

Standard FA and Anlegg

Characteristics, fresh concrete properties and durability

Dr Knut O Kjellsen
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Norcem cements - Iceland

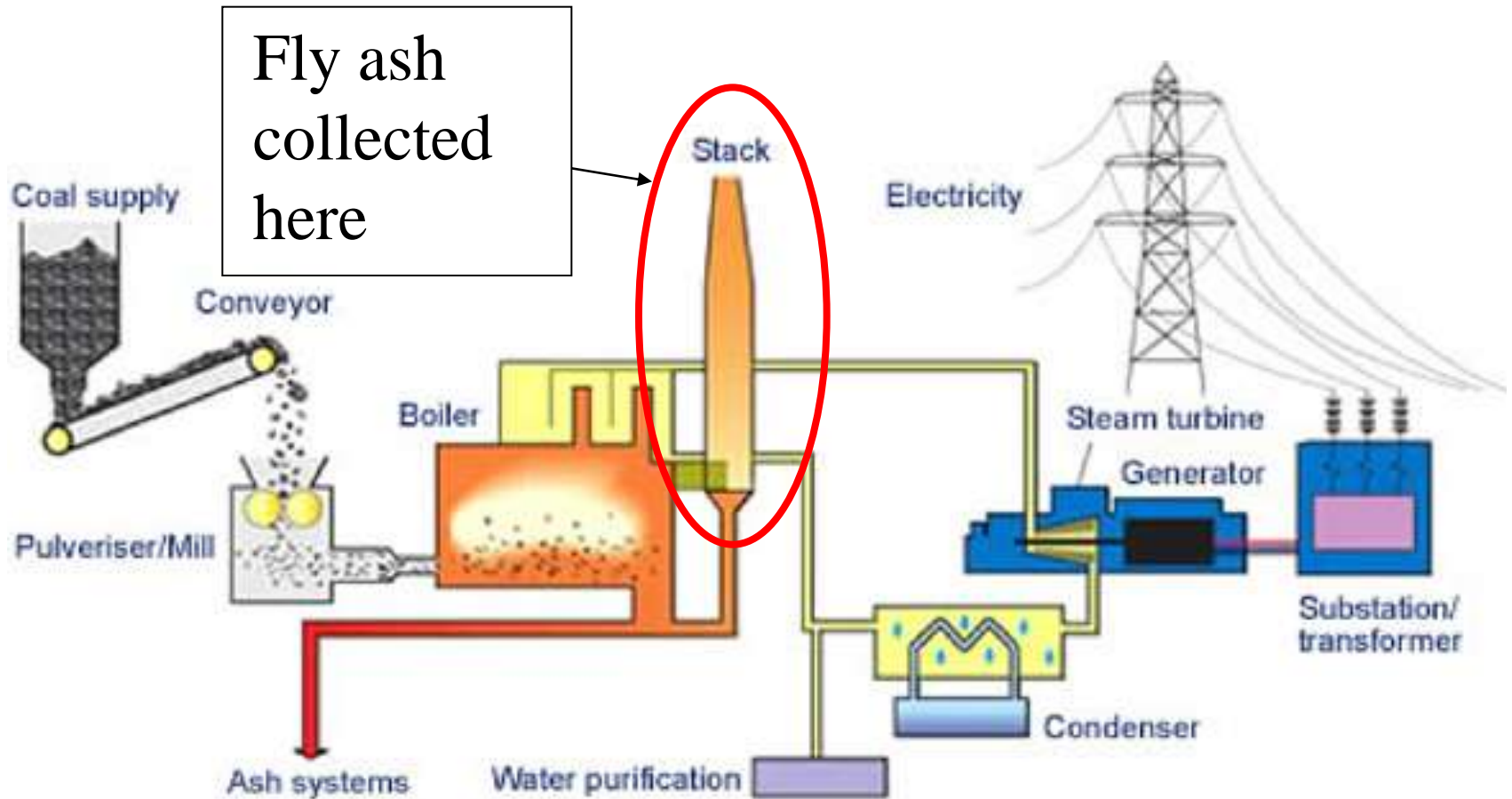
Standard FA and Anlegg

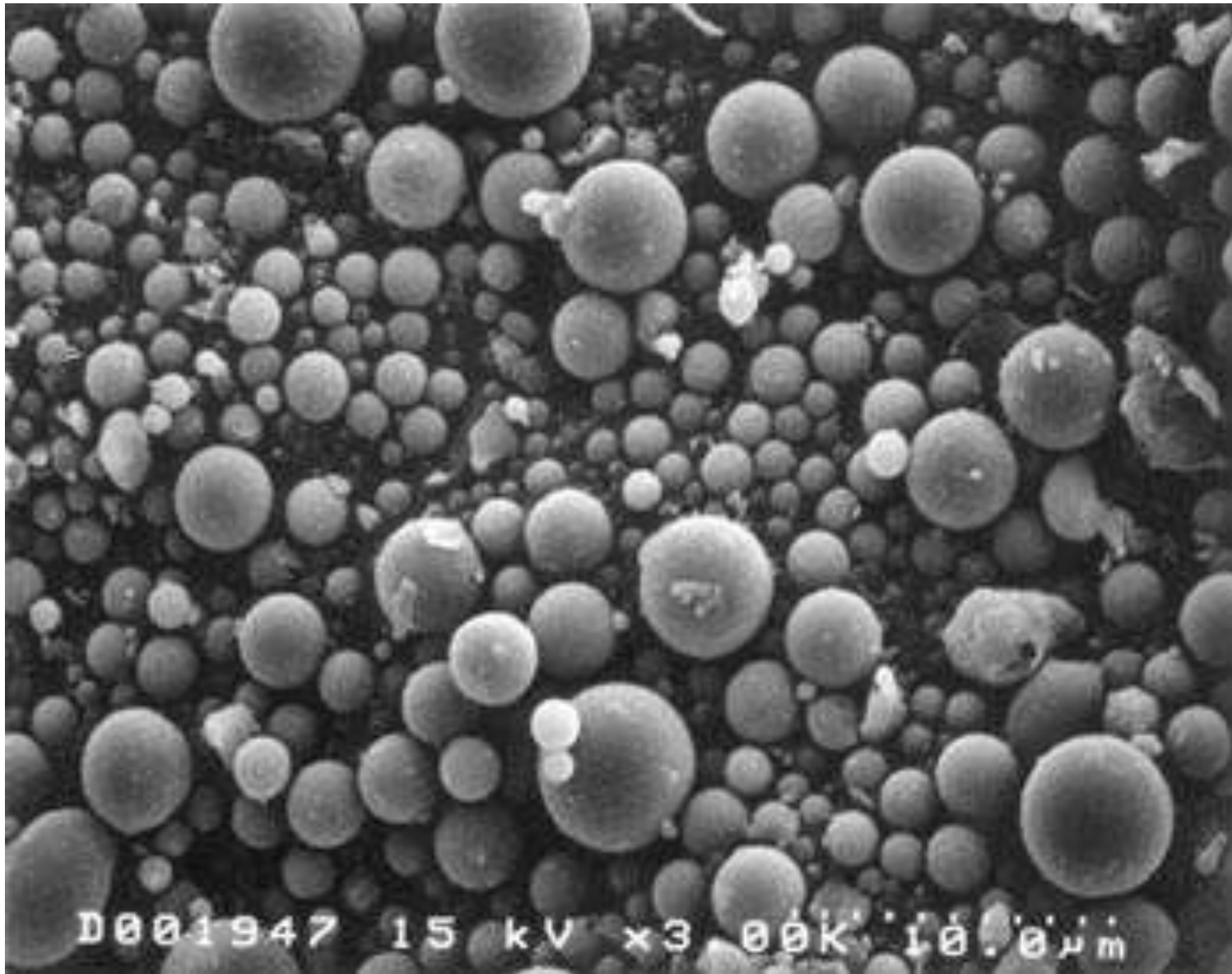
	STD FA	ANL
Type	CEM II/A-V 42,5 R	CEM I 52,5 N
k-factor	no	no
CO ₂ * (kg/tn)	613	733

