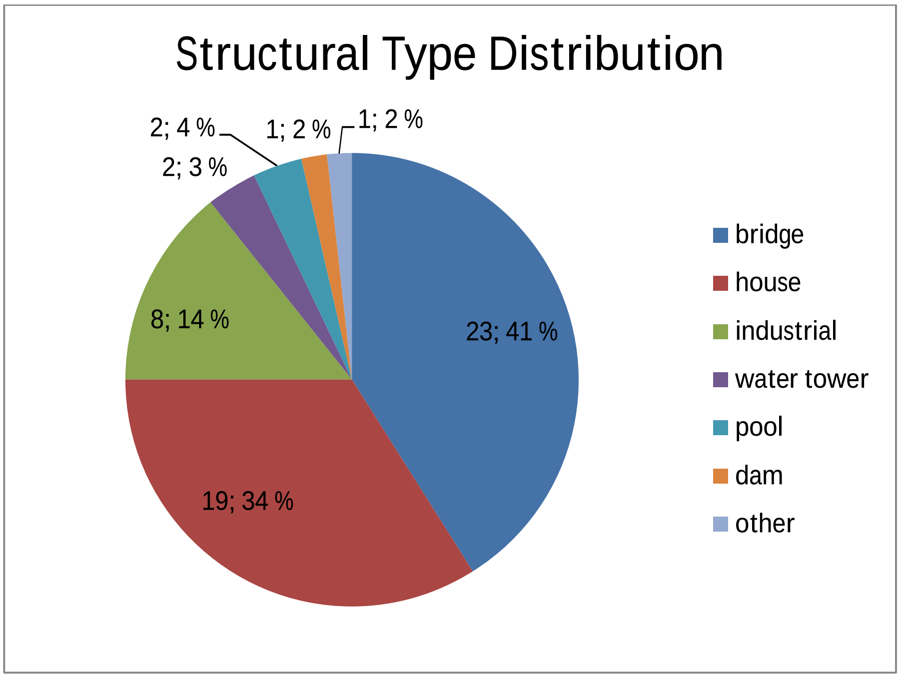

Figure 4. Types of concrete structures where AAR has been found based on survey results.

The survey asked to roughly identify the types of aggregates that were seen in petrographic studies. The distribution of the aggregate types seen in the survey is given in Figure 5. The largest proportion of the studies did not specify one aggregate type alone or it was unclear, for instance the aggregate was noted to be granite or quartzite.

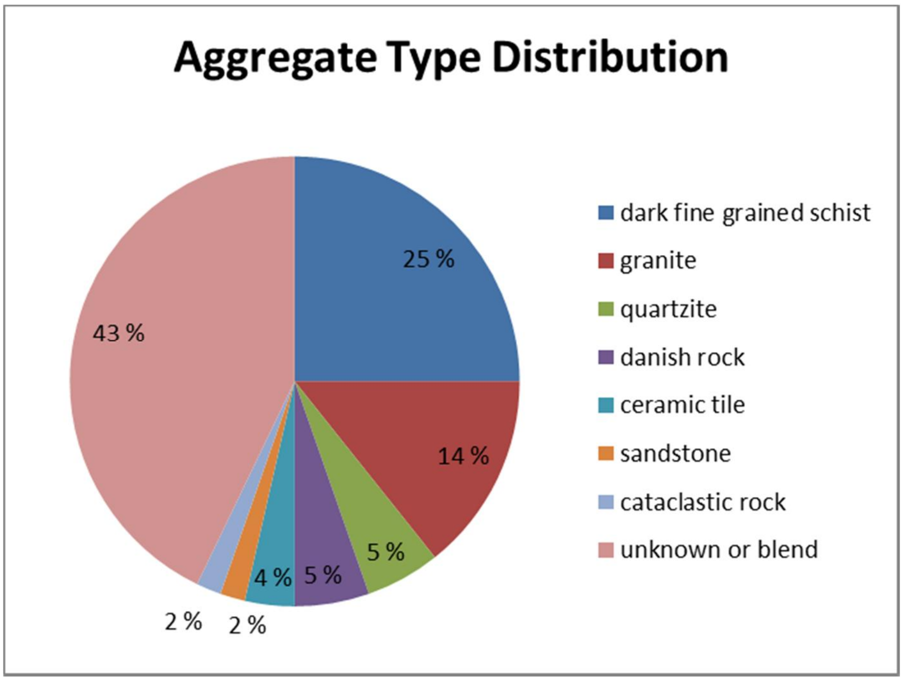

Figure 5. Types of aggregate in Finnish concrete/structures where AAR has been found based on survey results.

