

A Detailed Review on Alkali-Activated Slag (AAS) and Fly Ash Based Concrete

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Abstract: In the present world the technology is changing in high pace, concrete is one among them and has turned into a key piece of our lives. With each passing day, the use of cement is expanding at a high rate. One of the core constituents of concrete is Portland cement. With the increase in utilization of concrete, the manufacturing and consumption of cement have increased drastically. Despite the fact that bond has uncommon restricting properties and is extremely apt for use in concrete, the assembling of concrete outcomes in the discharge of a lot of CO₂. Due to this, researchers have commenced finding alternatives to cement that are economical as well as environment-friendly. Fly ash and Ground granulated blast furnace slag are industrial by-products which postulate admirable binding properties to concrete and accommodate as a supersession of cement. These alternatives are generally termed as Supplementary cementations materials (SCMs). The utilization of these materials not only avails in reducing the consumption of cement but withal accommodates as an efficient method for their safe disposal. This paper analyses the effect of utilizing these materials that can be utilized in concrete as partial replacement of cement. The literature review of sundry researchers reveals that a single alternative cannot provide all the benefits that cement does. Rather, a suitable combination of these products can be incorporated in concrete to provide properties better than that of Portland cement concrete. And research in the field of AAS and fly ash concrete states that this new material is high potential to replace an alternative to Portland cement. This article presents an in depth review of alkali-activated slag and fly ash based concrete. The paper covers composition, mixing and curing process, benefits, limitations, and applications of AAS and fly ash based concrete.

Keywords: Fly ash, ggbs, Alkali Activators .

INTRODUCTION AND BACKGROUND:

Concrete is the most flexible, essential and generally utilized building material, of which bond is an indispensable constituent. From the time immemorial Portland bond has been utilized as folio in solid development.[8] Notwithstanding, the creation of the bond isn't eco-accommodating and expends gigantic measure of vitality which eventually prompts the consumption of the non renewable energy source save. Also, it transmits toxic ozone harming substances which are destructive for the biosphere. An alluring contrasting option to Portland concrete is the cover acquired by antacid actuation of materials like fly fiery debris, GGBS.[12]

METHODOLOGY

1. ggbs as a binder additional in concrete

Debabrata Dutta et al (2014) experimentally found the detail of Ground Granulated Blast Furnace Slag (GGBS) is obtained during the steel making process, when the slag is quenched to form granules. Granulated Blast Furnace Slag (GGBS) is the byproduct obtained in the manufacture of pig Iron in blast furnaces at around 1400° to 1500°C in the molten form. The slag is obtained by rapidly chilling the molten ash from the furnace by means of chilled water and is ground about 400 m²/kg of fineness by using state of the art grinding mill to make GGBS. It is a non-metallic product

consisting essential of glass containing silicates and alumina Silicates of lime

Eccentricities of ggbs: Reduction in warmth of hydration and minimization of Thermal splits. Permeability and surplus lime freed amid the hydration of Portland bond are the main drivers for injurious impact on the solid. Absorption of surplus lime discharged out of OPC to shape in to auxiliary hydrated mineralogy. Pore refinement and grain refinement because of the auxiliary hydrated mineralogy, along these lines contributing for impermeability and enhancement of change zones.[9] Results in the low warmth of hydration and lower temperature rises. Concrete made with GGBS bond sets moa gradually than concrete made with opc . Depending on the measure of GGBS in the cementations material, yet in addition keeps on picking up quality over a more drawn out period underway conditions. Provides higher protection from chloride entrance and Provides higher protection from assault by sulfate and different chemicals.[25]

2. Flyash

fly ash is extracted from flue gases through Electrostatic Precipitator in dry form. This ash is fine material & possesses good pozzolanic property.[23]



tricalcium silicate water C-S-H gel Calcium hydroxide



dicalcium silicate + water C-S-H gel Calcium hydroxide

Advantage of fly ash : Heat of hydration , Thermal cracks is reduced, soundness of concrete is improved ,workability / pumpability is improved , converts the surplus lime liberated due to the hydration of opc into additional strength[13] .fly ash and liberated lime reacts and improves porosity, makes the concrete impermeable ,provides resistance ingress of moisture and toxic gases ,hence makes the concrete more durable . Reduced requirement of cement

Types of fly ash:

Class c -It is a product obtained from burning younger lignite And subbituminous coal . Contains more than 20% lime.it is also known as calcerious fly ash.