*EPD, www.epd-norge.no

Norcem cements - Iceland

STD FA – fly ash





Norcem cements - Iceland

Standard FA – fly ash

- Spherical particles
- Amorphous structure SiO_2 , Al_2O_3 , Fe_2O_3
- Pozzolanic material
- Fly ash comply with EN-450 Category A

Norcem cements - Iceland

Standard FA and Anlegg

	STD FA	ANL
Application	Buildings -Residential -Business -Pre-cast Infrastructure	Infrastructure High-strength

Norcem cements - Iceland

Standard FA and Anlegg

	STD FA	ANL
Blaine (m ² /kg)	450	360
Setting time (min)	120	120
Water demand (%)	30	27
Spec. weight (kg/m ³)	3.01	3.16
Strength, 2 day (MPa)	31	30
Strength, 28 day (MPa)	52	60

STD FA

Workability

- Low spec weight
- Increased pastevolume (ca 2 liter/100 kg cement)
- SCC
 - Improved stability
- Excellent workability in building concrete and lean concretes.
 - Improved surface finish
 - Improved compaction in dry-concrete (pre-cast)

STD FA and AAR



**CEMENT AND
CONCRETE
RESEARCH**

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Alkali-silica reactions and silica fume 20 years of experience in Iceland

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EFFEKT AV SILIKASTØV PÅ ALKALI-SILISKA REAKTIVITETEN AV SEMENT

EFFECT OF SILICA FUME ON THE ALKALI-SILICA ACTIVITY OF CEMENT

Gísli Guðmundsson

ÖSKRÓTTAKRÖNN

Þ.á.á. 1999 áskilindishóld í laknað sement og det fukna at senu af de granaslefjofur sem brukna til betong þroðubruun er alkali-silika reaktio for ses larpa vers spassknan på et fura for vobediljpa alkali-silika fokeogjover i betong var til orsku. Þar-for var ses larpa eljort þovontioin tiltak sil- sil gjoelvar de konstruogjover sem sem menta var mest orskuil á.á.á. laknað. Þess og vobediljuforkyng. Hlusa þovontioin tilisk var delvsa á velja sil- sil reaktio granaslefjofur og delvsa á bruku þovontioin-istilbanding i sementis.

Fórnung þá íslenska þjerp þraka effektivt sem þvora gromulast íbelding í senu. Þis þvoraft er þvora þovontioin sem sil- sil reaktioin er sil- sil gjoelvar de konstruogjover sem sem menta var mest orskuil á.á.á. laknað. Þess og vobediljuforkyng. Hlusa þovontioin tilisk var delvsa á velja sil- sil reaktio granaslefjofur og delvsa á bruku þovontioin-istilbanding i sementis.

Þetta vobediljuforkyng til íbelding þá vobediljuforkyng til sil- sil reaktioin er sil- sil gjoelvar de konstruogjover sem sem menta var mest orskuil á.á.á. laknað. Þess og vobediljuforkyng. Hlusa þovontioin tilisk var delvsa á velja sil- sil reaktio granaslefjofur og delvsa á bruku þovontioin-istilbanding i sementis.

IBLANDING AF SILIKASTØV I SEMENT - PRAKTISKE ERFARINGER

PRODUCTION OF BLENDED CEMENT BASED ON SILICA FUME - PRACTICAL EXPERIENCES

Gísli Guðmundsson

1. Inngangur.

I snart tré ár har man í Statana Sementfabrik í Akronas Island íbeldi þvoraþvoraþvora með 3-8% af silika-óþvora. Sementfabrikin í Akronas startaðe þroðubruun 1949. Þetta er en lilla fabrikk með kon sem vnn. Kapasitetin er 80 - 100.000 tons per ár og basarar på vdr-þvora. Hstoftinn til sementtilvorkningin er mest óvnniliga skjellisand sem kalksþvora og líparite, glastigt materiala af vulkanisk oprindelse sem silisilvorkþvora.

På grund af skjellisandit har sementit af hót indhold af alkali sem bevirkar på styrkuvrkningin, þvora til tidligstyrken, negativt på slátstyrken. For 15-20 ár síðan upgáðen at betongtillagasmaterialar i brug í Reykjavík-órúdr og flere steder í Island var alkalireaktivo. På grund af sementins alkaliindhold blev igangsæt understogelser på hvilken måde man kunne undgå færæ af byggekader på grund af alkalireaktioin. Hlusa understogelar blev údrift på byggfórskningsinstitutit í Reykjavík. Man kom til det resultat at den mest fornuftiga istilbanding af þvoraft var brug af þvoraþvoraþvora materialar, sem mest þvoraftið kunne tilsettes til sementin. Mange vulkaniske materialar í Island har þvoraþvoraþvora. På sement-fabrikin startaðe senu þvoraþvoraþvora 1972 og þvoraþvoraþvora den sívora eftir. Man brugte først líparite sem blev tilsettet til sementin. Man fann út at man kunne blanda up til 1% líparite uden merkilig reaktioin på 28 dage sementstyrken senu íbeldingin bevirkaðe reaktioin af alkaliþvoraþvoraþvora og opfyrdte ASTM-standardens krav for reaktive tillagasmaterialar.

Silica Fume to Enhance Concrete Quality, Icelandic Experience Concerning Alkali-Silica Reactions



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ABSTRACT

Silica fume has been intermixed with Icelandic cement since 1979. The main reason why silica fume is utilized in this way is to reduce or eliminate alkali-silica reactions in concrete. Now after more than 20 years of service there are no signs of alkali-silica reactions in concrete in Iceland. These findings are supported by standardized alkali silica test methods.

However, the homogeneity of silica fume both in cement and hardened concrete is not always as good as expected since small clumps of silica fume can be found in hardened concrete and test results have shown these clumps to be alkali silica reactive.

Key words: Alkali-silica reactions, silica fume, durability.

1. INTRODUCTION

Silica fume has been utilized in concrete for some decades now. Initially it was used as a cement replacement material, but in recent years silica fume is used more and more as a solid additive (micro filler) in concrete (1). Increased strength and improved durability are the main benefits. Incorporation of superplasticizers and silica fume offers flowable concrete with low w/c - ratio. In other words silica fume affects concrete quality in many ways and when properly proportioned it will greatly improve the quality of both fresh (green) and hardened concrete. Moreover, the utilization of silica fume in concrete affects the environment in a very beneficial way. Silica fume is a by- or a waste product, mainly from ferroaluminum plants. As a cement replacement material, its usage will lower the cement consumption hence, less carbon dioxide

with alkali content since 1979. Icelandic cement is unique in many ways. Cement raw materials, therefore, less appropriate material is utilized for production. As a result, the alkali content of some alkali-silica reactive aggregates are relatively common and favorable environmental material. ASR became a serious problem in Iceland during the 1970s. At that time research began to concentrate ASR materials in Icelandic concrete. Since the opening of a ferroaluminum plant in postwar material in all concrete. After 20 years of service there are no signs of ASR are supported by scientific research, standardized alkali-silica test methods, and field ASR (2,3).

