

Properties of Alkali Activated Slag Concrete- A Parametric Study

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ABSTRACT: This study deals with compressive strength, slant shear strength and bond strength of Alkali Activated Slag Concrete (AASC) with steel. While taking same mix proportions of materials replacing cement with GGBS completely, it can reach better results in above properties. This can be achieved by activating GGBS using alkali activators like NaOH and Na₂SiO₃. Achieving high bond strength between binding material and steel, high compressive strength and high resistance to adhesive failures is imperative for any structure in order to increase load carrying capacity and serviceability of the structure. Conventional concrete (CC) specimens of cubes and cubes with rods inserted have been casted. AASC specimens with same proportions as CC mix are also casted. Compressive strength, slant shear strength and pull-out tests are conducted on these specimens. By comparing the results we can establish the fact that with more effort on researching the alkali activated slag concrete we can lower the carbon foot print and decrease the usage of non-renewable resources which in turn increases the energy efficiency.

KEYWORDS: Alkali Activated Slag Concrete (AASC), bond strength, steel bars, slant shear, bi-shear.

I. INTRODUCTION

Every aspect of concrete technology throughout the history of civil engineering deals with the increase of strength of the concrete by various means and methods. But in order to achieve this goal, the right and sophisticated path should be to make it happen in a way that it should decrease environmental pollution and usage of non-renewable resources to which every engineer is responsible for. So as an engineer, we used alkali activated slag concrete to replace conventional concrete which in terms helps in decrease of cement production resulting in reduction of pollution due to cement production. Granulated blast furnace slag, a by-product of the iron production, is almost exclusively used as a binding ingredient instead of standard cements by grinding it into powder. Alkali Activated Slag Concrete (AASC) is obtained through activation of Ground Granulated Blast-furnace Slag (GGBS) using Sodium hydroxide and Sodium silicate solutions. The main reaction products in the formation of C-S-H gel with low CaO/SiO₂ ratio. Slag was the first cementitious materials to be activated by alkali and due to its latent hydraulic properties, the Ground Granulated Blast-furnace Slag (GGBS) become the most suitable materials for alkali activated cement. Alkali Activated Slag Concrete (AASC) is made with 100% of ground granulated blast furnace slag (GGBS), activated by alkalis instead of Portland cement in the binder of concrete. The major advantages of slag replacement of OPC in making concrete is the superior durability and lower heat of hydration as compared to 100% OPC binder. Slag is a by-product of steel production. Due to its very high fineness, it can effectively fill the pores of the concrete which are very much helpful for reducing the permeability of concrete. Impermeable concrete restricts the penetration of sea water inside the concrete and therefore increases the durability of concrete in sea water environments. When compared with Portland cements and concretes, AASC present several advantages, such as earlier and higher strengths, lower hydration heat, and stronger resistance to chemical attack. However, they also have some disadvantages such as quick setting and high shrinkage rate with formation of micro-cracking. In this present study, alkaline solutions are prepared by dissolving the appropriate quantities of NaOH flakes in sodium silicate solutions.

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II. LITERATURE REVIEW

Pedro Miguel Duarte Santos and Eduardo Nuno Brito Santos Júlio presented an experimental study to assess the influence of differential shrinkage and stiffness on the bond strength of new-to-old concrete interfaces. Both parameters were shown to have a significant influence on the bond strength and failure mode of concrete-to-concrete interfaces.

A. Momayez et al. conducted an investigation which aimed at studying the effect of test methods on bond strength between concrete substrate and repair material. Four test methods with cementitious or modified-cementitious repair materials, and two surface roughnesses were studied. The methods used were pull-off, slant shear, splitting prism and a new direct shear named Bi-Surface shear test.

D.V.S.P. Rajesh, A. Narender Reddy, et al investigated the Alkali Activated Slag Concrete with different activators to achieve good workability comparable with that of OPC. They concluded that Sodium silicate, sodium hydroxide activated slag mixes sets very quickly. Among AAS mix sodium silicate was the best; sodium carbonate was the second; and sodium hydroxide was third in terms of compressive, split tensile strengths and in terms of flexure strength and punching shear strength sodium hydroxide was best; sodium carbonate was second; sodium silicate (water glass) was third.

III. METHODOLOGY

Design of mixes:

In order to thoroughly investigate the AASC advantages over conventional concrete, it should be compared to different alkali activated slag concrete mixes. So three different mixes of AASC is to be compared with CC and also with each other.