Class f -It is a product obtained from burning harder older anthracite and bituminous coal. Contains less than 20% lime. It is also known as silicious fly ash.[27]

3 Alkali Activator-Usually caustic alkalis or alkaline salts are used as an alkali activators of alkali activated concrete . Glukhovsky et al(1980) classified them into six groups

1. MOH
2. non silicate weak acid salts : M_2CO_3 , M_2SO_3 , M_3PO_4 , MF etc
3. silicates : $M_2O.nSiO_2$
4. aluminates: $M_2O . nAl_2O_3$
5. aluminosilicates: $M_2O.Al_2O_3.(2-6)SiO_2$
6. non silicate strong acid salts : M_2SO_4

of all these activators , NaOH , Na_2CO_3 , $Na_2O.nSiO_2$ and Na_2SO_4 are most widely available and economical chemicals.

Types of Alkali Activator

1. Caustic soda or Sodium Hydroxide (NaOH)–(Kostick 1993a ,1994 , Garrett 1992) It is used as an accelerator for hydration of cement . Results in the decrease of strength after 7 to 14 days of hydration . because of very high heat of solution , a rapid temperature increase can result in dangerous boiling or spattering if caustic soda is added to a solution too fast .

2. Soda ash or Sodium carbonate(Na_2CO_3)- It is used as a chemical admixture for Portland cement concrete. When the dose is low , sodium carbonate can be used as an accelerator of cement hydration , but acts as a retarder when the dosage is high (odler et al 1976)

3. Sodium silicate($Na_2O.nSiO_2$) – It is widely used as an accelerator for concrete , often used as an accelerator for shotcrete. It is the most effective alkaline activator .with the development of new technology for reducing hydrated silicate powders , the application of soluble glass in construction is greatly expanded such as dry glue mixtures , adhesives , oil well cement etc. (Korneev and Brykov 2000 , aborin et al 2001)

4. Sodium Sulphate (Na_2SO_4) :[French Chemist , Louis Jacques] it is very effective alkali activator for portland cement and lime based cementing materials. The introduction of sulphates in cementing system usually promotes the formation of ettringite at early and later ages.

LITERATURE REVIEW

.Alkali activators : NaOH , sodium silicate as a solution with SiO_2 to Na_2O molar ratio of 2.055 [composition: $Na_2O = 12.8\%$, $SiO_2 = 25.5\%$, water=61.7%] Range 30–33% of paste volume did not effect the compressive strength, but the consistency is effected . Compressive strength is effected by W/s , on adding GGBS this effect is reduced . W/s ratio highly effects the setting of concrete. high w/s ratio resulted in longer initial and final setting times.on adding GGBS compressive strength is increased . on increasing GGBS content leads to shorter setting times. [2007 Ali Rafeet, Raffaele Vinai , Marios Soutsos, Wei Sha]

2. Sodium Silicate solution (27.69% SiO_2 , 8.39% Na_2O and 63.92% H_2O by mass) and sodium hydroxide (99 wt.%) were used. nano-silica decreases the slump flow due to high surface area, mixes with a low slag/FA results in better flowability .on increasing the % of nano silica the initial and final setting time is increased , but after setting slag/fly ash ratio shows a more considerable effect. High % of slag results in faster setting time .nano-silica replacement retards the reaction process at early the main reaction product is a C-A-S-H type gel with structure like chain, on adding nano-silica the chemically bound water content is increased. The gel chain structure remains stable regardless of the nano-silica and slag/fly ash. Adding nanosilica upto 2% gives good compressive strength at curing age of 3, 7 and 28 days, higher nano-silica % shows (-)effects. higher slag/fly ash shows a lower level of porosity. nano-silica content is increased the porosity is decreased , structure refinement.2% of nano silica results in less porosity [X. Gao, Q.L. Yu , H.J.H. Brouwers]