Keywords: Silica fume, Long term performance

crete for some decades replacement has been used (more) in concrete (1). bility are the main reasons and silica fume w/c ratio. In other dity in many ways, greatly improve the ad concrete. More- sicutu affects the en- ure it is a by-product rrollion plants. As used or more likely placement material, erce. For each ton of silica fume is highly silica fume has been nated alkali-sil-

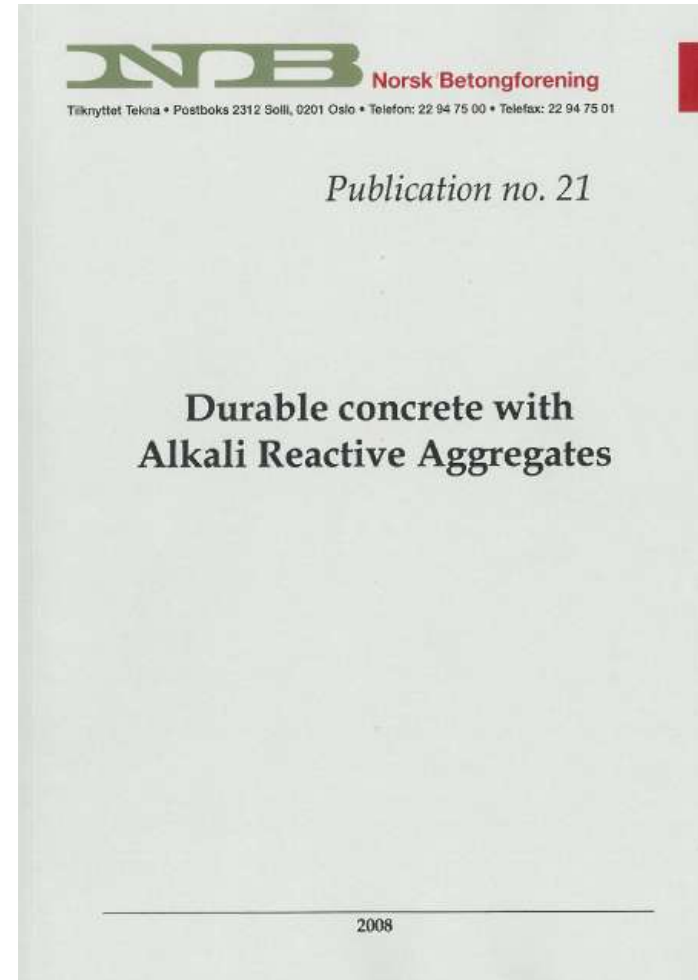
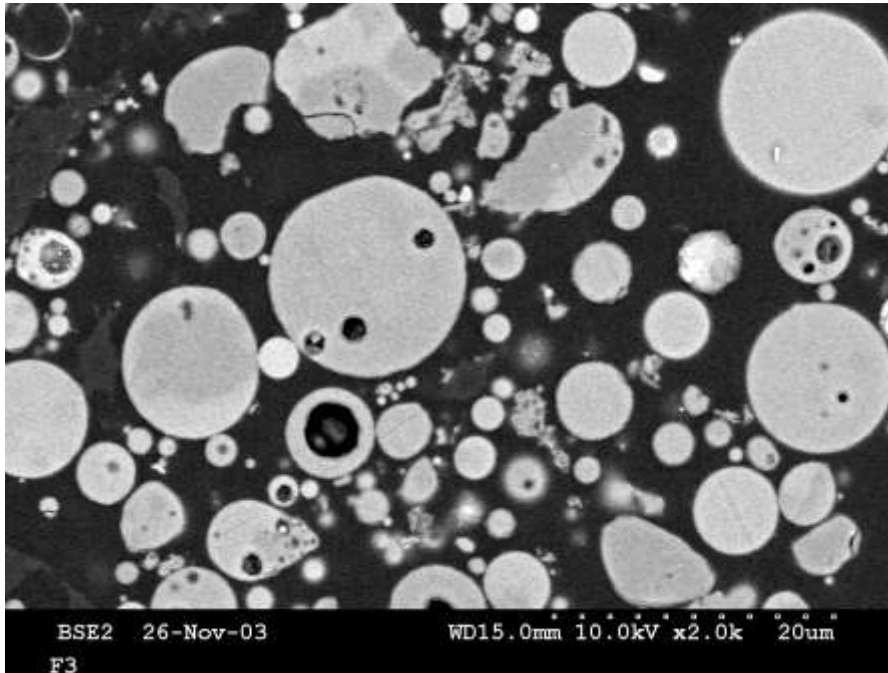
reactions (ASR) in concrete [2–12]. Before this, serious damage was caused by ASR in domestic houses in Iceland from 1961 to 1979. Preventive actions (potash cement-replacement aggregates) were taken for larger concrete structures. No such actions were taken for houses during this period. At that time, houses were not considered in any danger [6]. Icelandic Portland cement has an extremely high alkali content, currently about 1.65% w/w of $\text{Na}_2\text{O}_{\text{eq}}$, with a sodium to potassium oxide ratio of about 3:1 by weight [13]. The aggregates used in concrete are mainly volcanic, and some of them are very reactive in terms of ASR. The high reactivity is mostly due to a high content of dysoptic material, altered basalt and sea dredged material that was commonly used in Iceland. In 1979 four preventive measures were taken to fight ASR in concrete. These were (1) silica fume was blended into cement, (2) the criteria on reactive materials was changed, (3) sea dredged material had to be washed, and (4) the use of reactive material was limited. Since then, there have been no reported cases of ASR damage in concrete. Many condition surveys have been conducted on houses built after 1979 (for a complete list of references of these surveys see reference [13]). In these surveys the structures are observed visually and cross-sections are taken for laboratory inspection. No signs of ASR damage have been reported. Furthermore, all aggregates intended for concrete must be tested with the ASTM C 237 method or the Norwegian method. The aggregates must be tested with Icelandic

