EVALUATION OF THE ALKALI-SILICA REACTIVITY OF ROCKS FROM IRAN, ARAS REGION

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Abstract

This paper presents the results of a study on alkali silica reactivity of igneous rock deposits from ARAS region located at North-West of Iran which are going to be used in construction of ARAS dam and power plant.

While tremendous amount of research works have been carried out over the past few decades to develop quick and reliable test procedures for determining the potential alkali reactivity of concrete aggregates, few researches are available in Iranian concrete practices.

Petrographic studies, accelerated mortar bar test (AMBT) and concrete prism test (CPT) have been carried out in order to have better understanding of alkali reactivity of the deposits. On the other hand application of silica fume to reduce the risk of deleterious expansions has been investigated.

Results of different tests are discussed in a comparative base, from the view points of ASR potential, and the effect of SF to control the reactions.

Keywords: Alkali silica reaction, Expansion, Mortar bar, Prism, Petrography, Silica fume

1 INTRODUCTION

The alkali – silica reaction first recognized by Stanton (1940) is the reaction between silica components in rocks and alkalis usually derived from cement. [1] It initiates with the dissolution of silica by reactions involving the hydroxyl ion (OH^-), alkalis (Na^+, K^+) in the concrete pore solution react with dissolved silica to form alkali – silica gel [2]. As it absorbs moisture, it increases in volume thus generating pressures high enough to disrupt the microstructure of the concrete [1, 3].

Damages from ASR are serious and there are no proven methods to repair a damaged structure. This means that any possible preventing methods should be used during aggregates, cement and admixtures selection [4].

Although a tremendous amount of research works have been carried out concerning several aspects of alkali reactivity of aggregates within last decades [2], little works on this subject exist in Iranian concrete practices. There are several reports that prove the evidence of deterioration by alkali silica reaction in concrete structures in Iran.

Mineral admixtures are known to be effective in reducing the alkali-silica reaction. Due to its high silica content and high surface area, silica fume would be highly effective in controlling the alkali aggregate reaction [5].

Recent studies on alkali reactivity of rocks from several rock and sediment deposits from Zagros mountain chains in west of Iran show that there is high risk of ASR in these aggregates [6].

This paper presents results of an experiment carried out as a part of contract with Iran water and power resources development Company to evaluate the alkali reactivity of deposits which are going to be used in construction of ARAS dam (on ARAS river) and power plant. ARAS region is typically a mountainous region at the north-west of Iran, located between Iran and Armenia.

Petrography study of aggregates, accelerated mortar bar test and concrete prism test have been carried out in order to obtain a better understanding of alkali reactivity of these deposits. Application of silica fume to insure safety margins has been also investigated.

2 MATERIALS

The cement used in the study was an ordinary Portland cement (Type II according to ASTM C 150) [7] provided form Tehran Cement Company, Iran. Silica fume is obtained from Azna ferro-silicon alloy manufacture, Iran. The chemical compositions of the cement and silica fume are shown in Table 1.

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Five igneous deposits were taken from different parts of ARAS riverside, Iran. The aggregates are going to be used in construction of ARAS dam. Although they are all described as external igneous rocks, they are associated with different geological environment and display differences in their petrographical feature. Detailed descriptions of the petrography according to ASTM C 295 [8] are summarized in Table 2.

3 EXPERIMENTAL METHODS

To evaluate the alkali-silica reactivity of the aggregates, beside petrographic observations, a comparative study was carried out by means of two well-known methods: accelerated mortar bar test (AMBT) and concrete prism test (CPT). On the other hand, to improve safety factors regarding durability design, using silica fume of 7% (by weight of cement) is investigated for 3 of the 5 deposits with CPT method.

3.1 Accelerated mortar bar test (AMBT)

The accelerated mortar bar test according to ASTM C 1260 [9] which was originally proposed by Oberholster and Davis in 1986 is the most widely used accelerated method for the potential alkali-silica reactivity of concrete aggregates [3].

The mixing and molding procedures followed the requirements of ASTM C 1260. The bars were demolded after 24 h and placed into a water bath at room temperature then heated to 80 °C as specified in the test method. The bars were cured for 1 day, and then immersed in 1 N NaOH solution at 80 °C after the initial (zero-day) length measurement. The expansions were recorded at 0, 3, 7, 10, 14, 21, 28, days.

3.2 Concrete prism test (CPT)

The concrete prism test in accordance with ASTM C 1293 [10] is recognized as the most reliable test procedure for the evaluation of the alkali-silica reactivity [3].

The mixing and molding procedures followed the requirements of ASTM C 1293. The bars were demolded after 24 hours and initial length reading is done. Thereafter the specimens are moved to a storage container of temperature 38±2 °C and relative humidity of 95±5 %. Length readings were carried out at the ages of 7, 14, 28 days, as well as 3, 6, 9 and 12 months.

For specimens containing silica fume and to keep the total amount of cementitious materials constant, 7 % (by weight) of cement is replaced by SF.

