

Use of perlite powder to suppress the alkali–silica reaction

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Abstract

Reported below are the results from a study aimed at mitigating the deleterious alkali–silica reaction by using perlite powder as an admixture. The expansion of mortar bars containing various amounts of silica fume (SF), expanded perlite, and natural perlite was studied. Two kinds of reactive aggregates were used in the study: highly reactive river aggregate containing opal and marginally reactive monzo-diorite aggregate. Expanded perlite and silica fume were tested with both aggregate, separately; on the other hand, natural perlite was tested only with monzo-diorite aggregate. The bars were cast in accordance with ASTM C1260, accelerated mortar bar method, and were stored in NaOH solution for 30 days. Length changes were measured and reported. The results showed that both expanded and natural perlite powder (NPP) have potential to suppress the deleterious alkali–silica expansion.

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1. Introduction

Perlite, a hydrated volcanic glass, commonly has a pearly, vitreous luster characterized by concentric onion-skin fractures. A relatively high water content of 2% to 5% distinguishes perlite from other hydrous volcanic glasses, such as obsidian, hydrated volcanic ash, and pumicite. Upon rapid heating, perlite transforms into a cellular material of low bulk-density. As the chemical water held within the perlite boils, generally at temperatures in the range of 900–1100 °C, the resultant steam forms bubbles within the softened rock to produce a frothy-like structure. The formation of these bubbles allows perlite to expand up to 15–20 times of its original volume [1]. This new material is referred to as “expanded perlite” (commercially, the term perlite can denote either natural or expanded perlite). Because of its favorable physical and chemical characteristics, expanded perlite

finds diverse utilization in various applications: for use as a lightweight aggregate in the construction industry; as a rooting medium and soil conditioner in horticulture; as a bleaching agent in the textile industry; as an adsorbent in the chemical industry; and as filter aid and as filler in miscellaneous processes [2].

Nearly 65% of the perlite produced today is consumed by the construction industry. Its lightness, thermal, and acoustic insulation properties make expanded perlite an excellent candidate to be used as lightweight aggregate in concrete production. For insulation purposes, expanded perlite powder (EPP) is utilized as filler material in hollow bricks or as an additive in plasters. Studies to date have generally focused on the lightness and insulation properties of expanded perlite.

This study examines the efficacy of perlite powder in suppressing alkali–silica expansion. The experimental program included the production of mortar bars incorporated with alkali-reactive aggregate and certain amounts of perlite powder (both expanded and natural) and silica fume (SF), and the determination of length changes of mortar bars immersed in alkaline solution.

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2. Materials

Two different reactive aggregates were used in the study: marginally reactive monzo-diorite aggregate containing 20% quartz as reactive constituent and river aggregate containing 2% highly reactive opal. Ordinary portland cement, corresponding to ASTM Type I, was used to construct the concrete specimens. Expanded perlite in a powdered form was purchased from Etibank General Administration which produces expanded perlite in Cumaovasi, Izmir. The natural perlite was purchased in 0.6–1.2 mm sieved sizes and then ground to mineral admixture fineness using a laboratory-type grinding mill. After 2 h of grinding with 70 kg steel cylinders, 10 kg material was fined to 330 kg/m² as measured with Blaine apparatus. Chemical compositions of the materials are given in Table 1.

3. Experimental procedure

The experimental program was conducted in two series of tests. In the first series, the mortar bars containing either silica fume (SF) or expanded perlite powder (EPP) were tested for alkali–silica reaction resistance. Preliminary studies had shown that as a cement replacement EPP could be used in small quantities due to its high water absorption capacity. SF, a well-known mineral admixture used to mitigate alkali–silica expansion, was chosen as a baseline for comparison purpose since it can be applied in similar ranges to EPP. In the second series, natural perlite powder (NPP) was tested for alkali–silica reaction resistance. In the experimental program, the mineral fines were added to mortar as mass replacement of the ordinary portland cement.

Mortar bars were cast in accordance with ASTM C1260 except that the water binder ratio utilized was 0.5. In addition, 2% solid plasticizer by weight of binder was used to provide adequate workability for the bars containing admixtures. For control purpose, mortar bars containing only ordinary portland cement were cast. The mineral admixtures, SF and EPP, were introduced into the mortars as cement mass replacement in quantities of 4%, 8%, 12%, and 16%. EPP and SF were tested both with the river aggregate

and with the monzo-diorite separately. The bars were demoulded after 24 h, immersed in water bath at room temperature which gradually increased to 80 °C, then cured for another 24 h, their length measured, and then were immersed again into an 80 °C, 1 M NaOH solution. The mortar bars were measured every 3 days up to 30 days.

In the second series of experiments, natural perlite was tested as mineral admixture to compare its performance with expanded perlite. NPP was tested only using monzo-diorite aggregate. Because of its low water requirement, probably due to reduced surface area compared to EPP, NPP was utilized relatively at higher levels of 8%, 16%, 24%, and 32%, and no plasticizing agent was used. Testing and length measurement procedures adopted were the same as in the first series of the experimental program.

4. Results and discussion

Fig. 1 shows the expansive behavior of the mortar bars made with reactive river aggregate and various amounts of SF. As expected, the control sample showed the highest expansion, with a decreasing trend in the expansion with increased SF content (except in the case of mortar bars containing 8% and 12% SF where the expansion rate was nearly the same). ASTM C1260 proposes a 0.10% expansion limit at 14 days for innocuous aggregates. In this experiment, only mortar bars containing 16% SF met this criterion; however, the expansion at 30 days was 0.25% for the same level.

Fig. 2 shows the expansion curves of the same river aggregate cast with EPP. Mortar bars containing 4% EPP did little to inhibit expansion; however, increasing levels decreased the expansion. Mortar bars containing 16% EPP performed very well, achieving expansions of 0.04% and 0.10% at 14 and 30 days, respectively. Comparing the performances of mortar bars containing SF and EPP demonstrates that mortar bars containing low replacement levels (4% and 8%) of SF mitigated expansion more successfully than mortar bars containing EPP; however, mortar bars containing higher replacement levels of EPP (12% and 16%) performed better than mortar bars containing similar levels of SF. It should be noted that 16% EPP satisfied the criteria of 0.10% even at 30 days.

Expansion curves of the mortar bars cast with monzo-diorite aggregate are given in Figs. 3 and 4 for SF and EPP, respectively. Expansion rates were almost identical for SF and EPP for all replacement levels. For both mineral admixtures, expansion decreased as the amount of replacement increased. At 30 days, the expansion was the same, being 0.08%, for both SF and EPP at 12% replacement level; and 0.07% and 0.05% for SF and EPP, respectively, at the 16% replacement level. Clearly, a 12% replacement level of either SF or EPP limited expansion at a very safe limit for the reactive monzo-diorite aggregate.

The effectiveness of SF in reducing alkali–silica expansion has been demonstrated by numerous researchers. The

Table 1
Percent chemical composition of the fine materials

	OPC	EPP	NPP	SF
CaO	63.18	1.52	1.72	1.42
SiO ₂	19.27	73.56	70.96	96.14
Al ₂ O ₃	5.59	14.98	13.40	–
Fe ₂ O ₃	2.52	1.06	1.16	–
MgO	2.77	0.37	0.28	1.05
SO ₃	3.00	–	–	0.39
Na ₂ O	0.24	2.85	3.20	0.75
K ₂ O	1.10	4.90	4.65	0.65
Na ₂ O _{eq}	0.96	6.07	6.26	1.18
LoI ^a	1.59	1.59	3.27	1.51

^a Loss on ignition.

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