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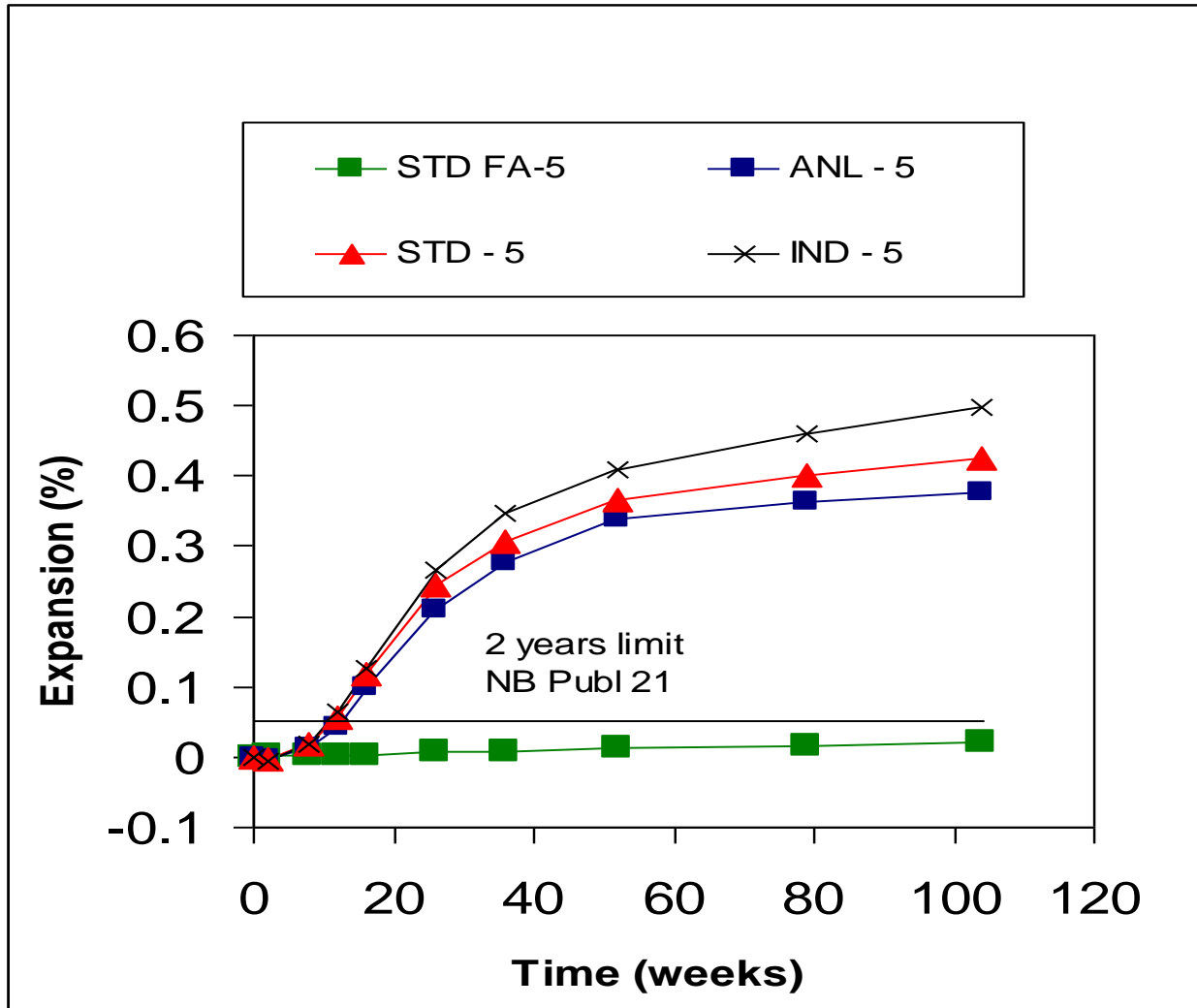
NORCEM
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STD FA and AAR



STD FA and AAR

Norwegian Test results



Fly ash and AAR

Long-term Experiences from the field

- In Norway (25 years)
- Lower Notch dam, Ontario (40 years)
- Nant-y-Moch dam, Wales (50 years)

50 Years Old and Still Going Strong

Fly ash puts paid to ASR

by Michael Thomas, R. Doug Hooton, Chris Rogers, and Benoît Fournier

The use of fly ash for controlling damaging alkali-silica reaction (ASR) was first reported in 1949 by Robert Blanks of the U.S. Bureau of Reclamation.¹ Since then, hundreds of papers have reported the results of laboratory studies on the efficacy of fly ash in this role. While many specifications now permit the use of potentially reactive aggregates, provided a sufficient level of fly ash (or other preventative measure) is used in the concrete, there have been relatively few documented cases of major structures where fly ash has been successfully used together with reactive aggregates.

A paper on two such cases, the Nant-y-Moch Dam in Wales, U.K., and the Lower Notch Dam in Ontario, Canada, was published by the primary author when those facilities were about 35 and 25 years old, respectively.² The dams were revisited in 2010 when they were about 50 and 40 years old; this article summarizes the performance of these structures with regard to ASR. Studies of performance in the field are essential for confirming the efficacy of preventive measures observed in the laboratory and for benchmarking accelerated laboratory tests intended for the rapid evaluation of such measures.

Nant-y-Moch Dam

The Nant-y-Moch Dam is part of the Cwm Rheidol Hydroelectric Scheme, which was constructed between 1957 and 1962 in central Wales, about 17 km (10 miles) east of the town of Aberystwyth. Downstream from Nant-y-Moch is the Dinas Dam, which forms part of the same hydroelectric scheme (Fig. 1). Both dams were built at the same time using aggregates from the same source. Details of the materials and mixture proportions used for these dams are given in Table 1.