Besides identifying aggregate, the survey respondents noted that in most AAR documented studies the mixture design of the concrete was unknown (i.e. w/c ratio, cement type, aggregate source location, etc.). The survey did not ask the age of the structures where the AAR was found. Both of these items should be a topic for future studies when clarifying the occurrences of AAR.

The survey indicated an increase in the number of AAR cases being reported in Finland, as seen from Figure 6. This may be attributed to the age of the structures but it could also be due to the recent increase in education, awareness and discussion about AAR in Finland [Pyy & Holt 2010]. It should be noted that this increasing trend of Finnish cases is also in-line with the growing scientific publications worldwide, as shown earlier in Figure 1 (Section 3).

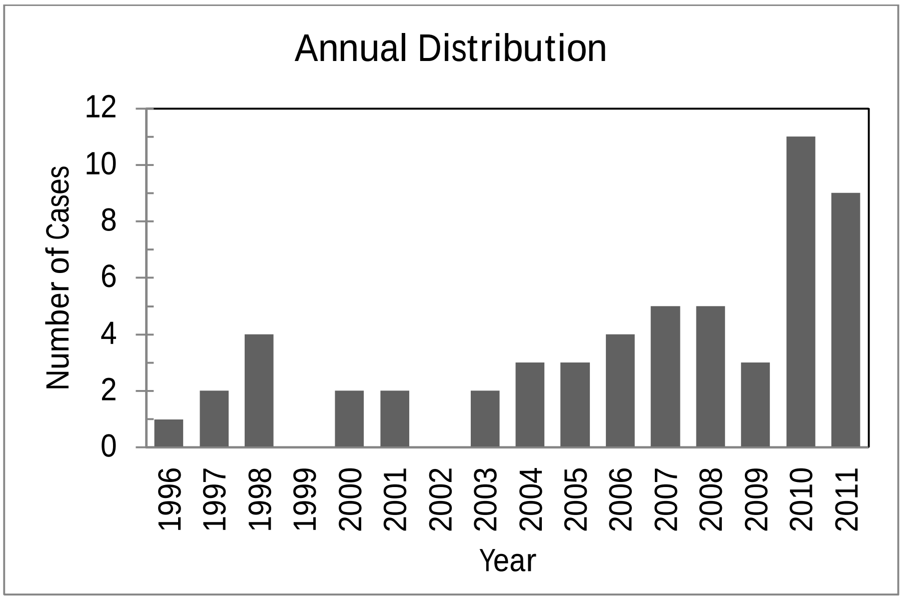

Figure 6. Number of AAR cases per year in Finland, based on survey results.

Finally, it should be noted that some of the respondents were aware of other concrete structures affected by AAR that did not get included in this initial survey due to lack of finding the initial report and/or thin-sections and in some case a lack of time for reporting by the survey deadline. A more thorough investigation in the future would provide a more accurate picture, yet this survey was a successful first step in identifying AAR occurrences in Finland.

6. Future Needs

This initial project was the first step in understanding AAR through a literature review and survey of Finnish researchers who have documented AAR in recent years. The next steps recommended for gaining knowledge and understanding on the risk of AAR in Finland are detailed here. These recommendations are based on steps taken by other countries as they have also followed a similar route as Finland in identifying the significance (or insignificance) or AAR damage.

The following tasks should be taken as the next steps in understanding AAR in Finland:

