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Influence of different types of Cement & mitigating effect of Pozzolonic materials & Lithium based salt in ASR of Concrete

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ABSTRACT : *This research paper report on influence of different types of cement in ASR of concrete & mitigation of ASR in concrete by using mineral admixture along with normal Portland cement & addition of Lithium based salt in normal Portland cement. Alkali-silica reaction in concrete is one of the important durability problem in concrete due to using of reactive type of aggregate with highly alkaline cement in concrete.So considering the problem of ASR in concrete, an experimental study was conducted for influence of different types of cement, application of pozzolonic materials & Lithium based salt in concrete containing reactive type aggregate as per classification of ASTM C-1260 & ASTM C-1293. The concrete samples with reactive type's aggregates with different types of cement, pozzolonic materials Fly ash&addition of Lithium salt with normal Portland cement in mix were examined for ASR expansion in concrete samples as perASTM C 1260. From the experimental outcome it shows that Portland composite cement of type CEM-II/B-M (Na_2O_{eq}=0.84%) & Portland pozzolana cement (PPC) (Na_2O_{eq}=0.64%) shows significantly higher expansion as compare to normal Portland cement (CEM-I) (Na_2O_{eq}=0.54%) due their high alkali content in the cement, while concrete with substitution of normal Portland cement (CEM-I) with pozzolonic materials Fly ash & addition of Lithium based salt shows significant reduction in expansion as compared to concrete with normal Portland cement (CEM-I).Thus this paper represent that there is an extensive reduction in ASR expansion on application of mineral admixture Fly ash & addition of Lithium based salt with normal Portland cement .Thus pozzolonic material & Lithium based salt shows the mitigating effect in ASR of concrete.*

KEYWORDS *CEM-I, PCC-CEM-II/A.M, PCC-CEM-II/B-M, PPC, ASR, Pozzolana, Fly Ash*

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I. INTRODUCTION

The Alkali Silica Reaction (ASR) in concrete is a very common problem in European country due to reactive nature of aggregate used in concrete. So mitigation of ASR in concrete is one of the important research topics among the researchers. The Alkali Silica Reaction in concrete is mainly depend on the three main factors i.e. presence of reactive Silica in aggregate, Alkali content in Concrete sourced from Cement or from any other ingredient like aggregate, water &chemical admixture & presence of moisture in the concrete i.e. RH . The primary cause in ASR is the type of aggregate used in concrete& Alkali content in the cement (Na_2O_{eq} %). However the relative humidity also plays an important role in ASR of concrete for expansion of Alkali silica gel formed in ASR. Thus ASR in concrete depend on the RH of the concrete & the expansion of the gel occur at RH higher than 80% , even in some cases it has also observed that ASR occur even at lower RH. Many past research works were already conducted on mitigation of ASR by using different type's mineral admixtures & Chemical admixture in concrete. So in this paper the performance of both Mineral admixture,Lithium based salt& also influence of different types of cement were examined through an experimental study as per ASTM C1260. The experimental results has revealed that Portland composite cement of type CEM-II/B-M (Na_2O_{eq}=0.84%) & Portland pozzolana cement (PPC) (Na_2O_{eq}=0.64%) shows significantly higher ASR expansion as compared to normal Portland cement (CEM-I) (Na_2O_{eq}=0.54%).The results also shows that on substitution of normal Portland cement (CEM-I) with pozzolonic materials Fly ash &concrete with addition of Lithium based salt with normal Portland cement (CEM-I) shows significant reduction in ASR expansion as compared to concrete with only normal Portland cement (CEM-I).The research work also shows that cement with higher Alkali equivalent (Na_2O_{eq} %) shows more expansion.

II. CHEMISTRY INVOLVED IN ALKALI SILICA REACTION IN CONCRETE

The chemical reaction involved in ASR is basically different-stage progression [2]. The stages starts with the presence of reactive silicain aggregate used for concrete & availability of highly alkaline solution of concrete. Chemical reaction involved in either concrete or mortar between hydroxyl ions (OH^-) of the alkalis (sodium and potassium) from hydrauliccement (or from other sources), and reactive silica of siliceous rocks andminerals, such as opal, chert, microcrystalline quartz, and acidicvolcanic glass, present in some aggregates. This reaction results the development of alkali-silica gel in concrete & in contact with water it get expanded abnormally and finally crackingof the concrete when the osmotic pressure is higher than the tensile strength of concrete. The step wise reaction involved in ASR [9] is explained below.

