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Influence of different form of Lithium salt and Barium Sulfate in mitigation of ASR expansion in Concrete

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Abstract: *There are different ways of preventive measures are applying to avoid or minimizing Alkali Silica Reaction (ASR) in concrete such as minimizing Alkali content in the cement, selection of innocuous type aggregate, addition of mineral admixture in concrete & using different types of Lithium & Barium based salt as a admixture in concrete or by external application on concrete surface. Among all the four ways of preventive measures reduction in Alkali content in the cement is not very significant in case of deleterious aggregate even it is recommended to keep the alkali content in cement below 0.6%, however for slow reactive aggregate it is significant for decreasing ASR expansion in concrete. Using of innocuous aggregate may not be possible for all the times where there is a source constraint of aggregate & using of mineral admixture like Fly ash or GGBS may not be very effective when it has high alkali content in their composition & it may further support ASR expansion rather than reduction of ASR. Lastly application of different types Lithium & Barium salt was tried since 1951& many previous research were conducted on effectiveness of those salts against ASR expansion. So in this paper an experimental investigation was carried outon ASR expansion as per ASTM C1260 by using different form of Lithium based salt & Barium salt at varying dosages in the mixcontaining reactive aggregate & normal Portland cement of alkali content less than 0.6% in the mix. The investigation results shows that application of Lithium & Barium based salt has significant influence on reduction of ASR expansion in concrete & also it has been noticed that increasing the dosage % of salt shows significant benefit in reduction of ASR in concrete.*

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I. Introduction

Concrete is a heterogeneous material consisting of different ingredient & durability of concrete is primarily depend on the properties of the ingredient used in the concrete & external exposure condition. Alkali Silica Reaction in concrete is a severe durability problem in concrete making with deleterious aggregate & the ASR problem in concrete simply consider as a cancer in concrete. So mitigation of ASR problem in concrete is a vast research topic since 1951. There are many ways have been applied for mitigating the ASR problem in concrete like minimizing Alkali content in the cement, selection of innocuous aggregate for making concrete, partial replacement of Portland cement with different types of mineral admixture like Fly ash & GGBS & application of different types salt like Lithium nitrate, Lithium hydroxide, Lithium Carbonate, Barium sulfate as a admixture in concrete. The first three method like minimizing alkali content in the cement, using of innocuous aggregate & using of mineral admixture like Fly ash & GGBS is not showing significant reduction in ASR expansion in concrete contain deleterious aggregate, however concrete with slow reactive aggregate shows significant reduction in ASR. Based on the limitation of first three method, many past research were carried out to mitigate the ASR expansion in concrete by using different types of Lithium based salt in concrete mix. Mc Coy and Cold has revealed this application 1st time in 1951 & afterward many researches were still on about the benefit or effectiveness of such Lithium based salt against ASR expansion in concrete. In this research paper a laboratory investigation was carried as per ASTM C1260 to evaluate the ASR expansion in different concrete samples containing reactive aggregate, Portland cement having alkali content less than 0.6% & different form of Lithium and Barium salt at various dosages in the mixes such as 0.25% Lithium nitrate, 0.5% Lithium nitrate , 0.75% Lithium nitrate , 1% Lithium nitrate , 0.25% Lithium hydroxide , 0.5% Lithium hydroxide, 0.75% Lithium hydroxide, 1% Lithium hydroxide, 0.25% Lithium Carbonate, 0.5% Lithium carbonate, 0.75% Lithium carbonate , 1% Lithium carbonate & 0.25% Barium sulfate, 0.5% Barium sulfate, 0.75% Barium sulfate, 1% Barium sulfate were used & effectiveness of type of salt & dosage % were evaluated against ASR expansion in the samples. From the investigation it has been observed that application of both Lithium & Barium based salt has significant effect on reduction of ASR expansion in concrete with increase in dosage of the salt up to 1% by weight of cementing material used in the mix. Thus these salt has the potential to mitigate the problem of ASR expansion in concrete at suitable dosage even concrete containing reactive nature of aggregate within it.

II. Material And Methods

The different materials used for this research investigation were normal Portland cement CEM-I, 52.5N class as per BSEN-197-1, Crushed aggregate of reactive Granite gneiss & admixture like Lithium nitrate, Lithium hydroxide, Lithium carbonate & Barium sulfate were used. The physical & chemical properties of different material used in this research investigation are briefly tabulated below.