1. Conducting a round-robin style investigation with a group of expert petrographers in Finland, where a common set of thin-sections showing varying levels of AAR are assessed. Include discussion on how to accurately detect and describe AAR. Option to include training of other geologists, researchers, junior petrographers, etc. on how to examine thin-sections and diagnose AAR.
2. Create a detailed map of reactive aggregates in Finland, based on geological surveys and experience. Cooperation with GTK is encouraged for this task.
3. Perform laboratory experiments with Finnish materials potentially susceptible to AAR. Produce concrete and mortar mixtures using a couple of the worst Finnish aggregates (along with a reference poor aggregate from abroad, such as Denmark), being combined with Finnish cements. Follow RILEM suggested test methods (or equivalent) for detecting AAR by mortar bar and concrete prism tests. Only by doing these tests with Finnish materials, will industry have an indication about what levels of damage we may expect. The values can be compared to the wide range of international experience, to help set guidelines for allowable mixture proportioning in Finland to avoid AAR. It would also be helpful in at least one test case to introduce a mineral by-product (such as blast furnace slag) to see the impact on reducing the AAR risk when combined with Finnish aggregate and cement.
4. Conduct an elaborate field study of a few Finnish structures (i.e. bridges) that have shown signs of AAR. The emphasis should be on the diagnostic methods of AAR compared to frost cracking. From cored samples, thin-sections would be prepared at various depths from the exposed concrete surface. The variation in cracking pattern with depth should be studied, to assess how the deterioration appearance is compared between AAR and frost damage.
5. Provide guidelines for Finnish industry and practitioners about how to assess AAR in Finnish structures. Also providing guidelines for concrete producers on acceptable material combinations for avoiding AAR and setting ranges or limits to the typical test results achieved in AAR laboratory assessments.

6. Promote Finnish - international networking on the topic of AAR so we can learn from others' history and progress on AAR. This could include participation in upcoming conferences/workshops. Also to continue dissemination internationally about the new Finnish experience with AAR.

7. Summary

This initial survey clearly showed that alkali aggregate reactions occur in Finland's concrete.

AAR is a worldwide problem that is gaining increased attention. This report has provided a brief state-of-the-art review on AAR mechanisms and assessment options. An overview has been provided regarding how other Nordic countries have addressed their emerging AAR concerns.

A survey has been distributed in Finland to assess the history of detecting AAR. Over 50 Finnish concrete cases were confirmed to have shown obvious signs of AAR in studies conducted over the past 15 years. These structures have come from a wide range of geographic areas of Finland and from various types of structures, though AAR has been most evident in bridges and houses. Some susceptible types of Finnish aggregates have been identified based on thin-section studies of structural concretes.

Although there are many structures surveyed as being affected by AAR in Finland, this figure is expected to increase rapidly as a result of geological constraints, the non-application and in some cases, inadequate or insufficient national regulatory norms on the topic of AAR.

The next steps to address the concern with AAR in Finland have been identified, including conducting microscopy round-robin testing, laboratory AAR reaction tests, further field studies and more in-depth education. A Finnish industrial consortium should be compiled to further research the extent and risk of AAR in Finland. A workshop was held to take the first steps in education and dissemination of the results gained from this project.

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9. Appendix A: Finland AAR Survey

A survey was sent by VTT in November 2011 to the companies/people listed in Table A1, inquiring about when and where AAR has been reported in past investigations. The survey is shown in Figures A1 and A2.

Table A1. Recipients of Finland AAR Survey.

#	Company Name	Contact	Titles	Address	City-Zip	Phone	Email	Reply	
								Yes	No
1	Betonialan Ohuthiekeskus FCM Oy	Arto Koskiahde	Managing Director	Nuijatie 25 B	01650 Vantaa	050 530 2923	arto.koskiahde@ohuthiekeskus.com	X	
2	Contesta Oy	Paula Raivio	Geologist	PL 23, Kilterinkuja 2	01601 Vantaa	09 2525 2441	paula.raivio@contesta.fi	X	
3	Kiratek Oy	Seppo Suoperä & Tapani Arola	Laboratory Director	Myyntimiehenkuja 4	Oulu	0207401002	seppo.suopera@kiratek.fi	X	
4	Kymmenlaakson Amattikorkeakoulu	Jari Harju	Laboratory Engineer	PL 9	48401 Kotka	052208271	jari.harju@kyamk.fi		X
5	Ositum Oy	Viveca Lindqvist	Geologist	Otakaari 12	02150 Espoo	0104252610	viveca.lindqvist@ositum.fi		X
6	Suomen Rakennustutkimus Oy	Jouni Niemelä	Laboratory Director	Meijerinkatu 3	65100 Vaasa	06 3177 045	jouni.niemela@netikka.fi		X
7	Tampereen Teknillinen Yliopisto (TTY)	Jukka Lahdensivu	Senior Researcher	PL 600, Rakennustekniikan laitos	33101 Tampere	040 0733 852	jukka.lahdensivu@tut.fi	X	
8	Vahanen Oy	Pasi Parviainen	Unit Manager		02600 Espoo	020 769 8698	pasi.parviainen@vahanen.com	X	
9	VTT Expert Services	Hannu Pyy	Senior Expert, Petrographer	Kemistintie 3	02150 Espoo	020 722 6905	hannu.pyy@vtt.fi	X	
10	WSP Finland Oy	Tomi Tolppi	Senior Researcher	Kiviharjunlenkki 1 D	90220 Oulu	040 726 2045	tomi.tolppi@wspgroup.fi	X	

