

POZZOLANIC ACTIVITY OF SILICA DUST

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ABSTRACT

Highly reactive aggregates and unusually alkali-rich cement call for special precautions in connection with concrete making in Iceland. Search in the past for efficient ways to counteract alkali-aggregate reactions is cited. High hopes are now connected with the pozzolanic use of silica fume from a ferro-silicon plant now under erection. The influence of this dust on cement strength and mortarbar expansion is described.

Hoch reaktive Betonzuschlagstoffe und Zement mit ungewöhnlich hohem Alkaligehalt fordern eine besondere Vorsicht bei der Betonherstellung in Island. Untersuchungen der letzten Jahre mit dem Ziel Alkali-kiesel-reaktionen entgegenzuwirken werden beschrieben. Beimischung zum Zement von einem sehr feinen kieselsäurereichen Staub der in einer Ferrosiliziumfabrik, die jetzt in Island gebaut wird, anfällt, hat sehr gute pozzolanische Eigenschaften erwiesen. Der Einfluss von diesem Staub auf die Festigkeit des Zementes und der Mörtelprismenexpansion wird beschrieben.

Introduction

The risk of alkali-aggregate expansion in concretes has been known to Icelandic engineers since well before the production of cement started in this country in 1956. Rhyolitic blends of basaltic materials had proven to show such expansion elsewhere, and Icelandic basalts were also known often to contain substantial amounts of glass, not to speak of the "moberg" or palagonite tuffs, which are so common in this country, and are composed practically of pure volcanic glass.

These matters became of increased concern when it was evidenced that Icelandic cement had to contain very high amount of alkalis, or ca. 1.5% Na₂O equivalent, and again when seadredged aggregates were taken into use.

Because of this, known methods of counteracting the undesirable effects were resorted to in all cases of major structural undertakings. These were then, theoretical as they were, the use of imported low alkali cement, meaning <0.6 N₂O equivalent, or the use of pozzolanas. The former was used exclusively

in all dam constructions, but in harbour constructions the pozzolan method was more common. No precautions were taken in the building industry proper, since alkali expansions in building elements such as walls were unknown at that time.

At the Building Research Institute, a committee was established in January 1967 to sponsor systematic studies on alkali-aggregate reactions under Icelandic conditions. The early works of this committee have been described (1), but no severe damages were then reported. This committee is still active.

Neither was at the second international meeting on the effects of alkalis on the properties of concrete, held in Reykjavik, August 1975, any factual proof of alkali damages reported. Suspicions were, however, clearly expressed. (2)

At the third symposium we presented clear proof of alkali-aggregate expansion damages in exterior walls of a single family house in the Reykjavik area (3). From then on numerous damages of this type have been reported, and these damages have become quite severe in places. Presently a survey on exterior wall damages is being carried out at the Building Research Institute, and it may already be stated that typical indications of alkali-expansion damages are much more frequent than expected.

Aware of the general expansion risks the BRI concrete committee has directed its counteractions towards preventive measures, mainly through search for pozzolanas and pozzolanic absorbtion of the excessive alkalis.

Our cement factory uses rhyolitic glass as an argillaceous raw material source. Laboratory experiments showed at an early stage, that if the same glass was also ground in with the clinker, mortarbar expansion was reduced. This was a practical solution which was readily accepted by the industry. The use of the glass, unfortunately was very modest at first, 5% addition 1973 - 1976, mainly because of endeavors to cope with portland cement specifications, but in autumn, 1976, this was boosted up to 9%.

Whether this is sufficient to prevent damages is today still uncertain, but it certainly reduces mortarbar expansion. This may well be read from Table 1, which is from a BRI project report (4) on this research.

Table 1
The Effect of Pozzolan Replacement on Mortarbar Expansion

Pozzolan	%	Mortarbar Expansion after			
		1 month	3 months	6 months	1 year
NONE	0	0.042	0.150	0.260	0.320
Rhyolitic glass	10	0.026	0.249	0.090	0.150
" "	15	0.005	0.020	0.025	0.044
" "	25	0.009	0.017	0.017	0.026
Silica Dust	5	0.014	0.021	0.028	0.062
" "	7 1/2	0.002	0.017	0.023	0.035
" "	10	0.002	0.012	0.014	0.021

As early as 1969 tests were conducted on the use of diatomaceous earth as a pozzolan additive (5). Its influence through alkali absorbtion proved excellent both on concrete strength and reduction of mortarbar expansion. Because of this various sources of lake precipitates were tested, but none, however, proved economically acceptable.

