Alkali-aggregate reaction: correlation of accelerated testing and field performance of concrete containing mineral additions

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Extended Abstract

The concrete prism test (CPT) is one approach used to assess the potential for an alkali-silica reaction (ASR) of a given mix design. As such, it is an important tool in designing concrete resistant to ASR. However, the transferability of the results obtained with accelerated tests to concrete behaviour under field conditions has to be validated. A validation of the Swiss CPT [1] and the transferability of its results to concrete structures have been established in [2,3]. However, this validation only applies to concrete produced with ordinary Portland cement (CEM I according to EN 197-1 [4]). Nowadays, blended cements containing supplementary cementitious materials (SCM) dominate the Swiss cement market [5]. So far, the transferability of the results of the CPT to concrete in field conditions has not been validated for mix designs containing SCM. A project using a similar approach as in [2,3] was started. Structures were identified where two prerequisites were present. Firstly, the concrete mix design had to include reactive aggregates, fly ash, microsilica or a combination of both SCM. Secondly, results of the CPT conducted at the time of construction had to be available. Eight structures fulfilling the criteria described above were identified. The goal of the project was to verify:

- whether fly ash and microsilica have the same effect on ASR in the CPT on the short term and on the structures on the long term;
- whether the expansion reached in the CPT shows a relation to eventual damages observed in the structures.

The selected structures were inspected, coring sites were defined and several cores were extracted. The concrete was analyzed using optical microscopy (OM) and scanning electron microscopy (SEM) with energy-dispersive X-ray spectroscopy (EDX).

Table 1: Investigated structures with concrete mix design, alkali content (without boosting) and expansion determined using the CPT [1] and the microbar test (MBT) [5] (FA = fly ash, MS = microsilica). All concrete tested with the CPT was boosted with an amount of NaOH representing 25 mass-% of the total alkali content of the concrete (third row) except in the case of the viaduct.

Type of structure Year of construction	Binder	Alkali-content of concrete [kg Na_2O_{eq} /m^3]	Expansion CPT	Aggregate expansion MBT
River dam (Wettingen (AG), 1930-1933, repair 2005-2007)	CEM I 340 kg/m^3. FA 50 kg/m^3, MS 20 kg/m^3	3.1 kg/m^3	-0.003 ‰ after 8 month	0.235 %
Viaduct (Dangelstutz (BE), 1999-2000)	CEM II/A-LL 305 kg/m^3, FA 20 kg/m^3	2.3 kg/m^3	0.049 ‰ after 5 month^3	0.197 %
Bridge 1 (Fully (VS), 2004-2006)	CEM I 300 kg/m^3, FA 100 kg/m^3	2.6 kg/m^3	0.122 ‰ after 5 month	0.250 %
Oil-water basin (Vevey (VD), 2005)	CEM I (with 4 mass-% SF) 350 kg/m^3, FA 50 kg/m^3	3.0 kg/m^3	0.161 ‰ after 12 month	0.189 %
Various components of Subway (Lausanne (VD), 2004-2007)	CEM I 350 kg/m^3, FA 25 kg/m^3	3.2 kg/m^3	0.171 ‰ after 5 month	0.161 %
Bridge 2 (Visp (VS), 2004-2006)	CEM I 325 kg/m^3, SF 20 kg/m^3	2.6 kg/m^3	0.259 ‰ after 18 month	No data
Train station (Salgesch (VS), 2004	CEM I 270 kg/m^3, FA 80 kg/m^3	2.6 kg/m^3	0.265 ‰ after 5 month	0.179 %
Tunnel entrance (Collombey (VS), 2003	CEM I ca. 350 kg/m^3, SF + FA < 50 kg/m^3	3.1 kg/m^3	0.300 ‰ after 5 month	0.204 %

All investigated structures were built between 1999 and 2007, translating to an age of 11 to 17 years when this analysis was performed. All accelerated ASR tests were conducted before the structures were built.

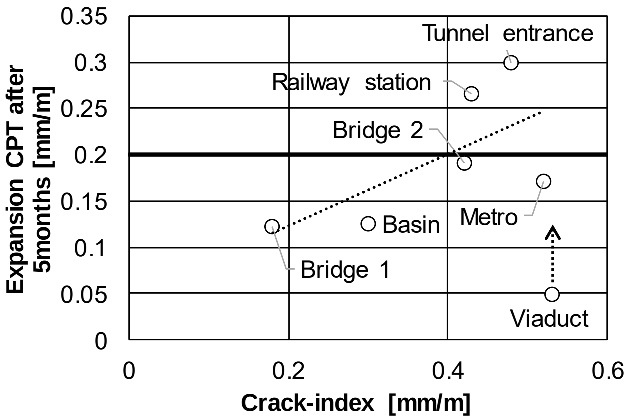

Figure 1: Expansion in the CPT as a function of crack-index determined on the structures. With alkali boosting, the expansion of the CPT in case of the viaduct would have moved into the direction of the arrow. The viaduct is not taken into account in the calculation of the regression line and the value of the river dam is not shown due to the differences in silica fume dispersion in the concrete used for CPT and structure.

Based on the results, the following conclusions can be drawn:

- The CPT seems to be suitable to asses the expansion potential of concrete containing SCM used in structures. However, the database has to be enlarged for further verification.
- Alkali boosting of the concrete used for the CPT seems to be necessary to better reflect the behavior of the concrete in the structure.
- Using different batches of silica fume and likely fly ash for the CPT and the structure may lead to a change in the expansion potential of one or the other.
- Low amounts of SCM (fly ash ≤ 80 kg/m^3, silica fume ≤ 20 kg/m^3) are not able to prevent ASR and seem only successful in slowing down the reaction. This applies as well to the combination of low amounts of fly ash and silica fume.

The analysis of thin sections is a suitable tool to determine the crack-index and identify expanding aggregate particles. However, it has to be complemented by SEM with EDX to identify ASR products in an early stage of reaction.

Keywords*: alkali-aggregate reaction, concrete prism test, field exposure, validation, microstructure*

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