ESISELVITYS ALKALIKIVIAINESRAEKTIOSTA SUOMESSA		
Kysymys- ja vastauslomake / Marraskuu 2011 / VTT		
Vastaajan taustatiedot:		
Nimi:		Hannu Pyy
Nimike / asema:		Erikoistutkija, tekn.lis
Yritys:		VTT Expert Services Oy
Postiosoite:		PL 1001
Puhelinnumero:		405 072 071
Sähköpostiosoite:		hannu.pyy@vtt.fi
Alkalikiviainesreaktion (AKR) tutkimisesta organisaatiossanne:		
Keskeinen menetelmä AKR:n toteamisessa betonirakenteista on ohuthietutkimus		
Teettekö ohuthietutkimuksia:		Kyllä
Montako ohuthiettä tutkitte vuosittain:		500-800
Osaatteko tunnistaa ohuthienäytteissä näkyvän AKR:n		Kyllä
Oletteko havainneet AKR:ta tutkimuksissanne:		Kyllä
	Jos kyllä, olivatko näytteet Suomesta vai ulkomailta:	Sekä että
Montako AKR-kohdetta olette tutkineet:		
	viime aikoina keskimäärin per vuosi	1…4
	yhteensä viimeisen 10 vuoden aikana	20
Jokaisesta AKR-tapauksesta toivomme, että vastaatte välilehdillä mahdollisimman tarkasti.		

Figure A1. Sample front page of survey.

AKR-tapauksen kuvaus

Kohde: Silta

Kohteen sijainti (kunta tms.): Espoo

Rakenne (esim. silta, julkisivu, uimala): Silta

Tutkimuspäivä: 1.9.2008

Miten AKR todettiin (silmämääräisessä tarkastelussa, ohuthietutkimuksella, jollain muulla):

Silmämääräiessä tarkastelussa ja ohuthietutkimuskissa

AKR:n aiheuttaman halkeilun voimakkuus (kiviainesrakeissa, pastassa):

Molemmissa kohtalainen

Geelin esiintyminen (rakenteen pinnalla, halkeamissa, kiviainestartunnoissa):

Todettiin lähinnä kiviainesrakeideen ulkopintojen lähellä halkeamissa ja huokosissa

AKR näytteissä (montako näytettä tutkittiin, monessako niistä todettiin AKR):

6 näytettä tutkittiin / AKR = 4 kpl

Mistä osista rakennetta AKR-näytteet otettiin (sijainti ja syvyys):

Reunapalkit ja kansilaatta

Betoni:

> betonin toimittaja x

> betonityyppi x

> sideainetyyppi

> v/s x

> seosaineet, lisäaineet jne: x

AKR:n aiheuttanut kiviainestyyppi(kivialji, mineraalikoostumus, raekoko)

Deformoitunut graniitti

Kiviaineslähteen sijainti: x

Tehtiinkö kohteesta ohuthieitä kyllä

> ovatko hieet tallella ja käytettävissä tutkimuksiin kyllä

> otetttiinko hieistä kuvia ja ovatko kuvat käytettävissä x

Tehtiinkö tutkimuksista kirjallinen tutkimusraportti kyllä

> onko raportti julkinen vai luottamuksellinen luottamuksellinen

> voiko raportin saada tutkimuksen käyttöön kokonaan tai osittain? Jos kyllä, voitteko lähettää raportin. x

Kiitos vastauksista

Figure A2. Sample subsequent page of survey, per structure with AAR occurrence.