Step-I: $Si –O- Si + OH^- = Si -OH + OH – Si$
Step-II: $Si -OH + OH^- + Na^+ (K^+) = 2Si-O-Na (K)^- + H_2O$
Step-III: $Si –O- Si + 2OH^- + 2Na^+ (K^+) = 2\ Si-O-Na (K) + H_2O$

III. EXPERIMENTAL SET UP

The experiment was conducted as per ASTM C1260 using reactive type aggregate & different types of cement , pozzolonic materials &addition of ASR inhibiting admixture in normal Portland cement (CEM-I) mortar for evaluation of ASR in concrete. The aggregate used for Accelerated Mortar Bar Test (AMBT) was prepared as per the guide line of ASTMC1260 by crushing the aggregate as per the recommended size in ASTMC 1260 [1]. The size of prism mortar bar is 25 mm x 25mm x 250 mm prepared with reactive type crushed aggregate. The w/c ratio was 0.47 as per ASTMC-1260 [1]. The number of specimen taken for each sample was 3 no's for evaluation of ASR expansion in the sample concrete. The testing of specimen was conducted at 7-days & 14-days respectively .The details of different samples of concrete were used for examining the ASR in concrete is given Table-1.

Table-1: Mix details for different concrete specimen used for evaluation of ASR in concrete.

Sample ID	Mix Details of Samples used for evaluation of ASR expansion	Aggregate type as per petrographic analysis & Aggregate mineralogical study.
S1	100% Portland Cement (CEM-I)	Reactive
S2	100% Portland Composite Cement CEM-II/A-M	Reactive
S3	100% Portland Composite Cement CEM-II/B-M	Reactive
S4	100% Portland Pozzolana Cement (PPC-Fly ash based)	Reactive
S5	100% Portland Cement (CEM-I) + 0.5% Lithium Nitrate	Reactive
S6	100% Portland Cement (CEM-I) + 1 % Lithium Nitrate	Reactive
S7	85% Portland Cement (CEM-I) + 15% Fly ash	Reactive
S8	80% Portland Cement (CEM-I) + 20 % Fly ash	Reactive
S9	75% Portland Cement (CEM-I) + 25% Fly ash	Reactive

