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Alkali Silica Reaction (ASR) Mitigation in Concrete by using Lithium Nitrate

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Abstract— **Expansive alkali silica gel forms due to the alkali reaction with reactive aggregates. Cracks and damage to the part of the concrete structure are the results of the formation of this expansive gel. There are several ways to minimize this reaction, out of which Lithium Nitrate compound is believed to reduce the reaction between alkalis (present in the cement) and silica (present in the aggregates). In this paper a laboratory investigation has been done with the combination of reactive aggregate, OPC and varying percentage of Lithium Nitrate to evaluate the effectiveness of Lithium Nitrate compound in controlling expansions resulting from alkali-silica reaction.**

However additional research is needed to delineate the effect of Lithium Nitrate on the concrete properties such as strength, electrical resistance, drying shrinkage, and resistance to freezing and thawing.

Index Terms— **ASR, OPC, Lithium Nitrate Compound**

I. INTRODUCTION

Alkali silica reaction (ASR) in concrete is now a well-known threat to the concrete structures. As ASR is potentially a very destructive reaction within concrete. In the presence of moisture, silica reacts with alkalis to form a gel which expands and disrupts mechanical properties during the service life of the concrete structures. Generally these conditions are common in water retaining / water conducting hydro power structures. Therefore investigation of the aggregates is essential, particularly for the hydro power projects especially from the ASR point of view as these structures are generally in contact with water.

Now a day's use of supplementary cementing materials (SCMs) increasing in concrete to counteract the ASR. In this study Lithium Nitrate admixture in different dosage have been used as SCM in concrete to counteract the ASR.

II. LITERATURE REVIEW

The strategy of using admixtures in concrete containing expansion in concrete due to use of reactive aggregates to prevent ASR was first established in 1950s [1, 2]. However it was only in 1950s that the use of lithium as one of the compound to arrest the ASR has been widely adopted by the Construction Industry. Many investigations conducted ASR test using different dosage of lithium admixtures for mitigation of ASR suggested that Lithium Nitrate was the most effective compound in preventing the negative effects of alkali aggregate reaction [3, 4, 5, and 6]. It has been demonstrated that this neutral and well soluble salt does not raise the pH value of the solution in the concrete pores, thus eliminating the risk of pessimum effect [7]. Though the mechanism with which Lithium Nitrate reduces expansion in concrete is not thoroughly established which depend on the reactivity of aggregate used and alkali content in concrete. The probable mechanisms as proposed by other researchers are summarized as:

Formation of a crystalline and non swelling lithium silicate at the paste/aggregate interface because of the pessimum effect of lithium admixtures [8, 9];
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Decrease in the silica dissolution on the surface of aggregate by the lithium ions [10]

Decrease in the repolymerization of the ASR gel into an expansive compound by the lithium ions [11]

Reduction in the ionic surface charge density of the alkali-silica gel occurring in the presence of lithium salts [12]

Feng et al found that the effectiveness of lithium ions may vary for aggregates with different reactivity levels [13]

Several mechanisms of the reaction in the presence of lithium ions have been proposed. Some of them are based on increased stability of silica due to reduced pH of pore solutions or a change in their chemical compositions [14]

Despite the positive effects of using Lithium Nitrate in ASR mitigation, its use in concrete by itself as a sole mitigation agent can be cost-prohibitive. Further the use of lithium admixture alone, unlike SCMs, does not contribute to pozzolanic reactions or refinement of microstructure in concrete that can significantly improve mechanical properties and reduce permeability in concrete. Only when no alternate strategies are available to mitigate ASR, the use of Lithium Nitrate or other lithium-based salts in concrete can be justified.

III. MATERIALS AND METHODS

Aggregate

Coarse aggregate sample has been obtained from one of the rock quarry which has been identified for one of the H. E project in West Bengal, India. These coarse aggregate samples have been reduced to crushed sand sizes as per ASTM C1260.