10. Appendix B: Finland Structures Identified with AAR

- Table of structures where AAR in Finland

ALKALIKIVIAINESREAKTIOKYSELYN VASTAUKSET 2011 - YHTEENVETOTAULUKKO

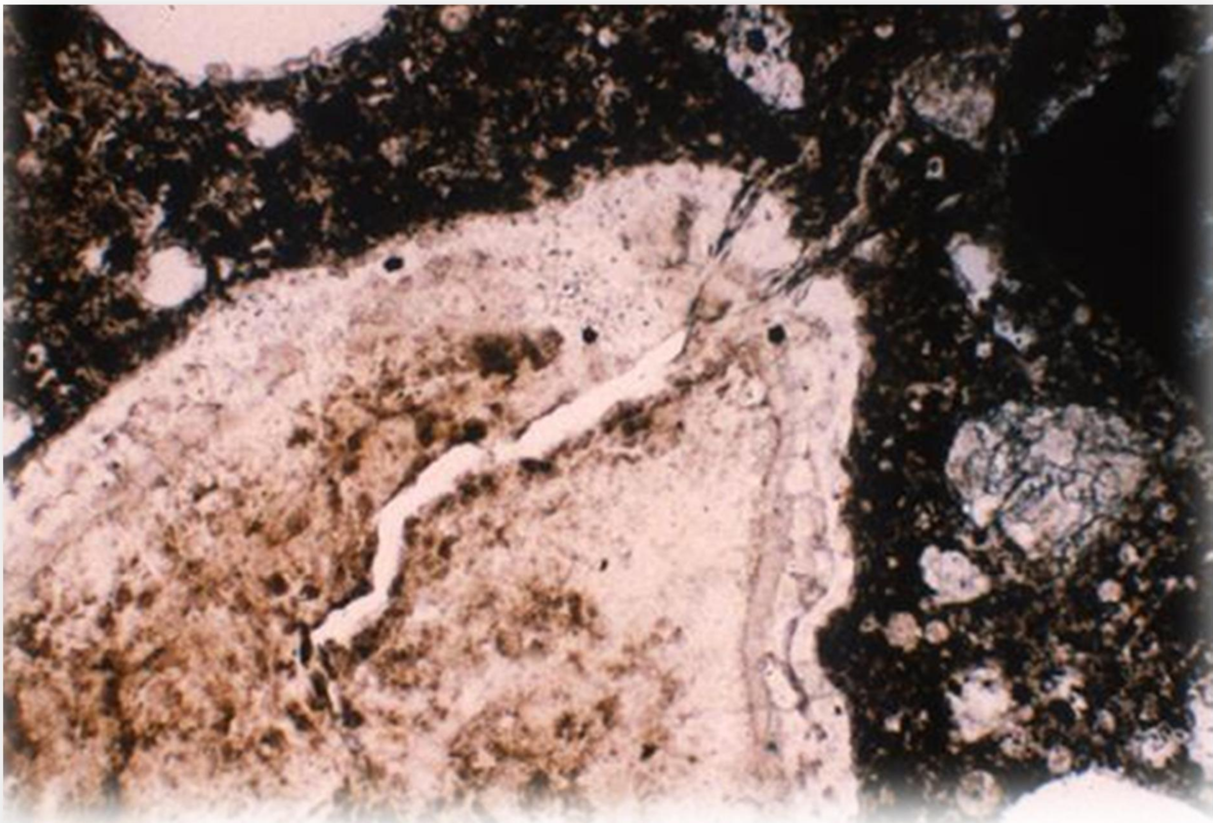
#	Tut	Pvm	Paikkakunta	Geographic area	Kohde	Type classification	Rakenne	Rak.vuosi	Hieitä yht.	AKR yht.	Reagoiva kiviaines	Aggregate classification
1	C	21.12.2011	Helsinki	Uusimaa	As Oy	house	kuorielementti		6	2	gra tai kvt, mahd. hiekkakivi ja gra:ssa karkea ms)	granite or quartzite = U
2	C	2.12.2011	Lempäälä	Häme	silta	bridge	kansilaatta		7	4	gra tai kv-ms-bt-l (on myös hapan metavulkaniitti ja kvt hieissä)	granite or fine garined dark schist or metavulcanite = U
3	W	1.12.2011	Helsinki	Uusimaa	Silta	bridge	Kansi		8	1	Kvartsikivi / kvartsiitti	Quartzite
4	V	11.11.2011	Länsi-Suomi	Länsi-Suomi	Silta	bridge	Kansi		2	1		u
5	V	10.11.2011	Pohjanmaa	Pohjanmaa	Uimahalli	pool facility	Uima-allas, seinä, lattia		4	2		u
6	E	26.10.2011	Virrat	Häme	silta	bridge	kansi, reunauloke	1975	4	2	graniitti	granite
7	V	30.9.2011	Itä-Suomi	Itä-Suomi	Silta	bridge			2	2		u
8	C	30.8.2011	Punkaharju	Itä-Suomi	Hautomoallas	pool facility	Lattia		9	1		u
9	W	11.7.2011	Häme	Häme	Silta	bridge	Kansi, palkki		7	2		u
10	V	8.12.2010	Etelä-Suomi	Uusimaa	Talo	house	Julkisivu		4	4	Keraaminen laatta	Ceramic tile
11	W	7.12.2010	Rantsila	Oulu	Silta	bridge	Reunapalkki		8	1	Tumma, hienorakeinen liuske	dark fine grained schist
12	E	30.11.2010	Kemi	Oulu	Paperitehdas	industry	pilarit, palkit		3	2	Tumma, hienorakeinen liuske	dark fine grained schist
13	C	19.11.2010	Helsinki	Uusimaa	As Oy	house	Tukimuuri, antura		9	5	Graniitti	Granite
14	E	18.11.2010	Tampere	Häme	silta	bridge	kansi, maatuki	1979	5	4	Tumma, hienorakeinen liuske	dark fine grained schist
15	E	25.10.2010	Kuopio	Itä-Suomi	silta	bridge	Reunapalkki	1971	4	3	tumma hienor. Liuske	dark fine grained schist
16	C	21.10.2010	Porvoo	Uusimaa	Kylmälaitetaso	bridge	Laatta		8	2	Graniitti tai kvartsiitti	granite or quartzite = U