3. Alkali Activator = NaOH, Water glass when the amounts of slag and water glass and the molarity of the NaOH solution increased the setting time of AAS and FA decreased. When the molarity of the NaOH solution was 4 M and the ratio of water glass to NaOH solution by weight was 0.5, AAS and FA paste had an initial time of 55 min and a final time of 160 min at a room temperature of 17 °C. The compressive strengths of AAS and FA concrete at 28 days increased with the amount of slag, except when the amounts of slag were 25% and 30% of the total binder weight. The compressive strength at 56 days decreased due to crack evolution caused by the shrinkage of the of AAS and FA paste, the appropriate replacement ratio of the slag for the fly ash by weight in AAS and FA mixture is 15–20% considering the setting time, workability and development of compressive strength. The mean pore sizes of the AAS and FA mortars measured were smaller than that of OPC specimens. This indicates that high shrinkage due to the increased number of small pores caused micro-cracks in the AAS and FA concrete, resulting in decreases of elastic modulus and the long-term compressive strength. [N.K. Lee, H.K. Lee]

4. The CO₂ emission of concrete increases with its compressive strength, indicating that the contribution of the binder to the total CO₂ footprint is more significant in OPC-based concrete than in AA concrete. The CO₂ emissions of OPC + SCM concrete is about 80% those of OPC concrete when the compressive strength is higher than 40 MPa. On the other hand, the CO₂ emission reduction rate of AA concrete relative to OPC concrete commonly ranges between 55 and 75%, therefore the reduction of CO₂ of AA concrete depends on the type, concentration, and dosage of the used alkali activators. The binder and CO₂ intensities commonly tend to decrease with an increase in the concrete compressive strength. Ca(OH)₂-based AA GGBS concrete shows an approximately 3.3 times lower CO₂ intensity than OPC concrete, even though the binder consumption is higher in Ca(OH)₂-based AA GGBS concrete than in OPC concrete

5. The paper investigated the physicochemical properties of binder gel in AAFS at high temperatures. Samples were produced by alkaline activation of fly ash and slag in a blend ratio of 1:1 by weight. Samples were exposed to temperatures of 200, 400, 600 or 800 °C.

Additional formation of the binder gel occurred in AAFS exposed to a temperature of 200 °C, which increased the micro-pore volume and decreased the porosity, thus increased the strength. The strength of AAFS continuously increased until exposure at 400 °C, at which the dehydration of C-A-S-H started to occur along with the simultaneous formation of N-A-S-H. The pore structure transformed from

microporous state to a mesoporous state. The porosity change was correlated with the strength. The porosity was lowest and the strength was highest at 400 °C. The binder gel started to crystallize at 600 °C, increasing the porosity and reducing the strength, and this continued to 800 °C until the gel became macroporous. The crystalline phases of åkermanite and gehlenite, nepheline, and anorthite, present in AAFS exposed to a temperature of 800 °C are analogously similar to, and therefore may correspond to the presence of C-A-S-H, NA-S-H and C-(N)-A-S-H, respectively, in the binder gel in the initial state.

6. low calcium class F fly ash with high silicate (Si) content is combined (GGBS), The alkaline activator used is sodium silicate with sodium hydroxide (NaOH) to achieve a Na₂O dosage of 15% and activator modulus (MS) of 1.25. A Sodium Silicate with alkali modulus (AM) of approximately 2.0 (Na₂O = 14.7% and SiO₂ = 29.4%) and a high concentration of sodium hydroxide, 15 M NaOH in liquid form were used. Decrease in initial strength and increase in final strength as the fly ash content increases. AASF Mix 1 (made by 100% slag) shows the highest initial compressive strength, long term strength is reduced and reaches the lowest compressive strength at 28 days. low initial strength, AASF mix 6 (made by 50% slag and 50% fly ash) highest compressive strength at 28 days.