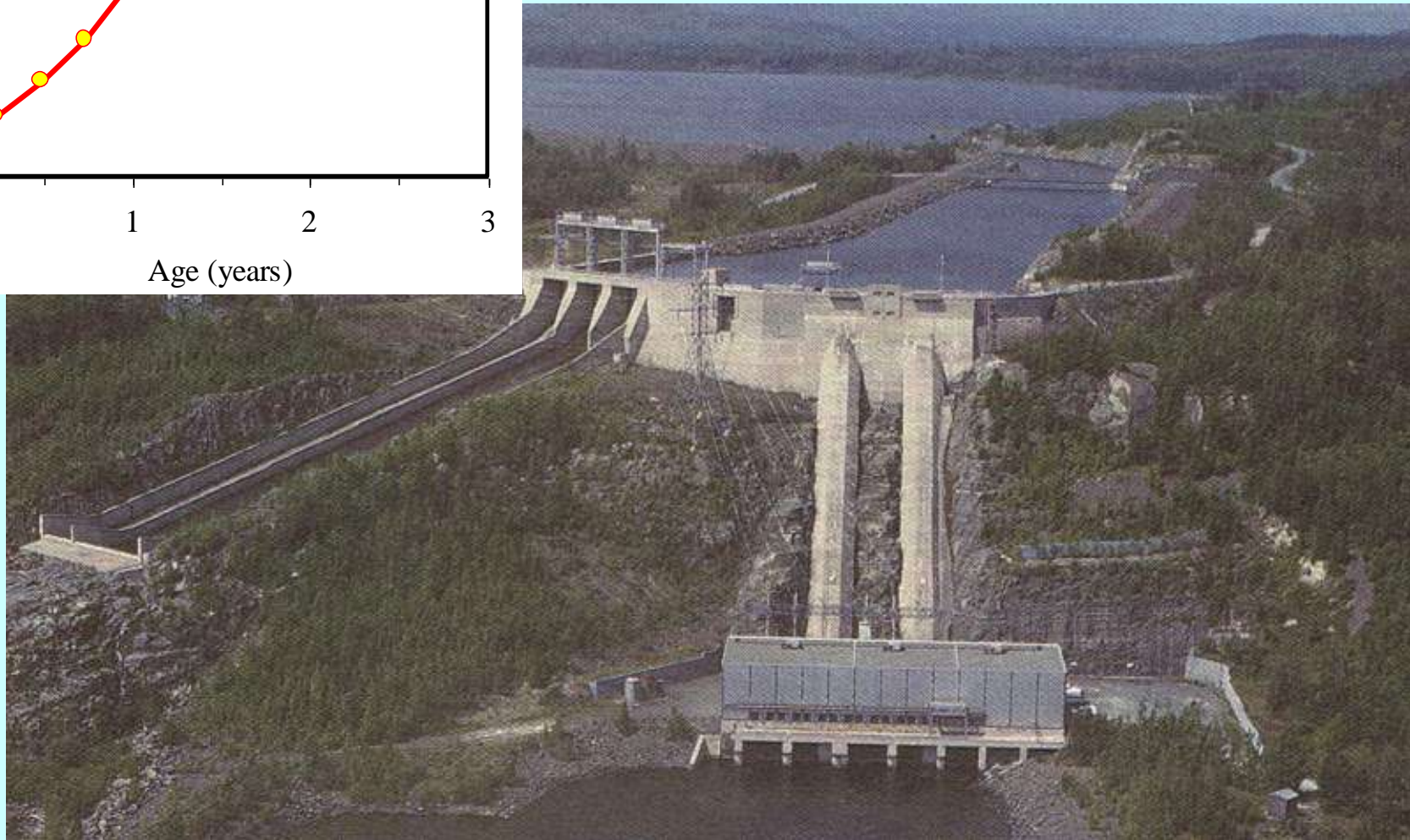
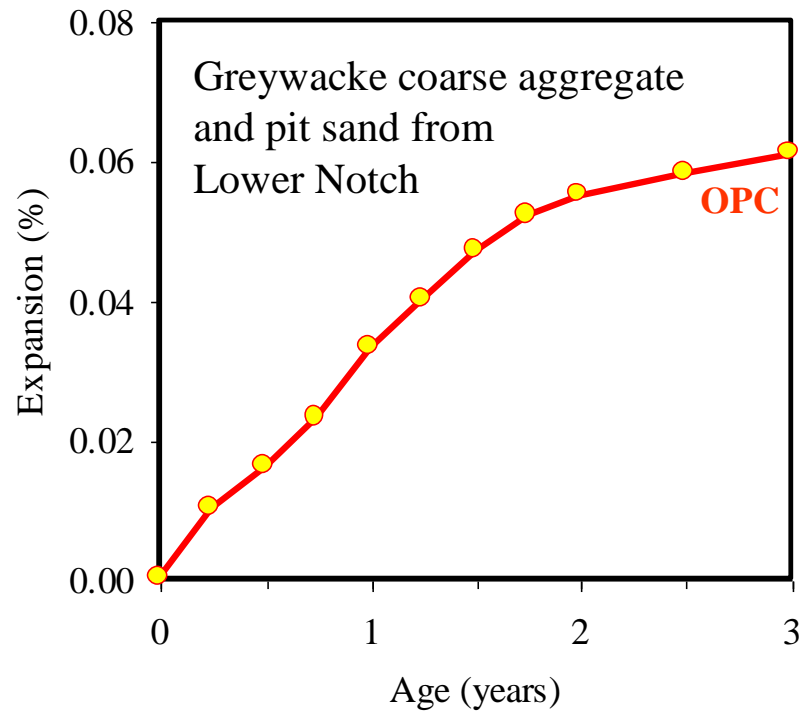
Problems with the Dinas Dam were first observed in 1986 in the form of map cracking and the development of a major longitudinal crack in the arch section³; ASR was subsequently verified as the cause of deterioration. When the primary author visited the dam in 1991, extensive cracking of the dam was observed at all exposed locations.³ Horizontal cracks were observed on the downstream face, along the crest, and on the visible part of the upstream face of the arch. The gravity abutments showed random map cracking, with crack widths in excess of 3 mm (0.25 in.). In 1997, survey data was used to show that the dam had experienced a total upstream radial movement of 113 mm

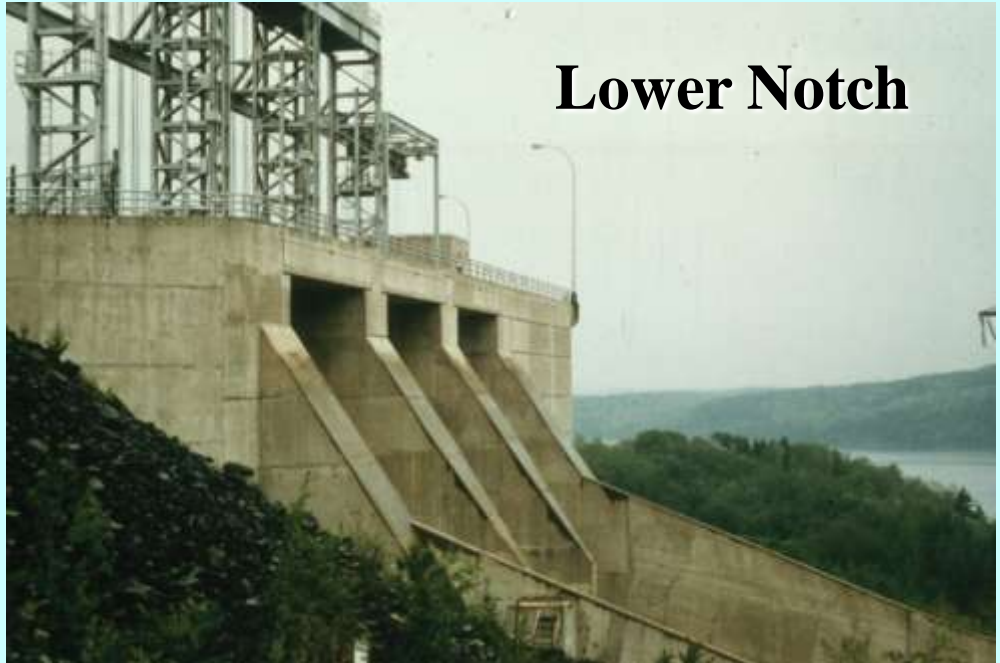
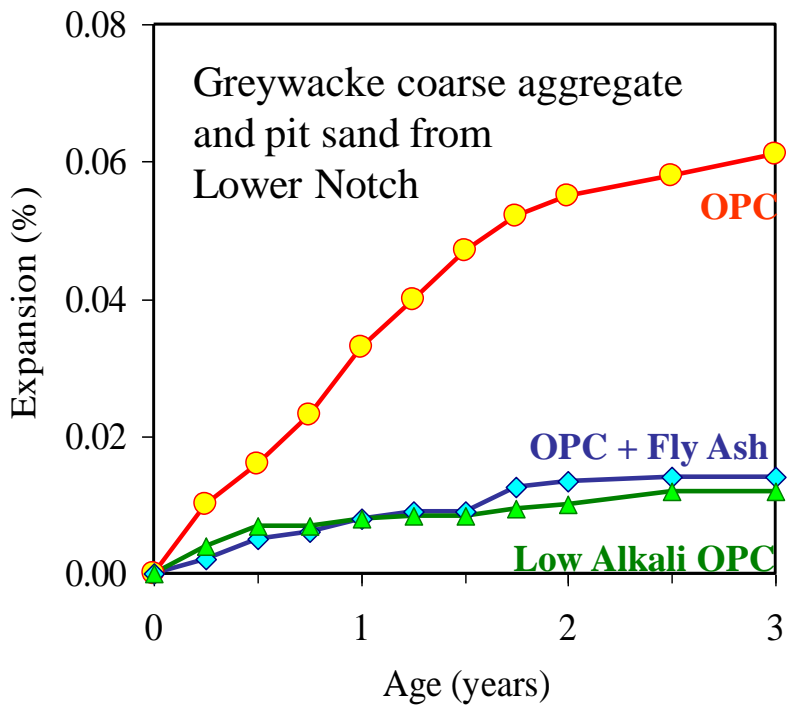