17	C	5.10.2010	Vantaa	Uusimaa	Voimalaitos	industry	Julkisivu		8	1	Kv-ms-bt-liuske	dark fine grained schist
18	C	19.8.2010	Helsinki	Uusimaa	As Oy	house	Parveke, pintalaatta		6	1		u
19	C	3.3.2010	Helsinki	Uusimaa	As Oy	house	Porraskatos, laatta ap		2	1		u
20	C	23.2.2010	Ahvenanmaa	Ahvenanmaa	Silta	bridge			2	1	Hiekkakivi	sandstone
21	C	18.9.2009	Kuopio	Itä-Suomi	Palvelutalo	house	Uima-allas, pohjalaatta		5	1		u
22	C	20.5.2009	Nurmijärvi	Uusimaa	Vesitorni	watertower	Vetopalkki		7	1	Kv-ms-liuske	dark fine grained schist
23	C	24.4.2009	Kauniainen	Uusimaa	Sairaala	house	Julkisivu		24	1		u
24	E	10.12.2008	Tampere	Häme	silta	bridge	kansi, reunauloke, välituki	1959	3	1	kataklastinen liuske	cataclastic rock
25	C	25.9.2008	Sipoo	Uusimaa	Sähköasema	industry	Perustus, yp		6	1		u
26	C	7.4.2008	Helsinki	Uusimaa	Vesisäiliö	watertower	Seinä, up		4	1		u
27	C	25.2.2008	Porvoo	Uusimaa	Pölynpoistolaito	industry	Palkki		6	1	Graniitti, rapakivityyppinen	granite
28	E	18.1.2008	Helsinki	Uusimaa	teollisuu-piippu	industry	piippu		2	2	Graniitti	granite
29	E	4.12.2007	Espoo	Uusimaa	silta	bridge	kansi, reunapalkki	1966	5	4	graniitti	granite
30	C	5.11.2007	Lappeenranta	Itä-Suomi	As Oy	house	Parvekelaatta		10	2	Graniitti	granite
31	E	10.10.2007	Mouhijärvi	Häme	silta	bridge	kansi	1960	4	2	tumma hienor. Liuske	dark fine grained schist
32	C	1.10.2007	Eno	Itä-Suomi	Alikulkusilta	bridge	Kansi		4	4	Kvartsiitti ja muskoviitti-serisiittikvartsiitti	Quartzite
33	O	n. 2007	Helsinki	Uusimaa	talo	house	julkisivu		6	2	mikrokiteinen kvartsi, mahd Tanskasta	Danish rock
34	W	26.11.2006	Oulu	Oulu	Silta	bridge	Kansi, siipimuuri, reunapalkki		4	4	Hienorakeinen liuske	dark fine grained schist
35	C	23.10.2006	Kerava	Uusimaa	Koulu	house	Julkisivu		5	1	Ei havaittu	u
36	E	9.6.2006	Eno	Itä-Suomi	silta	bridge	Kansi, siipimuuri	1958	6	5	serisiittikvartsiitti	Quartzite
37	C	15.3.2006	Kuopio	Itä-Suomi	As Oy	house	Parvekekaide		5	1	Kvartsikiilleliuske	dark fine grained schist