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Cement and varying percentage of Lithium Nitrate

Ordinary Portland cement (OPC-43) and varying percentage of $LiNO_3$ have been used with aggregate for studying ASR. Alkali content and Water Cement Ratio of the cement is presented in Table 1.

Table 1: Alkali Content and Water Cement Ratio of the Cements used in the study

Type of Material	Cement Alkalis (Na_2O) equivalent	Water Cement ratio
OPC-43	0.64	0.44

IV. METHODOLOGY

Accelerated Mortar-Bar Test (AMBT) as per ASTM C 1260 and ASTM C 1567 is quick, reliable and can characterize the potential reactivity of slow as well as fast reactive aggregates. Aggregates are crushed to sand sizes for mortar-bar expansion test. The mortar bars are stored in 1 N NaOH solution to provide an immediate source of sodium and hydroxyl ions to the bars. Temperature is maintained at 80°C to accelerate the ASR. Comparator readings are taken over a period of 14 and 28 days (Berube et al., 1995; Thomas et al., 1995) [15, 16]. The test conditions are more severe than most field service environments. Aggregate are categorized based on 14 days expansion observation as shown in Table 2

Table 2: Aggregate Categorization based on 14 days expansion

Average Expansion at 14 day	Reactivity
Less than or equal to 0.10%	Innocuous
Greater than 0.20 %	Deleterious
Greater than 0.10% but Less than 0.20%	Susceptible to reactive

Test Conducted

The study has been carried out using different percentage of Lithium Nitrate with the same type of aggregate and cement. The details of the test and material combination used are presented in Table 3

Table 3: Details of test and material combinations

Tests	Ingredient Materials
Alkali Silica Reaction	Aggregate +OPC +0.0% ($LiNO_3$)
	Aggregate +OPC+0.5% ($LiNO_3$)
	Aggregate +OPC+0.75% ($LiNO_3$)
	Aggregate +OPC+1.0% ($LiNO_3$)
	Aggregate +OPC+3.0% ($LiNO_3$)
	Aggregate +OPC+6.0% ($LiNO_3$)
	Aggregate +OPC+10.0% ($LiNO_3$)
	Aggregate +OPC+15.0% ($LiNO_3$)
	Aggregate +OPC+20.0% ($LiNO_3$)

Petrographical Analysis

Petrographic examination (ASTM C 295) of aggregates is one of the most reliable indicators of the potential for deleterious ASR. Petrographic evaluation provides valuable information about the types and quantities of minerals present in an aggregate.

The rock is rhyolite type and moderately hard. Sericite mica and strained quartz present in rock along with the other minerals may act as deleterious. As per IS 2386 [(Part VII): 1963] aggregate containing more than 20% strained quartz and undulatory extinction angle greater than 15° cause deleterious reaction.

Table 4: Mineralogical Composition of the Aggregate

Source	Strained Quartz (%)	Name of Rock Type	Remark
Rock Quarry in WB	25-30	Rhyolite	It is moderately hard and compact rock

From the mineralogical composition of the aggregate (Table 4), it reflects that the strained quartz percentage exceed the critical limits. The ASR test results of aggregates with the OPC also confirm the samples falling in deleterious zone.

V. LABORATORY INVESTIGATION AND DISCUSSIONS

The magnitude of expansion of this reactive aggregate has been measured with the rigorous laboratory investigation. In this study the testing has been carried out by using different percentage of Lithium Nitrate with the same type of aggregate and cement. Several trials were made on same type of cement and aggregate but with different percentage of Lithium Nitrate ($LiNO_3$) with the help of accelerated mortar bar test (AMBT) method. Based on 14 days expansion the cement aggregate combination with varying percentage of Lithium Nitrate is classified and has been graphically presented in terms of observed expansions in Figure 4.

ASR test for 14-days was conducted on the aggregate sample collected from one of the quarry of West Bengal, with 0% lithium nitrate and OPC-43. During the ASR test by AMBT, the expansion at 14 days was 0.209% which is more than the prescribed limit hence the aggregate is found to be deleterious with OPC-43 cements as represented in the Fig 3.