Fig 1: Schematic diagram showing the Cwm Rheidol Hydroelectric system, including the Nant-y-Moch Dam (D-1) and the Dinas Dam (D-2)

Lower Notch Dam

Built ~ 1970





20% to 30% fly ash used with high-alkali cement and highly reactive aggregate

Current condition (at 40 years) is excellent

NANT-Y-MOCH DAM FLYASH CONCRETE



UPSTREAM FACE

STD FA and AAR

- Lab studies show STD FA prevent AAR
- Long-term field studies show fly ash to be effective in preventing AAR

STD FA and AAR

Documentation testing with Icelandic aggregates

- Testing according to Icelandic Building Regulation (no 441/1998 131.4
- ASTM C-227 + RILEM AAR-3
- Normal reactive aggregate (Perla A)
- Highly reactive aggregate (Type H)

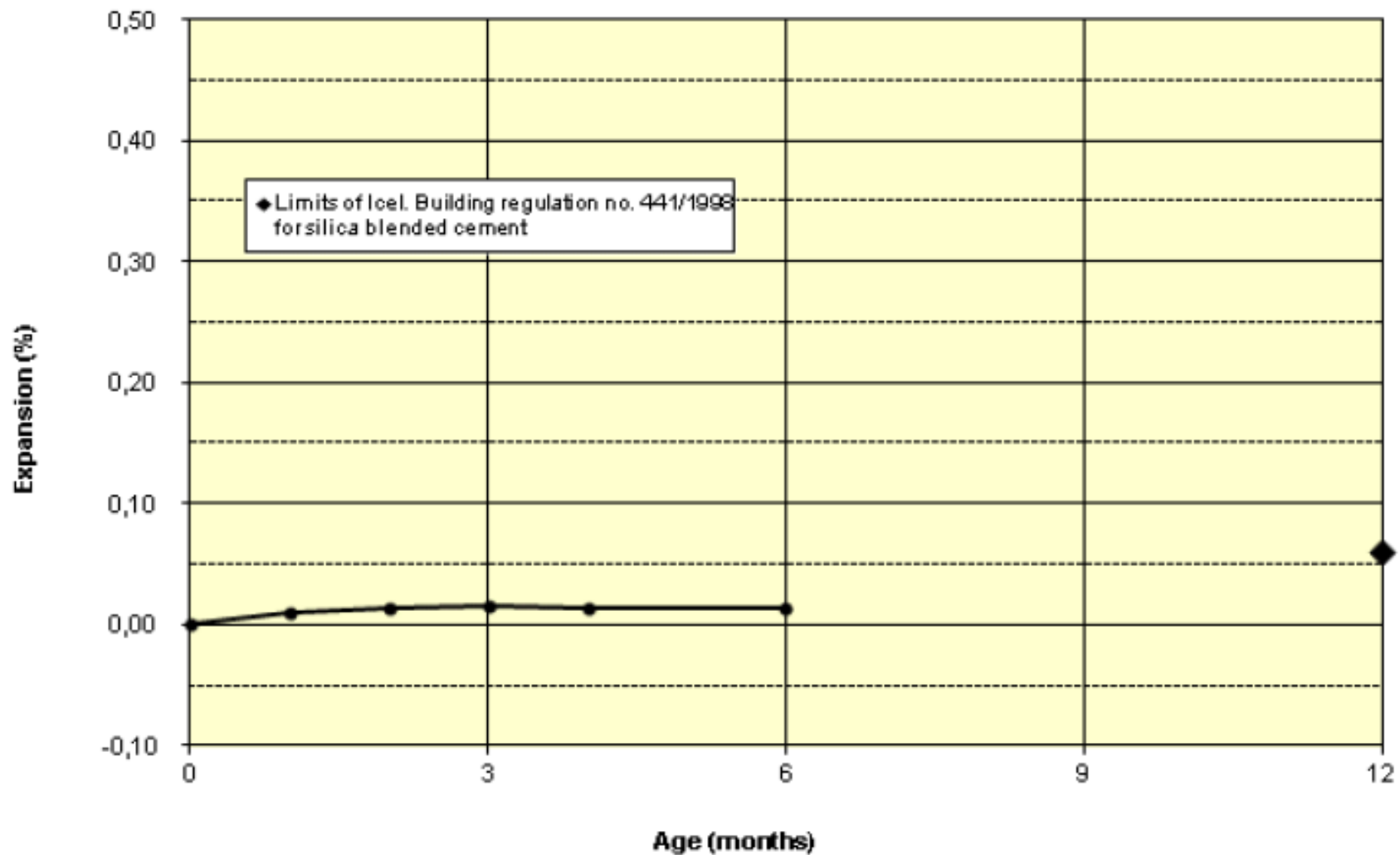


Figure 2. Average expansion of mortar bars according to ASTM C 227, with very high reactive aggregate ("Type H") with Norcem Standard FA cement.