7. Reaction product of alkali-activated FA/(FA+BFS) 1 was N-A-S-H gel, and the reaction product of alkali-activated FA/(FA+BFS) 0 was C-A-S-H gel. The reaction products of alkali-activated FA-BFS blends with the composition between two end members most probably consisted of coexisting N-A-S-H and C-A-S-H gels and/or a hybrid C-N-A-S-H. Compressive strength, Microstructure (SEM/EDS), FA particle size analysis was used as alkaline activator used is Sodium silicate solution. Modulus (n) of sodium silicate solution was adjusted by adding NaOH. [Nataša Marjanovića, Miroslav Komljenovića, Zvezdana Baščarevića, Violeta Nikolića]

8. Alkali Activator: Na₂CO₃, was 5% or 10% by weight of the powder mixtures.

The objective of this paper is to examine the properties of Na₂CO₃-activated fly ash/slag pastes, test is performed for mechanical strength, reaction kinetics, reaction products, and microstructure.

1. Sodium carbonate 10% FA 25% and GGBS 75% yield strength up to 60 MPa at 28 days and up to 80 MPa at 90 days. strength development is based on the quantity of activator dosage and FA/slag. Increasing the activator quantity increases the strengths at all ages while using FA content more than 25 wt% reduces the strength. With the

exception of mixes containing 50% FA, the water and sealed curing made no significant difference to the strength development. The remarkable influence of activator dosage and FA/slag ratio was also manifested in the reaction kinetics and the microstructure of the cement paste. The main reaction product was found to be a poorly crystalline, calcium silicate hydrate rich in Al and includes Na into its structure. The uptake of Al increased with increasing FA contents. Secondary products due to the role of carbonate were formed, such as hydrotalcite, calcite, and gaylussite.. [*Ahmed F. Abdalqader**, *Fei Jin*, *Abir Al-Tabbaa*]

9 GGBS, Class F fly ash, alkali sodium hydroxide and sodium silicate solution, that is composed of 27.69% SiO₂, 8.39% Na₂O and 63.9% H₂O by mass.. Increasing the slag/fly ash ratio and lowering the activator modulus increase the reaction intensity and shorten the main reaction processes, and activator modulus has a more significant influence than slag/fly ash ratio. The major reaction products in all mixes are C-A-S-H type gel with chain structure, the formation of this gel is attributed to the massive amount of available calcium in the solution. Highly polymerized N-A-S-H structures are not observed within the mentioned compositional range. All samples show similar thermal properties such as the physically bound water content and gel decomposition temperature, and these characters are independent of activator modulus and slag/fly ash mass ratio. But lowering the activator modulus and increasing the slag/fly ash ratio will increase total mass loss and decrease the phase changing temperature. The compressive strength results show that when increasing the slag/fly ash mass ratios, the optimum activator modulus shifts to higher values in general, this tendency is more significant in early ages. But either too high or too low modulus (1.8 or 1.0 in this case) will lead to relatively low strength. The changes in the optimum parameters in strength indicate that both slag/ fly ash ratio and activator modulus are dominating factors, and in order to achieve a desired strength, these two parameters should be considered simultaneously [X. Gao, Q.L. Yu, H.J.H. Brouwers]

CONCLUSION

Civil Engineering being the core of any country's progress, it's economic & industrial growth depends on the availability of power. In a country like India also it plays an eminent role, among all which are available, coal can be considered as a major source of fuel for

power generation. About 60% power is produced using coal as fuel. Indian coal is having low calorific value (3000-3500 K cal.) & very high ash content (30-45%) resulting in huge quantity of ash is generated in the coal based thermal power. Keeping this in view following conclusions were drawn. flyash and ggbs (industrial waste product) is present in ample amount in India. According to the previous research we came to conclusion that using flyash and ggbs in combination with alkali activators : [MOH, M₂CO₃, M₂SO₃, M₃PO₄, MF, M₂O.nSiO₂, :M₂O . nAl₂O₃, : M₂O.Al₂O₃.(2-6)SiO₂, : M₂SO₄] improves physical, chemical and mechanical properties of concrete. A new direction could be given to the research work using alkalis like caustic alkalis, non silicate, weak acid salts silicates, aluminates, aluminosilicates. AAS and FA is giving better test result than conventional concrete.

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