Table-1: Chemical composition of cement CEM-I, 52.5N

Name of the Component	Component %
CaO	63.45
SiO_2	21.35
Al_2O_3	5.21
Fe_2O_3	3.86
SO_3	2.96
MgO	2.13
Na_2O	0.194
K_2O	0.541
Na_2O_{eq}	0.549

Table-2: Physical properties of cement CEM-I, 52.5N

Name of test parameter	Test Results
Sp Gravity	3.15
Fineness in cm2/gm	3554
% Residue on 45 micron	3.34

Table-3: Physical properties of mixing water.

Name of the test parameter	Test Results
pH	7.6
Chloride content in mg/L	256
Sulfate content in mg/L	1.92
Total Solid in mg/L	758
Total Alkalinity as CaCO3 in mg/L	296

Table-4: Aggregate potential reactivity test as per petrographic test & AMBT as per ASTM C1260.

Name of the test parameter	Test Results
Rock type as per petrographic test	Reactive Granite gneiss
Accelerated Mortar Bar expansion %	0.23 (> 0.20% Reactive in nature)

Testing method:

The testing method used for this lab investigation is as per ASTM C1260. For all different samples of concrete with different types of Lithium & Barium salt in it at various dosages. Three no's specimen of 25 mm x25mm x250 mm size mortar bar for each samples were casted for evaluation of ASR expansion in concrete as per ASTM C1260. The curing & testing of the specimen were carried out up to 14 days as per ASTM C1260. The details of different samples mixes used for this research work is tabulated below.

Table-5: Mix details of samples used for experimental works.

Mix ID of Samples	Mix details of Samples
S_0	Normal Portland cement + Reactive aggregate
S_{1A}	Normal Portland cement + Reactive aggregate + 0.25% Lithium Nitrate
S_{1B}	Normal Portland cement + Reactive aggregate + 0.5% Lithium Nitrate
S_{1C}	Normal Portland cement + Reactive aggregate + 0.75% Lithium Nitrate
S_{1D}	Normal Portland cement + Reactive aggregate + 1 % Lithium Nitrate
S_{2A}	Normal Portland cement + Reactive aggregate + 0.25% Lithium Hydroxide
S_{2B}	Normal Portland cement + Reactive aggregate + 0.5% Lithium Hydroxide
S_{2C}	Normal Portland cement + Reactive aggregate + 0.75% Lithium Hydroxide
S_{2D}	Normal Portland cement + Reactive aggregate + 1 % Lithium Hydroxide
S_{3A}	Normal Portland cement + Reactive aggregate + 0.25% Lithium Carbonate
S_{3B}	Normal Portland cement + Reactive aggregate + 0.5% Lithium Carbonate
S_{3C}	Normal Portland cement + Reactive aggregate + 0.75% Lithium Carbonate
S_{3D}	Normal Portland cement + Reactive aggregate + 1% Lithium Carbonate
S_{4A}	Normal Portland cement + Reactive aggregate + 0.25% Barium Sulfate
S_{4B}	Normal Portland cement + Reactive aggregate + 0.5% Barium Sulfate
S_{4C}	Normal Portland cement + Reactive aggregate + 0.75% Barium Sulfate
S_{4D}	Normal Portland cement + Reactive aggregate + 1 % Barium Sulfate

Figure-1: Sample preparation for the experiment & testing of the specimen.

III. Resultand Discussions

The average expansion of all the three specimens of each samples were tested for evaluation of ASR expansion at 7-days & 14-days of curing at 1N NaOH solution at 176^0 F (80^0 C). The average expansion of different samples at 7-days & 14-days are tabulated below.

Table-6: Av expansion of different samples of concrete due to ASR in concrete at 7-days and 14-days