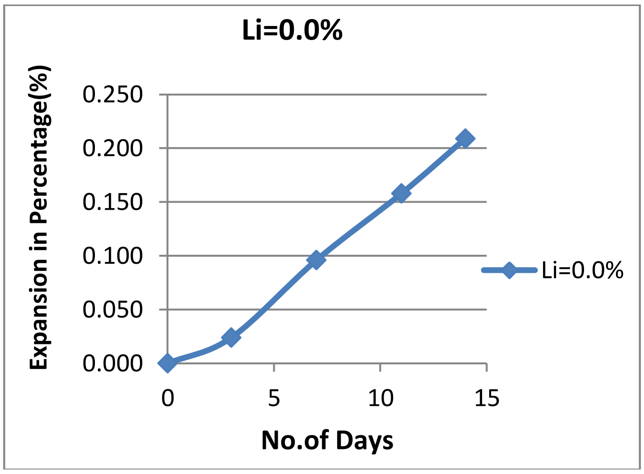

Fig:3

The different percentage of the Lithium Nitrate and its effectiveness in arresting the ASR expansion has been shown in Fig 3 and Fig 4.

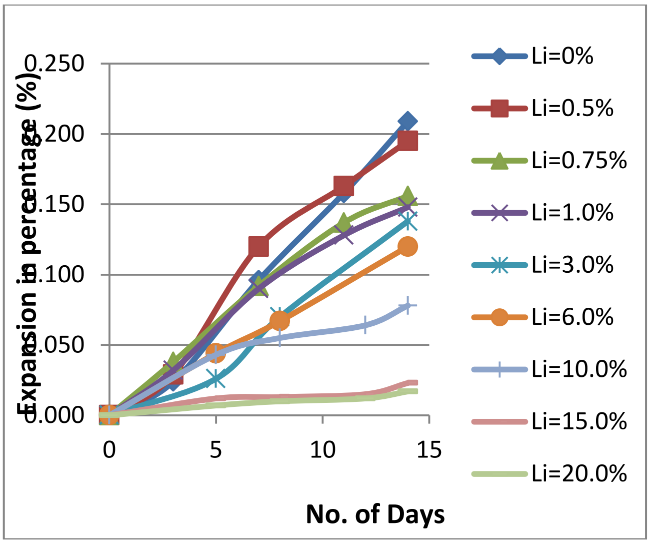

Fig:4

Table 5: Classification of cement & aggregate combination with varying doses of $LiNO_3$ and its ASR expansion

Material Combination	Lithium Nitrate Percentage	% expansion after 14 days
Agg.+OPC-43	0.50	0.195
Agg.+OPC-43	0.75	0.156
Agg.+OPC-43	1.00	0.156
Agg.+OPC-43	3.00	0.138
Agg.+OPC-43	6.00	0.120
Agg.+OPC-43	10.00	0.078
Agg.+OPC-43	15.00	0.023
Agg.+OPC-43	20.00	0.017

It is revealed from the table 5 and graphical representation, for deleterious rock sample, up to 6.0% Lithium Nitrate has no significant effect on ASR mitigation but between 10% - 20% there is significant effect on ASR mitigation. However the study is not carried out beyond 20% of Lithium Nitrate.

VI. Conclusion

Reactivity of aggregate and effect of using OPC and Lithium Nitrate combination on the reactivity of aggregate has been measured experimentally with the help of accelerated mortar bar test method as per ASTM C 1260 & ASTM C 1567. It has been established by the investigation that the aggregates used for this study are of deleterious nature when tested with OPC. The test results reveal that Aggregate-OPC combination with varying percentage of Lithium Nitrate has nil effect on ASR up to 6.0% but dosage of Lithium Nitrate percentage between 10% to 20% is effective in controlling ASR, as it arrests the expansion produced from the reaction of aggregate-OPC combination by 60 to 91%. The test results clearly show that by adding Lithium Nitrate over 10% is effective in controlling expansion due to ASR. However it needs more testing on other types of deleterious aggregate of different mineralogy to generalize the findings.

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