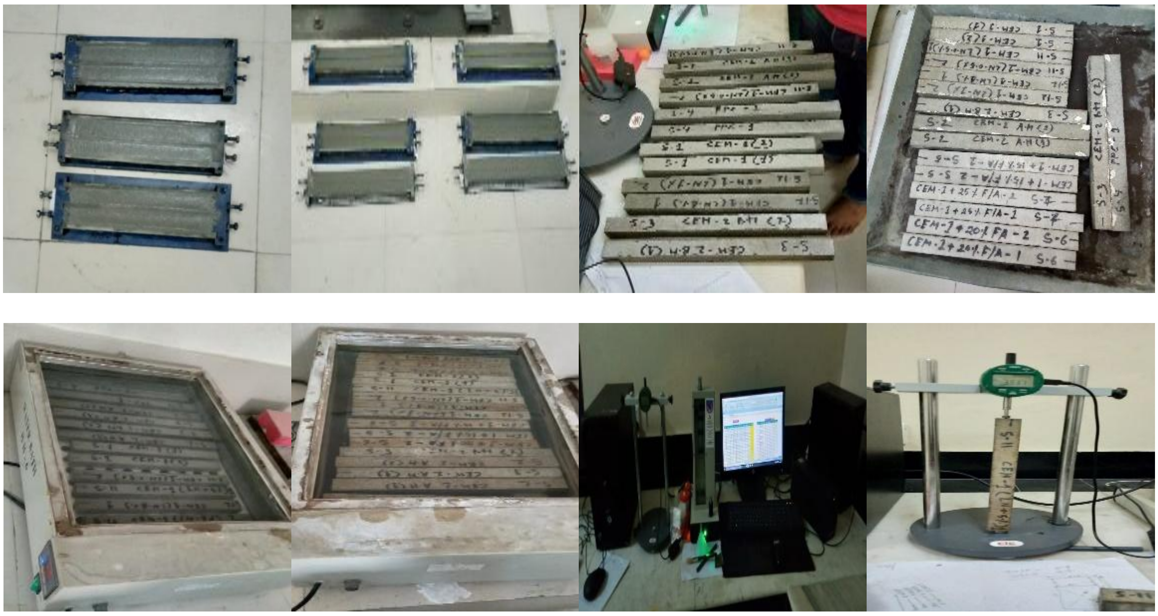

Fig.1. Evaluation of ASR in different types of cement mortar as per ASTM C1260

IV. MATERIALS

The different material used for the experiment were normal Portland cement (CEM-I), Portland composite cement of type CEM-II/A-M, CEM-II/B-M as per BSEN-197-1, Portland Pozzolana cement (PPC) as per IS-1489, Part-1, Pulverized Fly ash of Type-F & Lithium Nitrate. The aggregate used for the experiment was crushed granite rocks of reactive type as per ASTM C1260 [1]. The test results of different materials used for the experiment are hereby tabulated below.

Table-2: The chemical properties of different types of cement & pozzolonic material Fly ash.

Component	CEM-I	CEM- II/ A-M	CEM-II/ B-M	PPC	Fly Ash
CaO	63.28	55.44	51.7	44.39	1.86
SiO_2	20.95	25.23	26.22	29.18	61.09
Al_2O_3	5.01	8.21	9.12	11.46	27.56
Fe_2O_3	3.72	3.33	3.65	3.48	5.35
SO_3	2.91	2.63	2.31	2.76	0.12
MgO	2.03	1.82	1.30	1.93	0.13
Na_2O	0.192	0.221	0.272	0.221	0.571
K_2O	0.531	0.512	0.873	0.642	0.171
Na_2O_{eq}	0.54	0.557	0.846	0.643	0.683

Table-3: Total Alkali content in different sample used for examination of ASR expansion.

Sample ID	Mix Details of Samples used for evaluation of ASR expansion	Total alkali content % in cementitious materials
S1	100% Portland Cement (CEM-I)	0.54
S2	100% Portland Composite Cement CEM-II/A-M	0.557
S3	100% Portland Composite Cement CEM-II/B-M	0.846
S4	100% Portland Pozzolana Cement (PPC-Fly ash based)	0.643
S5	100% Portland Cement (CEM-I) + 0.5% Lithium Nitrate	0.54
S6	100% Portland Cement (CEM-I) + 1 % Lithium Nitrate	0.54
S7	85% Portland Cement (CEM-I) + 15% Fly ash	0.561
S8	80% Portland Cement (CEM-I) + 20 % Fly ash	0.568
S9	75% Portland Cement (CEM-I) + 25% Fly ash	0.575

Table-4: Mixing water properties.

Test Parameter	Test Results
pH	7.6
Chloride content in mg/L	252
Sulfate content in mg/L	1.81
Total Solid in mg/L	755
Total Alkalinity as CaCO3 in mg/L	289

V. RESULTS & DISCUSSIONS

The experimental results shows that cement with higher alkali content shows higher expansion of ASR in concrete & at the same time it also shows that replacement of normal Portland cement (CEM-I) with pozzolonic materials shows reduction in expansion due to pozzolonic reaction in concrete, as pozzolonic materials consume alkalis in concrete which in turn formation of binding materials & it results the reduction in permeability of concrete [3]& also it prevent the ASR in concrete. The addition of Lithium nitrate with normal Portland cement shows reduction in ASR expansion as the Lithium salt react with reactive silica of aggregate & it results formation of lithium-silica gel which is hydrophobic in nature i.e. it does not absorb water and therefore it does not expand. So Lithium based salt helps to prevent the formation of Sodium or Potassium based silica gel which is expansive in nature & absorb water. The reaction mechanism of Lithium based salt in ASR prevention in concrete [12] as per the equation shown below.

Reactive Silica of Aggregate + Lithium salt = Lithium Silica Gel (Non expansive & hydrophobic in nature)

Thus addition of Lithium based salt 0.5% to 1% by weight of cement shows an extensive reduction in ASR expansion as compared to samples with normal Portland cement without any mineral admixture or ASR-inhibiting admixture like Lithium based salt in the mix. It is also shows that samples with Portland composite cement CEM-II/B-M shows maximum expansion, it is due to its higher fineness as more the fineness in cement there will be rapid release of alkalis [2] for producing of alkali silica gel in concrete.