4 RESULTS

Summary of petrography observations is shown in Table 2. Results of AMBT and CPT are shown in tables 3 and 4 and Figures 1 and 2 respectively. AMBT and CPT tests to investigate the effect of adding 6% Silica fume were carried out on 3 deposits (TPC 2, TPC 3 and TPC 4) and the results are given in Table 5 and Figure 3.

5 DISCUSSION

According to recommendation mentioned in ASTM C 1260, aggregates used in specimens which have expansion of less than 0.1% after 14 days exposure to 1-N NaOH solution are likely to have a low risk of deleterious expansion when used in concrete. According to the results in this study it can be found that all the aggregates have high potential for alkali silica reactivity.

Regarding recommendations in ASTM C 1293, aggregates used in specimens which have expansion equal or greater than 0.04% at one year, may be reasonably classified as potentially deleteriously reactive.

Among 5 deposits investigated in this study, Deposits TPC 2 and TPC 5 show relatively a higher potential of alkali reaction according to the results obtained from both AMBT and CPT methods. Results from ASTM C 1293 proves that while all aggregates have failed in AMBT method, three of five deposits have expansions of less than 0.04% at the age of one year. Thus there would be little risk of alkali reactivity of the aggregates according to recommendations mentioned in ASTM C 1293. Thomas et al [11] cites that condition of AMBT is overly severe as it identifies many of aggregates reactive despite their good performance in concrete prism tests.

Results of CPT at the age of 1 year show that silica fume of 7% by weight of cement seems to be beneficial in controlling the expansion due to ASR and may increase safety factors regarding service life design of the structures. Although continuing the concrete prism test up to 2 years would be beneficial in better evaluation of the effect of SF on ASR potential.

6 CONCLUSION

From this study, following conclusions can be drawn out:

1- Petrography studies of the deposits show the evidence of potentially alkali reactive minerals in the deposits.

2- While results from accelerated mortar bar tests show that all aggregates are potentially reactive, some of the aggregates can be considered non reactive according to ASTM C 1293 recommendations. This shows the presence of false-negative results obtained from ASTM C 1260.

3- Considering the safety margins, application of silica fume in order to mitigate the deleterious expansion of the concrete is recommended.

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TABLE 1: Chemical composition of Cement.

	Chemical Composition, % by mass									
Components	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	$Na_2O_{eq}{}^*$	L.O.I
Cement	22.42	4.68	3.68	63.25	3.63	1.74	0.25	0.75	0.74	0.45
Silica Fume	93.16	1.13	0.72	-	0.53	0.05	-	-	-	1.58
$^*Na_2Oeq = Na_2O + 0.658 * K_2O$										

TABLE2: Summarized petrography description of the deposits.

Sample	Rock Type	Condition	Mineral Compositions	Colour	Texture	Type of Reactive Mineral
TPC 1	Igneous	intact	quartz, mafic, felsic, calcite, dolomite	light gray	Microcrystalline + Micro porphyry	Unstable silica
TPC 2	Igneous	weathered clay minerals	quartz, mafic, felsic, calcite, dolomite	light + black	Crystalline + glassy + fragmental	Dolomite, quartz
TPC 3	Igneous	weathered kaolinite	Felsic, Mafic	light gray	Fully crystalline texture, partial fragmental	Unstable silica
TPC 4	Igneous	weathered calcite	quartz, mafic, felsic dolomite, hematite	gray	Crystalline + fragmental	Zeolite, unstable silica
TPC 5	Igneous	weathered Kaolinite	Felsic, Mafic	white + gray	Microcrystalline + Micro porphyry	Zeolite, quartz, dolomite, chert

TABLE 3: Expansion of Mortar bars according to ASTM C 1260, 1 N NaOH, 80 °C.

Age (Days)	3	7	10	14
Sample	**Expansion of Mortar bars (%)**			
MB-TPC 1	0.03	0.14	0.20	0.25
MB-TPC 2	0.17	0.33	0.38	0.43
MB-TPC 3	0.22	0.37	0.42	0.46
MB-TPC 4	0.18	0.30	0.32	0.36
MB-TPC 5	0.26	0.36	0.41	0.48

TABLE 4: Expansion of concrete prisms according to ASTM C 1293, RH 100%, 38±2 °C.

Age (Days)	**7**	**28**	**56**	**90**	**180**	**270**	**360**
Sample	**Expansion of Concrete Prisms (%)**						
CP-TPC 1	0.018	0.020	0.022	0.022	0.029	0.030	0.031
CP-TPC 2	0.021	0.024	0.026	0.027	0.044	0.046	0.047
CP-TPC 3	0.020	0.023	0.024	0.025	0.036	0.037	0.037
CP-TPC 4	0.004	0.007	0.014	0.017	0.023	0.030	0.032
CP-TPC 5	0.020	0.022	0.032	0.043	0.055	0.056	0.057

TABLE 5: Expansion of concrete prisms according to ASTM C 1293, RH 100%, 38±2 °C.