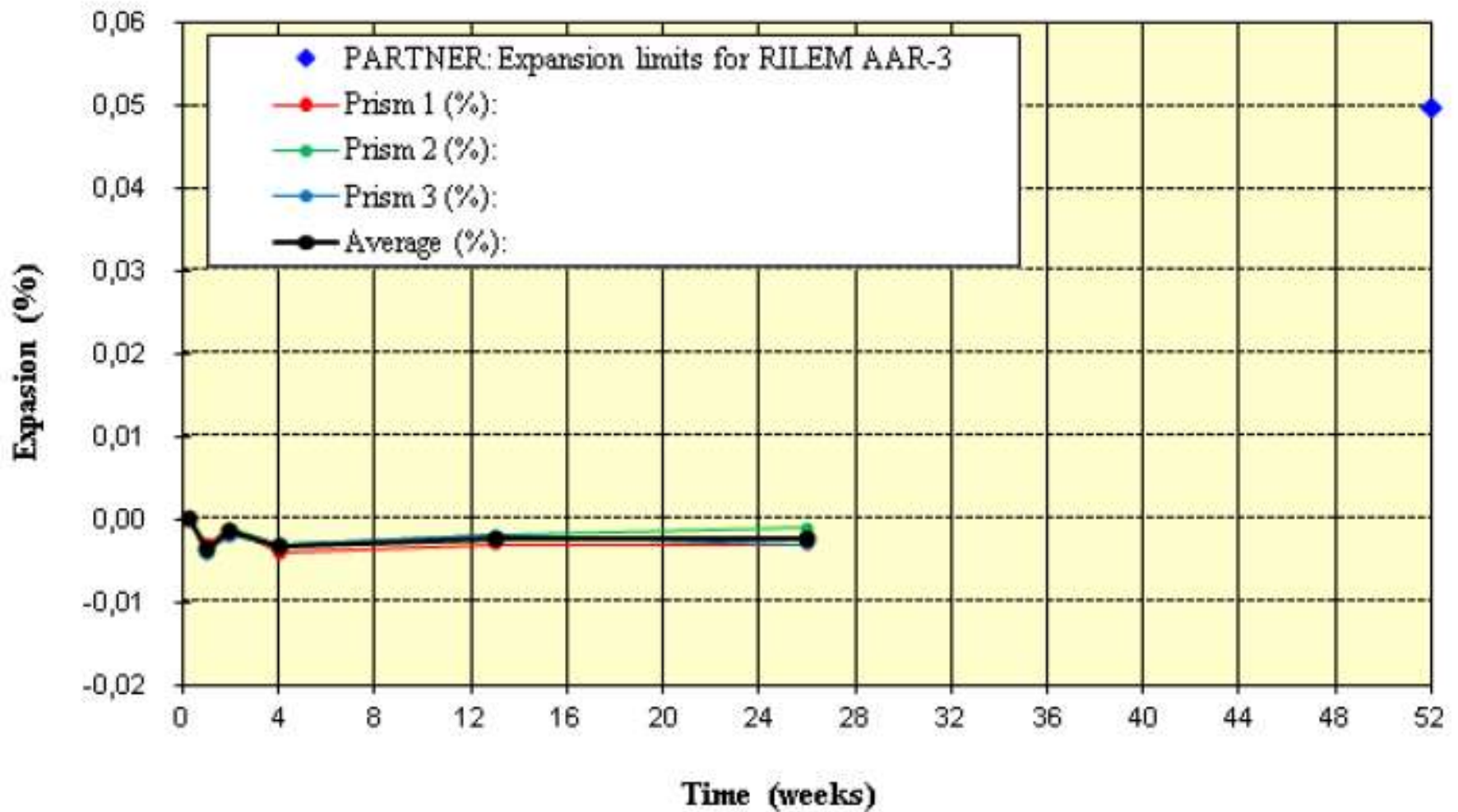


Figure 4. Expansion of concrete prisms according to RILEM AAR-3, with very high reactive aggregate ("Type H") with Norcem Standard FA cement.

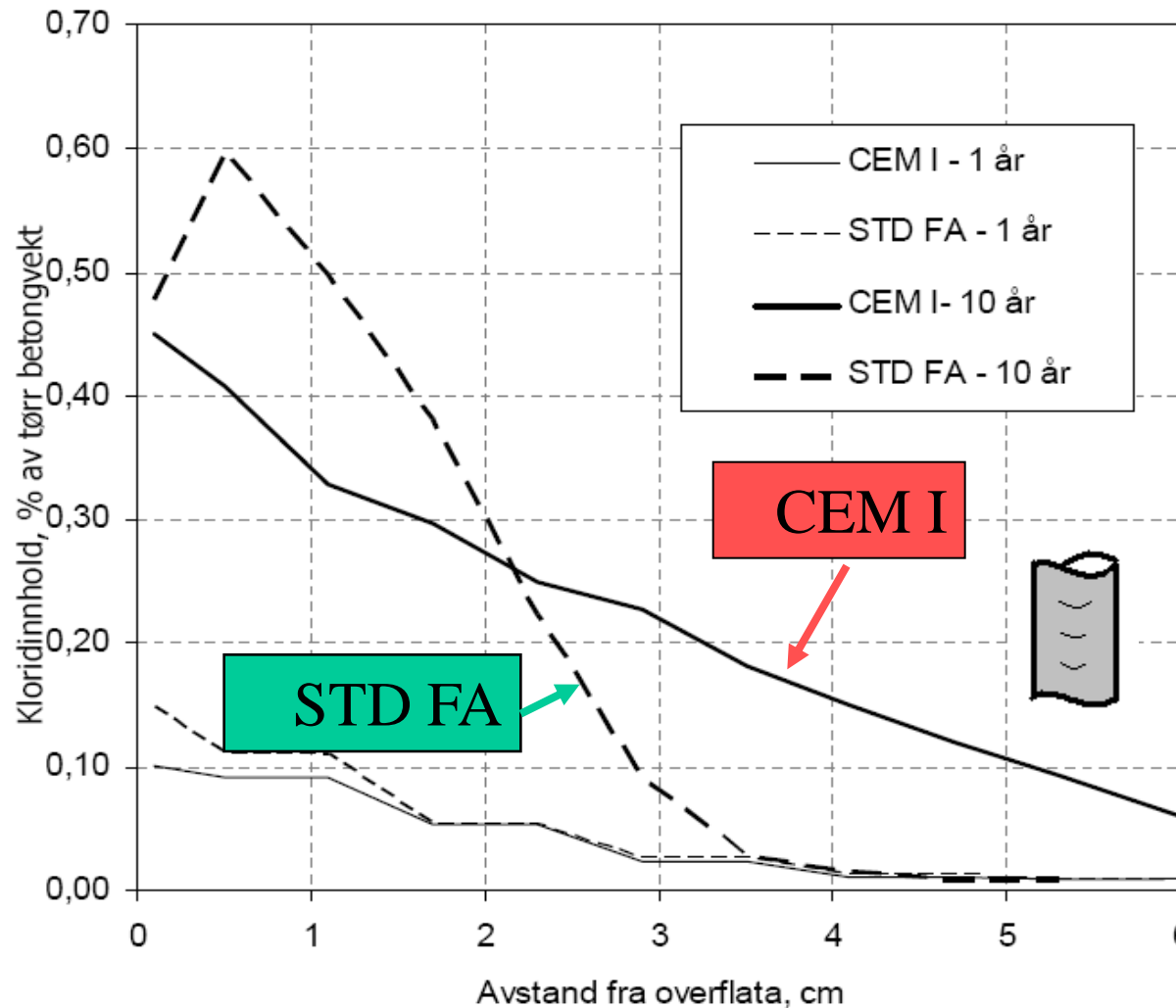
STD FA and AAR Status, Iceland

- 6 months regulatory testing shows very good results, expansion well below the limits
- Final 12 months testing in June 2012

STD FA and chloride intrusion



STD FA and chloride intrusion



STD FA and chloride intrusion

- Recommended in the publication 'Durability of Concrete Structures in Marine Environment', Norwegian Concrete Association
- Recommended by the Norwegian Road Administration

