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Alkali Aggregate reaction in Dam Structures – a Review

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ABSTRACT

Alkali – Aggregate Reaction is an unwanted reaction which occurs in concrete, mainly the area which is subjected to more moisture content. It occurs over time, between cement paste and silica. This in turn alters the expansion of the aggregate and often in an unpredictable way, which will result in loss of strength of concrete and also a complete failure. Hydro structures, mainly Dams store water, presence of moisture can cause such problem, comparatively more than the other structures. Normally, most of the dams had been constructed several years back and they still exist. The design was based on the environmental conditions prevailed at that period. But now the fast changing environmental aspects and industrial growth and technological development apart from global warming has severe impact on the life and performance of the dams. Dam Structures cannot be easily replaced, and the swelling can block spillway gates or turbine operations. The durability of dams has the impact on human life, society and the environment. To enhance the life and durability of the dams or hydro structures, several studies were made. There are two forms of Alkali Aggregate Reactions available, Alkali Silica Reaction and Alkali Carbonate Reaction and this paper reviews Alkali Aggregate reaction within concrete construction.

Keywords: Alkali – Aggregate Reaction, moisture, durability.

1. INTRODUCTION

Concrete is the most utilized construction material across the world. Good quality constituent materials are essential for making sound concrete. In certain situations, proper water cement ratio, proportioning of concrete ingredients, mix design, other parameters can avail nothing if the reactive silica is present in the aggregates and excess alkali in the cement. Under such circumstances, there will be alkali aggregate reaction (AAR) in addition to the Hydration reaction. While the Hydration reaction contributes for strength and durability, AAR is unfavorable one causing bulging of concrete and eventually resulting in setting up of several cracks.

The Alkali Aggregate Reaction (AAR) in concrete is considered as a great menace to the durability of concrete structures especially the hydraulic structures. The manifestations of this deleterious reaction appear only a few years after construction. Damage to concrete caused by AAR takes a variety of forms, the most common being surface cracking and, sometimes, exudations of gel at the exposed face. Such damage has been reported in many countries, particularly in those with hot-wet climate conditions.

The damage first appears varies from a few months to several decades after construction. Cracks usually grow wider with time and site repairs are often found to be quite ineffectual. AAR is a serious form of deterioration and measures need to be taken to minimize it. Typical indicators of AAR are random map cracking and, in advanced cases, closed joints and spalling of concrete.

Interest in the Alkali-Aggregate Reaction (AAR) in concrete structures has increased in recent times because of the risk for dam safety and the high cost of repairs and replacements. One of the first structures identified as affected by AAR was the Parker Dam (USA) in 1941 and an ICOLD survey in 1985 has shown the worldwide distribution of damaged dams because of AAR.

2. REVIEW OF LITERATURE

a) **Zihui Li, et.al** investigated the alkali-silica reactivity of alkali-activated concrete (AAC). Authors used Ordinary Portland Cement, alkali-activated fly ash (AAF), and alkali-activated slag (AAS) for manufacturing the concrete. For accelerated test reactive aggregates were used. For Long-term test non-reactive aggregates were used. AAF mixtures with reactive aggregates expanded minimally but some AAS mixtures with non-reactive aggregates showed significant expansion. High expansion was observed in AAS mixtures with reactive aggregates. Micro structural evaluation using scanning electron microscopy revealed significant cracking but did not identify ASR gel in the majority of specimens.

b) **L. F. M. Sanchez, et.al** suggested that for assessing the condition of concrete affected by the Alkali –Aggregate Reaction (AAR), Damage Rating Index(DRI), *Stiffness Damage Test* (*SDT*), mechanical and microscopic tools were reliable. Twenty concrete mixtures with different strengths were used for this study. Both reactive & non-reactive aggregates were also used in this project. In addition to this author evaluated both AAR crack development and its influence on the mechanical properties of affected concrete. The results showed that the development of AAR distress follows to basic concepts. 1) The Formation of ASR Gel resulting in cracks 2) Extension of cracks. This cracks affected the tensile strength properties of the concrete than the compressive strength properties.

c) **Chang Li, et al** investigated the Alkali-Silica Reaction (ASR) using Fine Light Weight Aggregate (FLWAs) which is the solution for reducing ASR. The FLWAs used in this were expanded slate, shale and clay. The Authors conducted accelerated mortar bar test (AMBT), concrete prism test (CPT), pore solution analysis and scanning electron microscope (SEM) analysis. It is determined by AMBT and CPT results that the expanded clay was the most effective in reducing the expansion caused by ASR. Also in Pore solution analysis expanded shale and clay can reduce the alkalinity as well as increase aluminum content in the pore solution. SEM analysis revealed that reaction products formed in the pores of the FLWAs, whose composition was closer to C-A-S-H, rather than alkali-silica reaction product.

d) **Andreas Leemann & Beat Münch**, found the formation of alkali-silica-reaction (ASR) products in concrete aggregates generate stress leading to the formation of cracks. This cracks proceeds from the cement paste. The Authors introduced a new approach for the identification and visualization of the ASR product formation which leads to concrete damage. Caesium is added as a tracer during concrete production. Four different types of concrete mixed with varying grain size were prepared. Three prisms were produced with each concrete mixture. Concrete Prism Test (CPT) was performed. This revealed that addition of Caesium does not change ASR effect in concrete.

e) **R. A. Deschenes Jr, et.al** studied that the Alkali-silica reaction (ASR), freezing and thawing (F/T) cause premature deterioration. It also reduces the service life of concrete structures.