Mix ID of Samples	Mix details of Samples	Av Expansion % at 7-days	Av Expansion % at 14-days
S_0	Normal Portland cement + Reactive aggregate (Without any admixture)	0.185	0.23
S_{1A}	Normal Portland cement + Reactive aggregate + 0.25% Lithium Nitrate	0.132	0.189
S_{1B}	Normal Portland cement + Reactive aggregate + 0.5% Lithium Nitrate	0.105	0.142
S_{1C}	Normal Portland cement + Reactive aggregate + 0.75% Lithium Nitrate	0.086	0.093
S_{1D}	Normal Portland cement + Reactive aggregate + 1 % Lithium Nitrate	0.015	0.017
S_{2A}	Normal Portland cement + Reactive aggregate + 0.25% Lithium Hydroxide	0.115	0.165
S_{2B}	Normal Portland cement + Reactive aggregate + 0.5% Lithium Hydroxide	0.092	0.093
S_{2C}	Normal Portland cement + Reactive aggregate + 0.75% Lithium Hydroxide	0.054	0.055
S_{2D}	Normal Portland cement + Reactive aggregate + 1 % Lithium Hydroxide	0.013	0.015
S_{3A}	Normal Portland cement + Reactive aggregate + 0.25% Lithium Carbonate	0.145	0.194
S_{3B}	Normal Portland cement + Reactive aggregate + 0.5% Lithium Carbonate	0.112	0.151
S_{3C}	Normal Portland cement + Reactive aggregate + 0.75% Lithium Carbonate	0.089	0.098
S_{3D}	Normal Portland cement + Reactive aggregate + 1% Lithium Carbonate	0.017	0.019
S_{4A}	Normal Portland cement + Reactive aggregate + 0.25% Barium Sulfate	0.156	0.191
S_{4B}	Normal Portland cement + Reactive aggregate + 0.5% Barium Sulfate	0.109	0.153
S_{4C}	Normal Portland cement + Reactive aggregate + 0.75% Barium Sulfate	0.092	0.101
S_{4D}	Normal Portland cement + Reactive aggregate + 1 % Barium Sulfate	0.019	0.023

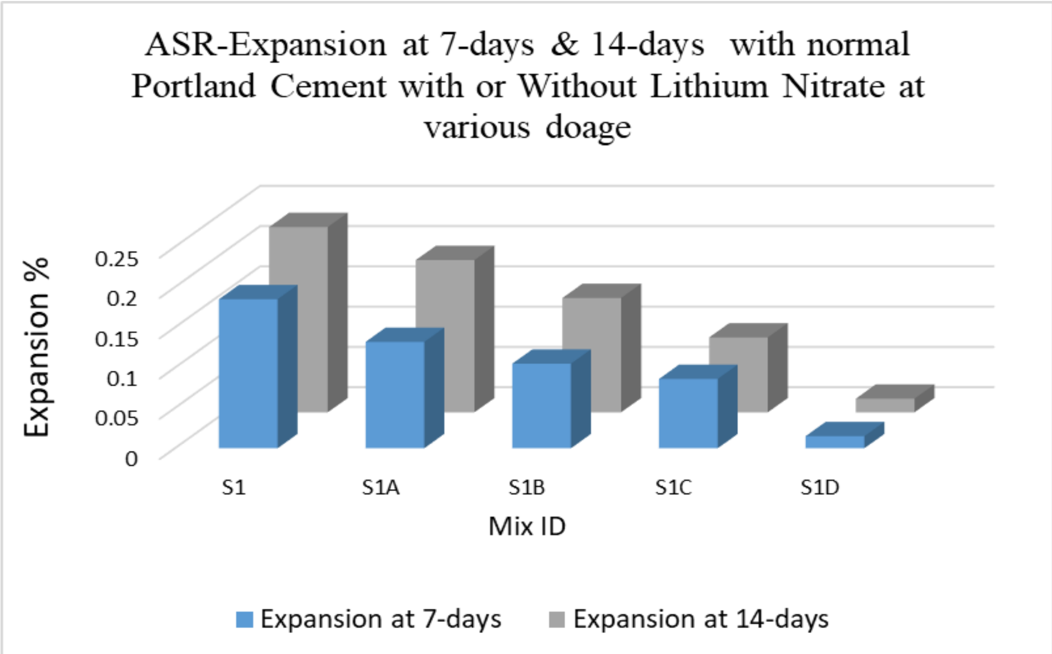

Figure -2: Av ASR Expansion at 7-days and 14-days of sample contain normal Portland cement with or without Lithium Nitrate of dosage 0.5% & 1% of cement.