Early this decade it was foreseen that a ferro silicon alloy plant would be erected near the Icelandic cement plant. A waste from this plant would be huge amounts of silica dust. Since cement production in this country had been short of silica rich minerals the possibilities to utilize this waste was appreciated. Better still would it be if this waste could act as a pozzolana and replace the rhyolite glass now used.

The first tests on this type of admixture were conducted at the BRI laboratory in early 1972. The material used was a fume from an open silicon furnace, (Blaine fineness ca 20.000 cm²/g) and was provided by the National Research Council from Union Carbide Corporation.

From the first tests on, it has been clear that the silica dust was much more effective than the rhyolitic glass as a cement replacement. Standard ISO-tests were therefore run on all cement blends, and from these, strength results are given in Table 2.

Table 2
Compressive and Flexural Strengths of Cements

Pozzolan	%	Compressive kp/cm ²				Flexural kp/cm ²			
		7d.	28d.	90d.	1 year	7d.	28d.	90d.	1 year
NONE	0	347	468	517	589	60	75	81	86
Rh. glass	10	332	460	512	547	55	77	87	85
" "	15	360	483	527	592	67	90	83	87
" "	25	292	451	506	562	60	83	82	80
SiO ₂ dust	5	402	438	574	612	74	91	88	80
" "	7 1/2	421	566	617	653	79	94	87	87
" "	10	434	598	648	662	80	95	88	86

The superiority of the silica dust mixes is evident. The relatively high early strengths of all mixes is thought to be due to the high alkalinity of the mortar.

Concrete test batches were also made from the cements blended with silica dust and compared with the standard 9% rhyolitic glass mixes. Typical results may be seen on the diagram in Fig. 1.

From the foresaid it may be deducted that silica dust added to our alkali rich cement will not only counteract the malicious expansion in our concretes but greatly increase the strength of these. Much research, however, is still needed to follow up these preliminary investigations.

In continuation of these tests the cement plant produced some 500 tons of cement with a 7 1/2% silica fume replacement. The fume was added as waterbound pellets (ca. 20% moisture). Some difficulties, not fully explained, were experienced in connection with pneumatic transportation of this cement, but otherwise customers were quite satisfied with its quality.

The addition of reactive silica fume to alkali rich mortars does however not reduce the formation of silica gel. On the contrary one should expect an increase in that substance. The sorbent properties of silica gels are generally known. Possibly this does explain why there seems to be more moisture in concrete walls cast with pozzolanic cements than standard cements. In this con-

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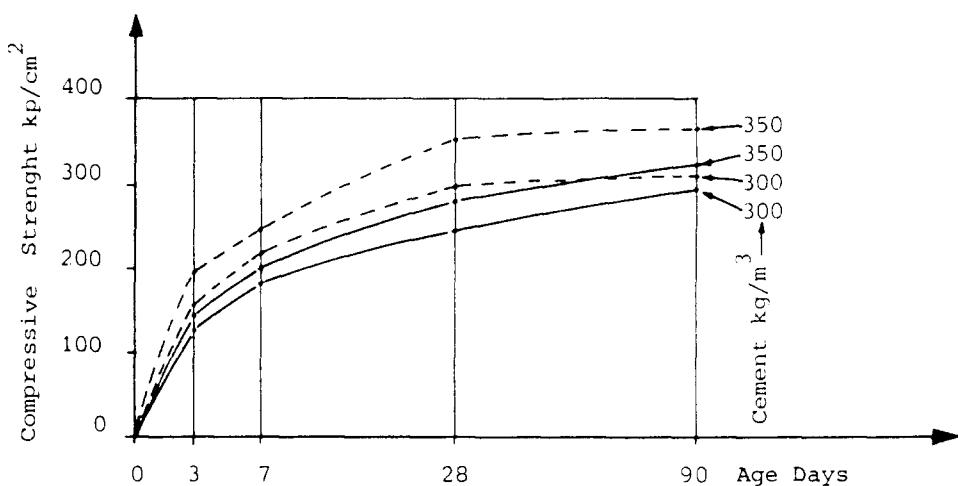


FIG. 1
Rate of Hardening of Pozzolan Concretes
(— 9% Rhyolite and ---- 7.5% Silica Fume Replacement)

nection one should remember that moisture is the common denominator for all building damages, including frost damages.

References

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