Both are difficult to mitigate in existing concrete pavements once deterioration occurs. The authors evaluated the efficacy of silane surface treatments. It is used to reduce the moisture state of concrete pavements, which reduces the further deterioration from ASR and F/T. The remaining useful lifetime of the pavement is increased due to this. It also increases the remaining useful life of the pavement. The pavement test section evaluated contained a borderline-reactive fine aggregate and marginal air entrainment. The efficacy of silane was evaluated by incrementing a pavement test section with devices for monitoring strain and internal RH. Core samples were extracted before and after treatment. Using Damage Rating Index (DRI) , the core samples were. It clearly stated that silane may reduce the rate of deterioration in the concrete pavement compared to untreated control sections.

f) **Bryce D. Fiore, et.al** studied that concrete production requires considerable quantities of natural aggregates, and contributes to large amounts of solid waste in both production and when removed from service. With many structures reaching the end of their service life, a means of concrete disposal is needed that is both practical and eco-friendly. Reusing concrete waste as recycled concrete aggregate (RCA) in new concrete is a promising solution. However, the current use of RCA is generally limited to backfill and road base. Additionally, alkali-silica reaction (ASR) can pose a substantial obstacle to highly durable concrete and with limited research on ASR behavior in RCA, effective design recommendations are lacking. Current methods of ASR mitigation depend on experimental testing for aggregate classification. The ASTM C1260 test was performed with nine laboratories and 10 operators to determine within- and between-laboratory variation on ASR expansions. The result of this investigation suggests a small change to the existing precision statements of ASTM C1260 to allow the standard to incorporate RCA into the accelerated mortar bar test (AMBT). In addition, testing revealed that expansions using RCA and natural aggregates produced nonreactive or moderately reactive mortar mixtures far more frequently than highly reactive mixtures.

g) **Mohammad Amin Hariri-Ardebili,et.al** reported on a computational framework that assesses the integrity of a structure suffering from alkali-aggregate reaction (AAR). The authors did detailed field observation and laboratory tests. Results were then interpreted in a format suitable for structural analysis. Then, they performed probabilistic-based three-dimensional (3-D) nonlinear finite element simulations. The results obtained initially (deformation and stress field) were completely unintuitive and highlighted the complexity of the impact of AAR on a structural response. The results were cast in a risk-informed condition assessment framework through a new paradigm for AAR, based on work in the field of earthquake engineering. They analyzed the occurrence of the damage and its time period. For this investigation, a major viaduct in Switzerland is used.

h) **Zdzisława Owsiak** examined alkali reactivity tests for selected silica aggregates, both rapid and slow alkali reactive, with the use of ASTM procedures. In this project Quartzite, Sandstone, Hornstone, Quartz sand with opal and Granite aggregates were used. The tests had covered the determination of the aggregate silica content dissolved in a solution of sodium hydroxide, the scale of the expansion of mortar and concrete bars with the silica aggregate and high-alkali cement and the scale of the expansion of the mortar bars stored in a sodium hydroxide solution at 80 °C. Exemplary photographs of the microstructure of alkali reaction products had been presented. Four methods ASTM C 289, ASTM C 227, ASTM C 1260 and ASTM C 1293 had conducted and reactive aggregates were found. The duration of the test varies from 14 days to 1 year. Test results showed that after a long period Alkali Aggregate Reaction (ASR) is occurring.

i) **M. D. A. Thomas** investigated about the field studies of fly ash concrete structures containing reactive (alkali-silica) aggregates. Data was presented from a number of hydraulic structures in Wales and Ontario constructed using geologically similar greywacke-argillite aggregates. From three dam's core had been taken out and examined. The laboratory investigations like Petrographic examination, Chemical analysis, etc. All the structures without ash showed evidence of damage due to ASR. After more than 25 years of service the fly ash concrete structures were in excellent despite having higher alkali contents than many of the damaged structures. Among all Class F fly ash had been successfully used for many decades with no reported incidences of ASR in structures containing sufficient levels of ash.

j) **Daniela Eugenia Angulo-Ramírez, et.al**, evaluated the performance of alkali-aggregate reaction of two types of binder systems: a Portland blended cement and an Alkali-activated Portland blended cement. The first system consists of 80% granulated blast furnace slag and 20% Portland cement (OPC) and was hydrated in the presence of water (CE), whereas the second incorporated an alkaline activator, making it a hybrid cement (HB). Using mortar bars, the expansion measurements were carried out, and their behavior was compared to a reference system based on 100% OPC. Additionally, a microstructural characterization was performed using scanning electron microscopy. The results clearly illustrated that CE and HB cements had smaller expansions than OPC.

CONCLUSION

By all this researches, it is clear that concrete structures are affected by AAR with the presence of moisture at a period of time. It is due to high alkaline cement paste and non-crystalline silicon dioxide, which is found in many common aggregates. So there must be measures to control this. The above studies clearly indicating that use of Class F fly ash, Silica fume, Blast furnace slag, etc. Also the tests that can be conducted to identify the AAR were ASTM C 227 Mortar-Bar Method, ASTM C 289 Chemical Method, ASTM C 295 Petrographic Examination, ASTM C 1260 Rapid Mortar-Bar Test, ASTM C 1293 Concrete Prism Test.

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