38	W	26.5.2005	Oulu	Oulu	Silta	bridge	Kansi		3	1	Mustaliuske, fylliitti	dark fine grained schist
39	C	7.4.2005	Jyväskylä	Keski-Suomi	Kompostointilait	industry	Seinä		11	2	Kv-bt-musk-liuske ja graniitti	granite and schist = U
40	C	31.3.2005	Mikkeli	Itä-Suomi	Kompostointilait	industry	Lattia		4	1	Graniittinen	granite
41	C	13.8.2004	Oulu	Oulu	Kokilli	other			7	1	Kv-ms-serisiittiliuske	dark fine grained schist
42	E	4.8.2004	Turku	Varsinais-Suomi	silta	bridge	kansi	1965	6	2	graniitti	granite
43	E	3.6.2004	Orivesi	Häme	ylikulkusilta	bridge	kansi, reunapalkki	1971	2	1	Tumma liuske	dark fine grained schist
44	C	9.12.2003	Helsinki	Uusimaa	As Oy	house	Parveke?, kaide		12	1		u
45	E	3.7.2003	Helsinki	Uusimaa	K Oy	house	julkisivu, sw-elementti	1977	2	2	klinkkerilaatta	Ceramic tile
46	O	n.2001	Kaarina	Varsinais-Suomi	Talo	house	julkisivu		8	2	Flintti, Tanskasta	Danish rock
47	O	n.2001	Kotka	Itä-Suomi	teollisuushalli	industry	runkorakenteet		5	2	breksiatyyppinen, kvartsirikas juonikivi	u
48	O	n.2000	Harjavalta	Varsinais-Suomi	patorakenne	dam	patorakenne		6	3	?	u
49	C	28.5.2000	Turku	Varsinais-Suomi	Koy	house	Julkisivu, pesubetoni		10	3	Mikrokiteinen kvartsi, mahd ulkom.	u
50	C	7.12.1998	Kuopio	Itä-Suomi	As Oy	house	Parveke, laatta yp		3	1	Ei havaittu	u
51	C	25.4.1998	Oulu	Oulu	Patosilta	bridge	Pilarin taso, vaakapinta		5	1	Ei havaittu	u
52	C	11.2.1998	Kittilä?	Lappi	Silta	bridge			4	1	Kiillel, pitkälle rapaut, sis. hienor. kvartsia. Ounasjoentie ristsilta RVN/KTT?	dark fine grained schist
53	C	30.1.1998	Turku	Varsinais-Suomi	Autohalli	house	Katto		5	2	Breksia, kvartsijuonia	u
54	C	28.8.1997	Porvoo	Uusimaa	As Oy	house	Julkisivu, up		10	1	Mainittu vain tunnistamaton geeli huokosissa	u
55	E	n.1997	Oulu	Oulu	silta	bridge	kansi		6	4	Tumma, hienorakeinen liuske	dark fine grained schist
56	O	n.1996	Vantaa	Uusimaa	Talo	house	julkisivu		8	4	Flintti, Tanskasta	Danish rock
											open rows & U =unknown rocktype	