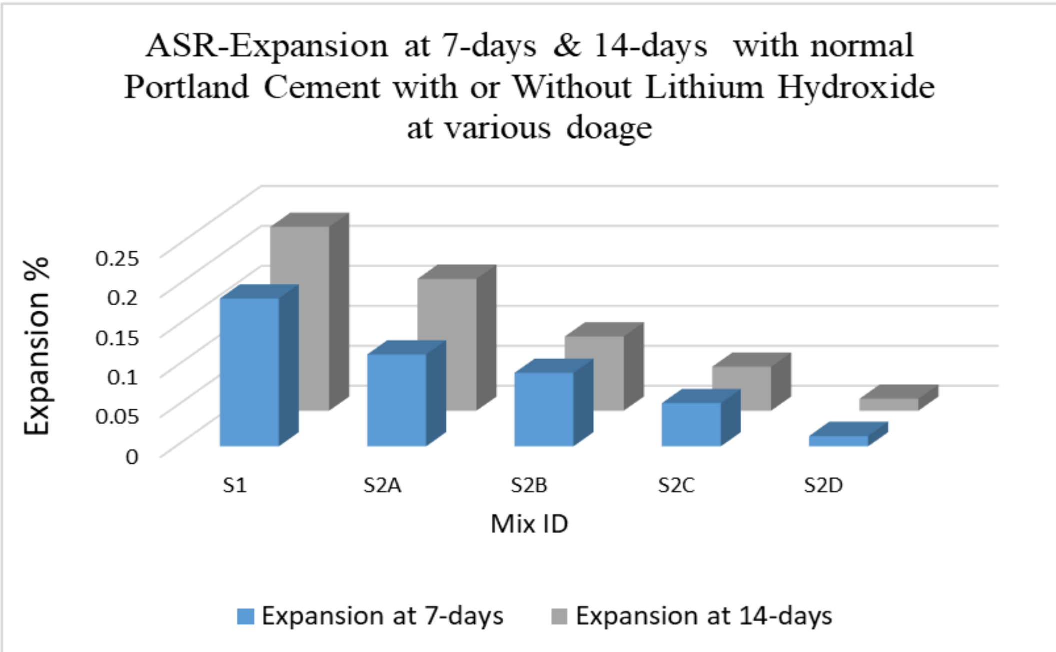

Figure -3: Av ASR Expansion at 7-days and 14-days of sample contain normal Portland cement with or without Lithium Hydroxide of dosage 0.5% & 1% of cement.

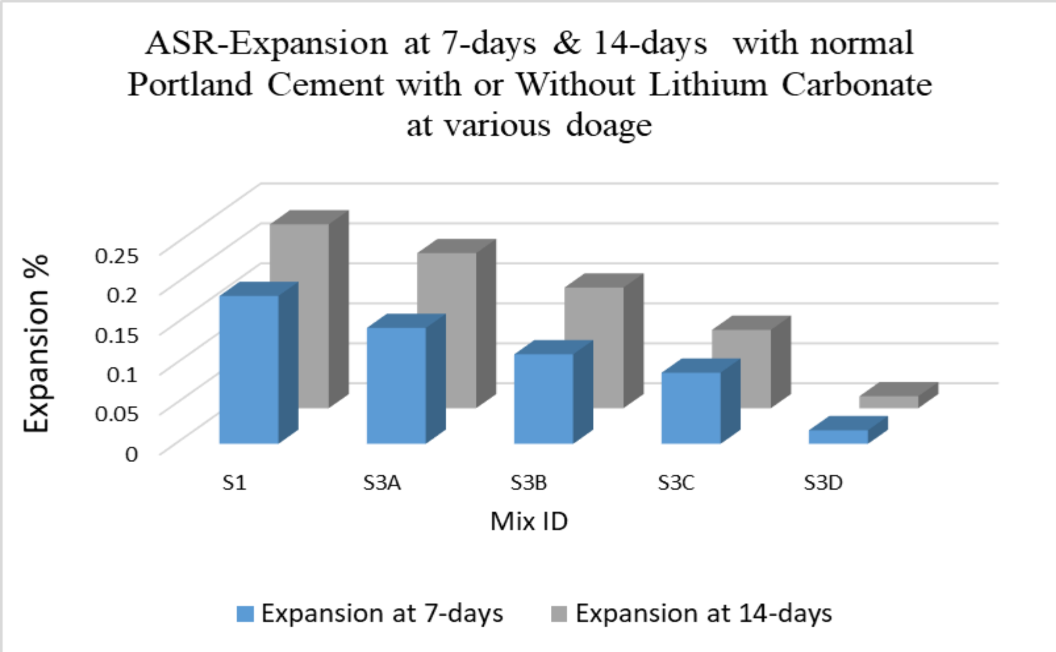

Figure -4: Av ASR Expansion at 7-days and 14-days of sample contain normal Portland cement with or without Lithium carbonate of dosage 0.5% & 1% of cement.