Table-5: The Av ASR expansion results of different samples at 7-days & 14-days.

Sample ID	Mix Details of Samples used for evaluation of ASR expansion	Av Expansion at 7-days	Av Expansion at 14-days
S1	100% Portland Cement (CEM-I)	0.21	0.225
S2	100% Portland Composite Cement CEM-II/A-M	0.221	0.232
S3	100% Portland Composite Cement CEM-II/B-M	0.231	0.242
S4	100% Portland Pozzolana Cement (PPC-Fly ash based)	0.228	0.234
S5	100% Portland Cement (CEM-I) + 0.5% Lithium Nitrate	0.087	0.089
S6	100% Portland Cement (CEM-I) + 1 % Lithium Nitrate	0.068	0.073
S7	85% Portland Cement (CEM-I) + 15% Fly ash	0.13	0.135
S8	80% Portland Cement (CEM-I) + 20 % Fly ash	0.11	0.123
S9	75% Portland Cement (CEM-I) + 25% Fly ash	0.092	0.097

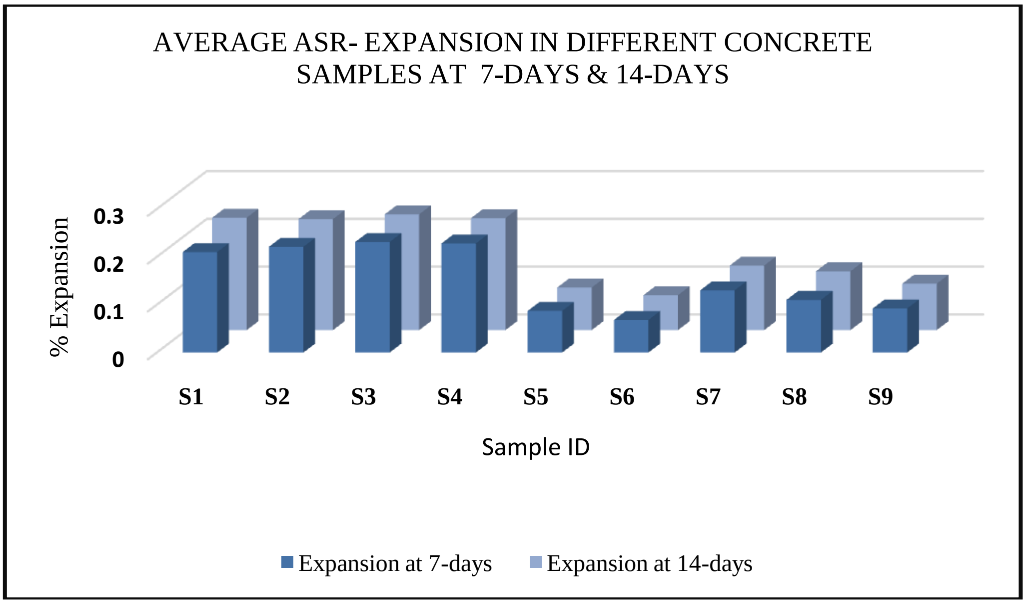

Fig.1. Average ASR expansion in different samples of cement mortar as per ASTM C1260

VI. CONCLUSION

The following are the outcome of the research work on different types of concrete samples used for evaluation of ASR expansion in concrete with reactive type aggregate.

I. The higher is the alkali content in the cement shows higher the ASR expansion in concrete.

II. The addition of mineral admixture like Fly ash along with normal Portland cement shows reduction in ASR expansion due to pozzolonic reaction in concrete.

III. The addition of Lithium based salt with normal Portland cement shows extensive reduction in ASR expansion in concrete. The dosage of 0.5% to 1% shows significant improvement in reduction of ASR expansion.

IV. Portland composite cement & Portland Pozzolana cement shows significantly higher expansion due to high alkali content in the cement. So type of cement doesn't give any benefit in case of ASR preventive measures. Actually it depend on the alkali content of the cement.
V. Even the cement with total alkali content less than 0.6% still ASR existence is there in concrete for reactive type aggregate.
VI. Addition of Lithium based salt shows more preventive against ASR than concrete with mineral admixture Fly ash.

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