11. Appendix C: Finland AAR Workshop Overview

A Workshop was organized at VTT in cooperation with Suomen Betoniyhdistys, on January 24, 2012 from 9.00-12.00. The event was announced in *Betoni* magazine (issue 4, December 2011) and an email invite with PDF flyer (Figure C1) was sent to the BY mailing list in early January. Approximately 50 people attended the workshop, as listed below. The agenda of the workshop is shown on the following page.

Workshop Attendees

Vesa Anttila, Rudus Oy
Tapani Arola, Kiratek Oy
Petri Bergman, Insinööritoimisto ConMix
Miguel Ferreira, VTT
Henrik Halonen, Lahti Precision Oy
Erika Holmberg, Lemminkäinen Infra Oy
Erika Holt, VTT
Jouni Huura, Huura Oy
Tiina Hyvärinen, VTT Expert Services
Pasi-Pekka Immonen, WSP Finland Oy
Markus Inkiläinen, Lammin Betoni Oy
Jan-Erik Järventie, Lammi-Kivitalot Oy
Kari Jääskeläinen, Rakennustekniikan opisto
Satu Kosomaa, Finnsementti Oy
Hannele Kuosa, VTT
Harri Kylämetsä, Consolis Oy
Rain Köiv, VTT Expert Services
Jukka Lahdensivu, Tampereen teknillinen yliopisto
Markku Leivo, VTT
Kalle Loimula, VTT
Mia Löija, VTT
Seppo Matala, Matala Consulting
Aki Meuronen, Aaro Kohonen Oy
Kiia Miettunen, VTT Expert Services
Erik Nordenswan, Nordkalk Oy
Simo Nykänen, A-Insinöörit Suunnittelu Oy
Kalervo Orantie, VTT Expert Services
Elina Paukku, Aaro Kohonen Oy
Taina Piiroinen, NCC Roads Oy
Jouni Punkki, Consolis Oy
Hannu Pyy, VTT Expert Services
Ossi Räsänen, Liikennevirasto
Paula Raivio, Contesta Oy
Sami Rouvila, Lammin Betoni Oy
Liisa Salparanta, VTT
Jorma Sikstus, Sto Finexter Oy
Ville Sjöblom, VTT
Katriina Tallbacka, Inspecta Sertifiointi Oy
Juhani Toivonen, Parma Oy
Tomi Tolppi, WSP Finland Oy
Akseli Torppa, Geologian tutkimuskeskus
Jetta Uotila, A-Insinöörit Suunnittelu Oy
Tapio Vehmas, VTT
Erkki Vesikari, VTT
Tero Virtanen, Rudus Oy
Jouko Vuokko, Geologian tutkimuskeskus
Inari Weijo, Insinööritoimisto Lauri Mehto Oy
Markus Äijälä, A-Insinöörit Suunnittelu Oy



BETONIN ALKALIKIVIAINESREAKTIO SEMINAARI

VTT:LLÄ ESPOOSSA 24.1.2012 – VTT & SUOMEN BETONIYHDISTYS

Alkalikiviainesreaktio on betonissa todettu kemiallinen reaktio, joka pahimmillaan voi johtaa vakaviin vaurioihin rakenteissa. Kyse on useimmiten ulkorakenteista, mutta myös sisätiloissa, kuten hyvin kosteat tai märät ja lämpimät tilat, reaktiota tavataan.
Seminaari sisältää aihetta käsitteleviä esityksiä, joissa paneudutaan mm. nykyiseen tietämykseen alkali-reaktion mekanismeista, sekä ulkomailla tehtyihin tutkimuksiin ja ohjeistuksiin. Lisäksi tilaisuudessa esitellään VTT:llä loppuvuodesta 2011 tehdyn alkalireaktiota käsittelevän kansallisen esitutkimuksen tuloksia.
Tilaisuus on tarkoitettu kaikille, joita alkalireaktioon ja sen mahdollisuuteen liittyvät asiat kiinnostavat, kuten suunnittelijat, teollisuuden ja tutkimuksen parissa työskentelevät, rakennetun ympäristön käytöstä ja säilyvyydestä vastaavat jne.

Ajankohta: tiistai 24.1.2012 klo 9.00 – 12.00
Paikka: VTT; Vuorimiehentie 3, Otaniemi, Espoo
Tilaisuus on maksuton

Ilmoittautumiset viimeistään 23.1.2012 sähköpostilla tai puhelimella:
Hannu Pyy (hannu.pyy@vtt.fi tai 040 507 2071) tai Erika Holt (erika.holt@vtt.fi tai 040 593 1986)
Ilmoittauduttaessa mainitkaa yritys, henkilön nimi, sähköpostiosoite ja puhelinnumero.

Suomen Betoniyhdistys

Figure C1. Workshop announcement.

AAR WORKSHOP – AGENDA

Date: Tuesday, January 24, 2012. 9-12

Location: VTT, Vuorimiehentie 3 (Digitalo), Espoo, Room AP107 (1st floor)

9.05	Welcome (Erika)
9.10	Introductions (everyone attending)
9.20	AAR Background (Hannu)
9.45	Experiences from Finnish Industry (Jouni Huura, Huura Oy)
10.00	International perspectives for addressing AAR (Miguel)
10.15	Coffee Break & Discussions
10.45	Results of 2011 Pre-Study (Hannu)
11.25	Future needs in Finland (Markku)
11.45	Discussion & Final Remarks
12.00	End