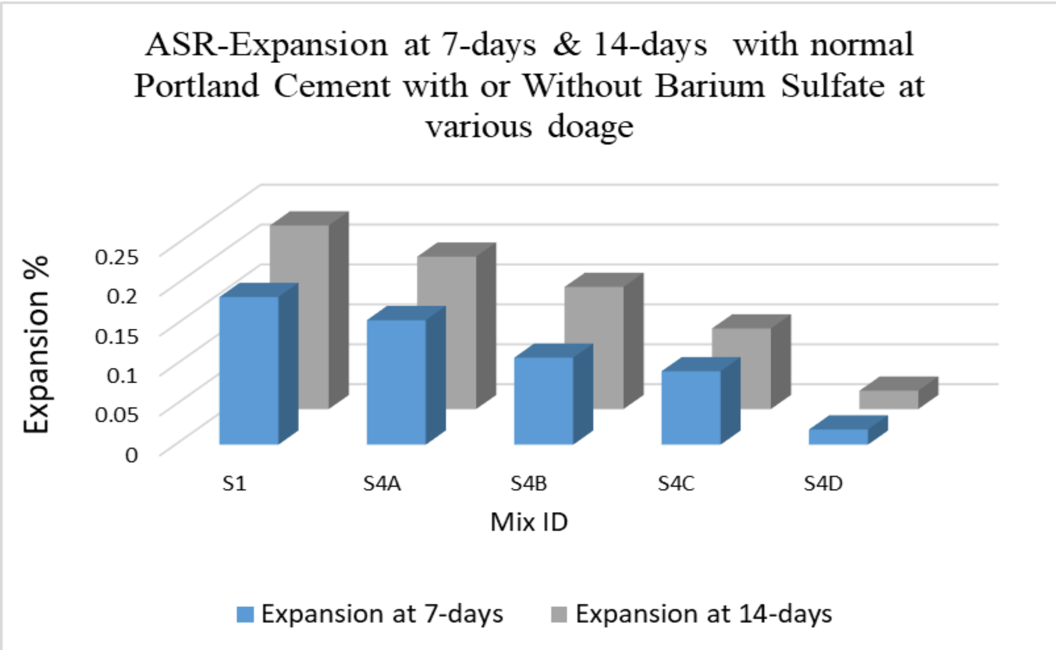

Figure -5: Av ASR Expansion at 7-days and 14-days of sample contain normal Portland cement with or without Barium sulfate of dosage 0.5% & 1% of cement..

From the experimental results it shows that samples without any ASR inhibiting chemicals expansion is very high , while on addition of ASR inhibiting admixture with dosages vary from 0.25% to 1% it shows that expansion of ASR is getting reduced with increase in dosage . Among the different form of Lithium salt Lithium hydroxide shows maximum mitigation of ASR expansion than other salts of Lithium based salt like Lithium nitrate & Lithium carbonate. The results shows that mitigation power of ASR expansion for different salts used in the experiment are in following decreasing order

Lithium hydroxide > Lithium nitrate > Lithium carbonate > Barium sulfate.

The results also shows that amount of dosage plays an important role for mitigation of ASR expansion in concrete. Higher the dosage minimum is the expansion. The increase in dosage is simply increasing the molar ration of Na: Li & thus it helps to prevent ASR in concrete. The addition of Lithium carbonate in concrete does not shows much significant reduction in ASR expansion as compared to Lithium nitrate & Lithium hydroxide as

Lithium carbonate produce more OH^-which in turn increase the ASR expansion reactive aggregate [1]. However Lithium hydroxide is more soluble than other two salt of Lithium & also it is strong in producing Lithium-Silicate gel by replacing Sodium from Sodium silicate gel which is hydrophilic in nature, while Lithium silicate gel is hydrophobic nature & thus helps to reduce ASR expansion in concrete.

IV. Conclusion

The experimental results shows that on addition of different types Lithium based salt & Barium salt in concrete containing reactive aggregate has controlled expansion than concrete having no ASR inhibiting chemicals like Lithium nitrate , Lithium hydroxide , Lithium carbonate & Barium sulfate. Thus addition of such salt has the potential to minimize or eliminate the ASR expansion in concrete. Among the different form of Lithium based salt Lithium hydroxide shows maximum potential to minimize the ASR expansion than other Lithium based salt like Lithium carbonate & Lithium nitrate. The Barium sulfate shows not much significant reduction at 7-days, however at 14-days it shows potential to minimize ASR expansion in concrete. The results also shows that on increase in dosage of salts there is decrease in ASR expansion in concrete. The dosage below 0.5% shows insignificant reduction in ASR expansion & dosage of 1% shows maximum reduction. Hence dosage level also shows significant role in preventing ASR expansion along with type of salt.

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