NB norsk
betongforening

Publikasjon nr. 35

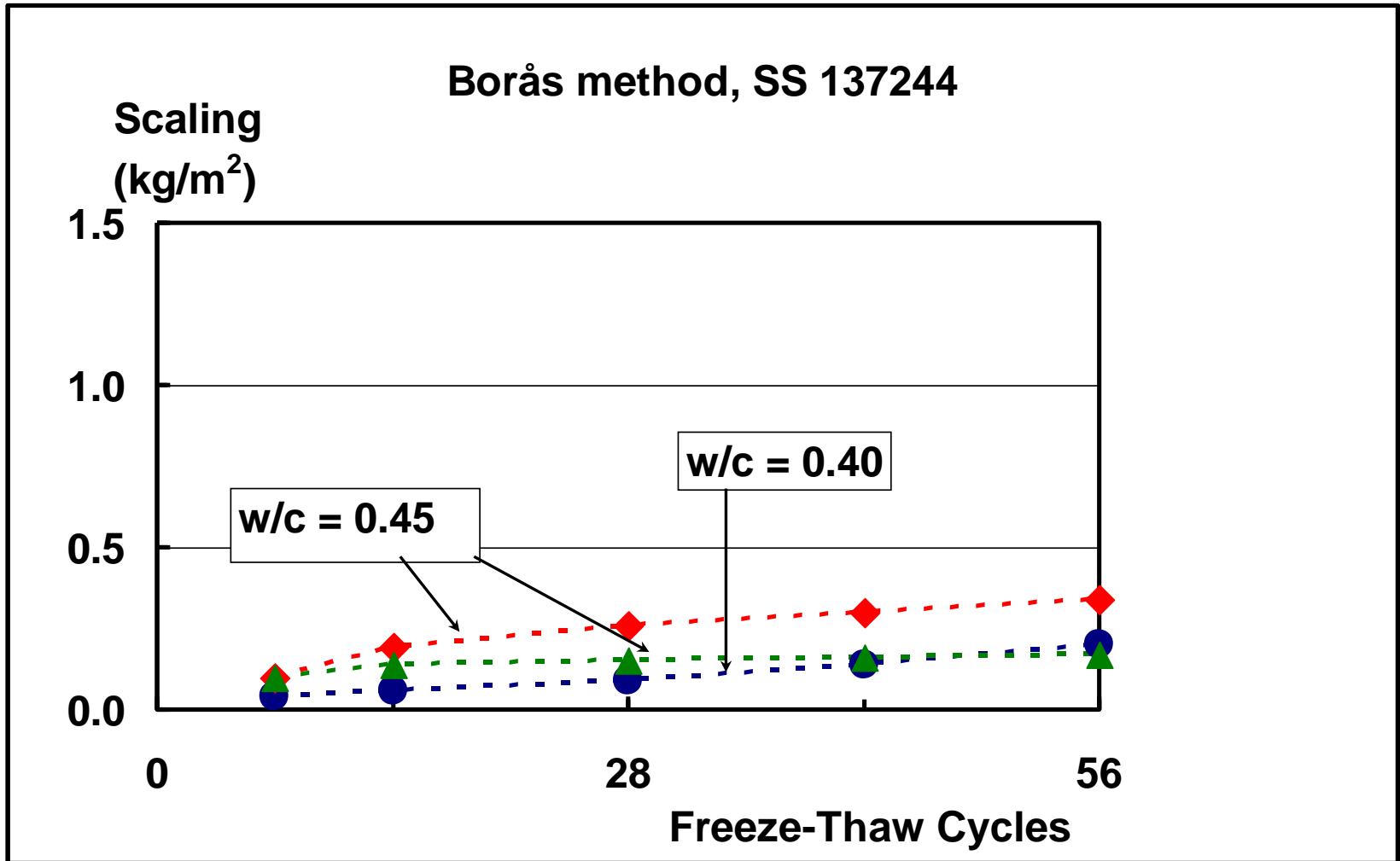
**Bestandighet av
betongkonstruksjoner
i marint miljø**

STD FA and freeze-thaw resistance

- STD FA => excellent freeze-thaw resistance provided entrained air-system
- 4% air
- Borås method SS 137244
 - $m_{S,56} < 0.5 \text{ kg/m}^2$
 - $m_{S,56} / m_{S,28} < 2$



STD FA and freeze-thaw resistance



STD FA and freeze-thaw resistance

Results: STD FA concrete tested
according to SS 137244

$m_{S,56}$	$m_{S,56} / m_{S,28}$
0.24 kg/m ²	1.53

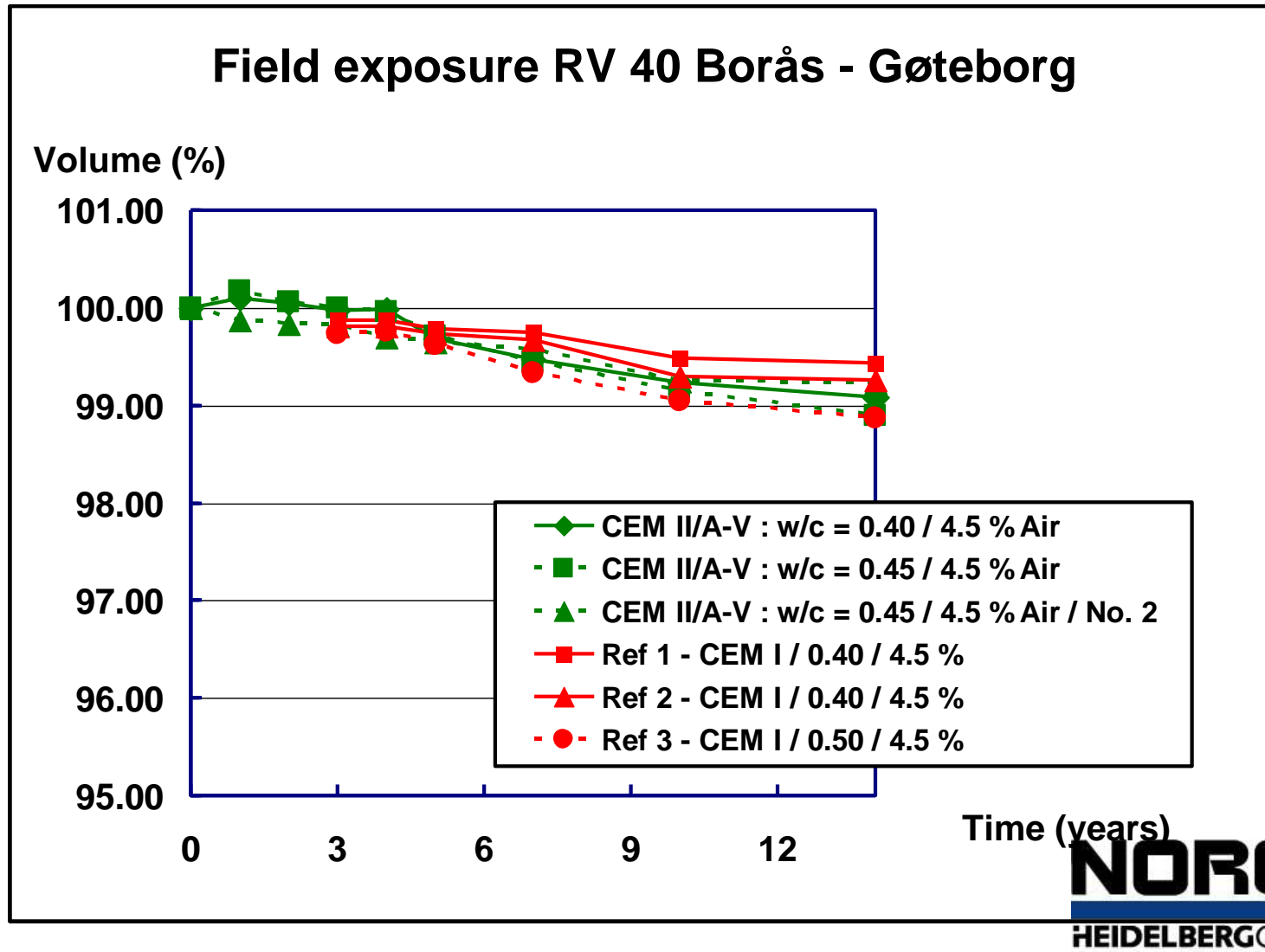
STD FA and freeze-thaw resistance

Long-term field test results (RV40 Borås-Göteborg)



STD FA and freeze-thaw resistance

Long-term field test results



STD FA and freeze-thaw resistance

- Freeze-thaw resistant provided air-entrainment
- Increased dosage of air-entraining agent
 - May be needed
 - Residue of coal in the fly ash

Curing technology – Winter Concreting

- HETT 97
 - Simulate temperature and strength development
 - Planning of concrete works in cold weather and for massive structures



Curing technology – Winter Concreting

- HETT 97
 - 'www.norcem.no'
 - Materialdatabase