Age (Days)	**7**	**28**	**56**	**90**	**180**	**270**	**360**
Sample	**Expansion of Concrete Prisms (%), containing 7% silica fume**						
CPS-TPC 2	0.005	0.006	0.007	0.008	0.012	0.018	0.027
CPS-TPC 3	0.002	0.005	0.006	0.008	0.013	0.023	0.028
CPS-TPC 4	0.001	0.003	0.005	0.007	0.011	0.022	0.024

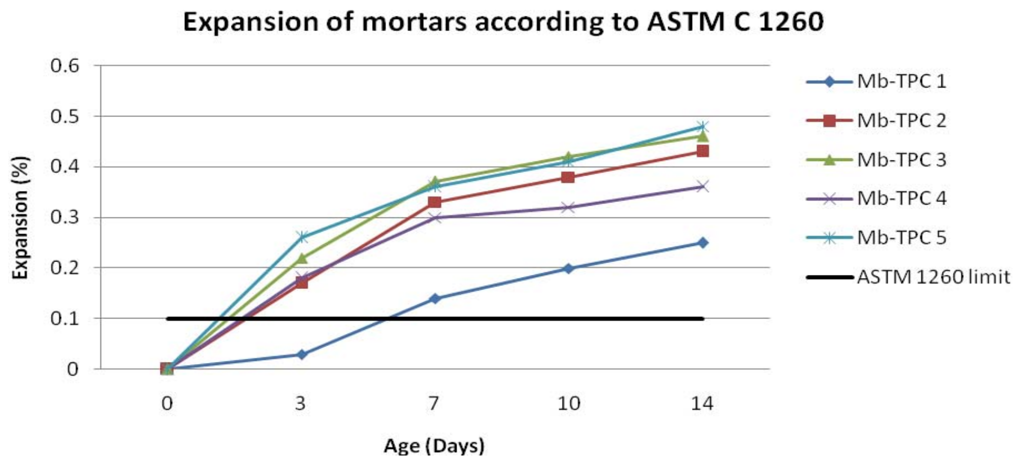

Figure 1: Expansion of Mortar bars according to ASTM C 1260.

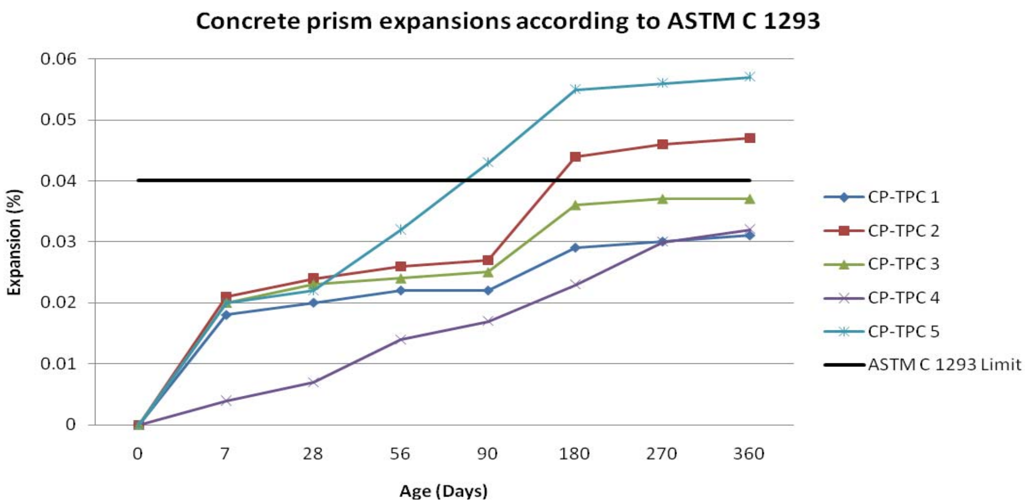

Figure 2: Expansion of concrete prisms according to ASTM C 1293.

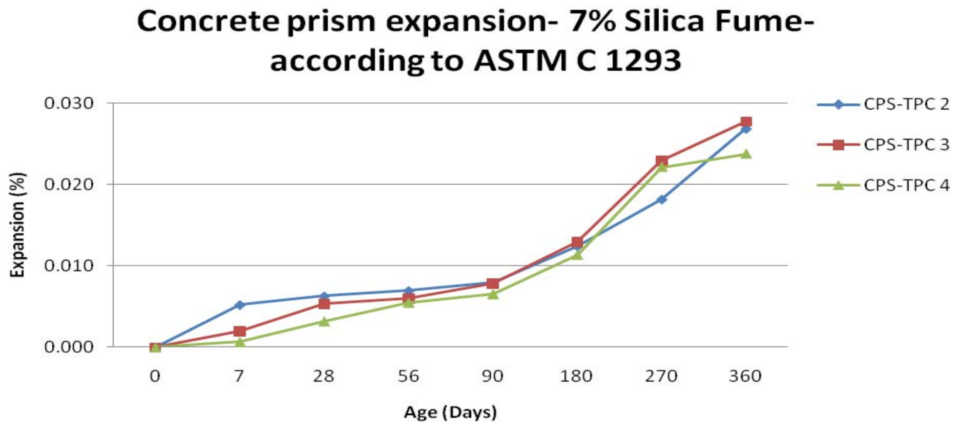

Figure 3: Expansion of concrete prisms containing 7% silica fume according to ASTM C 1293.