Table 1. Design of mixes

| Material | Conventional Concrete(CC) | Mix 1 | Mix 2 | Mix 3 |
|---------------------------------------|---------------------------|-------|-------|-------|
| Cement (Kg) | 320 | | | |
| GGBS (Kg) | - | 320 | 320 | 320 |
| Fine aggregate (Kg) | 708.5 | 708.5 | 708.5 | 708.5 |
| Coarse aggregate(20mm) (Kg) | 831.3 | 831.3 | 831.3 | 831.3 |
| Coarse aggregate(10mm) (Kg) | 415.7 | 415.7 | 415.7 | 415.7 |
| Water(litres) | 160 | 160 | 160 | 160 |
| Alkaline /GGBS | | 0.4 | 0.5 | 0.5 |
| Alkaline solution (Kg) | | 128 | 160 | 160 |
| $\text{Na}_2\text{SiO}_3/\text{NaOH}$ | | 70:30 | 70:30 | 70:30 |
| Na_2SiO_3 (Kg) | | 90 | 112 | 112 |
| NaOH(Kg) | | 38 | 48 | 48 |
| Molarity | | 16M | 12M | 16M |

Table-1 indicates the quantities of ingredients that are to be mixed in order to get different mix proportions. For conventional concrete GGBS is not added and for remaining all mixes, GGBS is added in certain proportion.

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Sizes of the specimens:

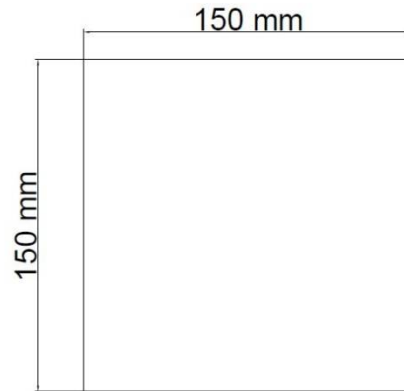


Fig 1. Specimen of compressive strength test

For compressive strength test conducted in this study, cubes of sizes 150mm x 150mm x 150mm and 100mm x 100mm x 100mm are prepared.

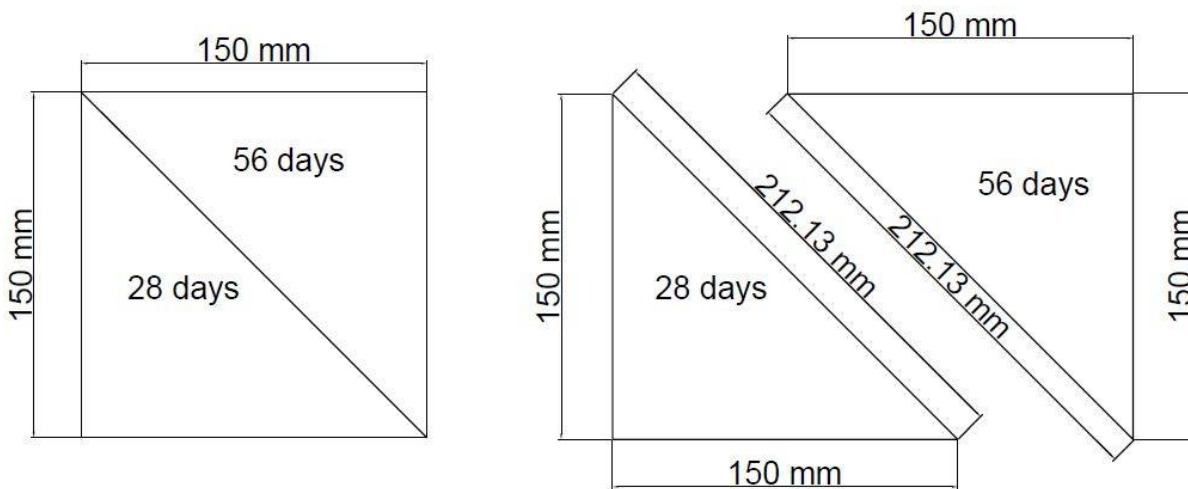


Fig2. Specimen of slant shear test

For slant shear test, cubes of 150m x 150mm x150mm in which half part is of 28 days age where as the other half is of 56 days age are used for this study.

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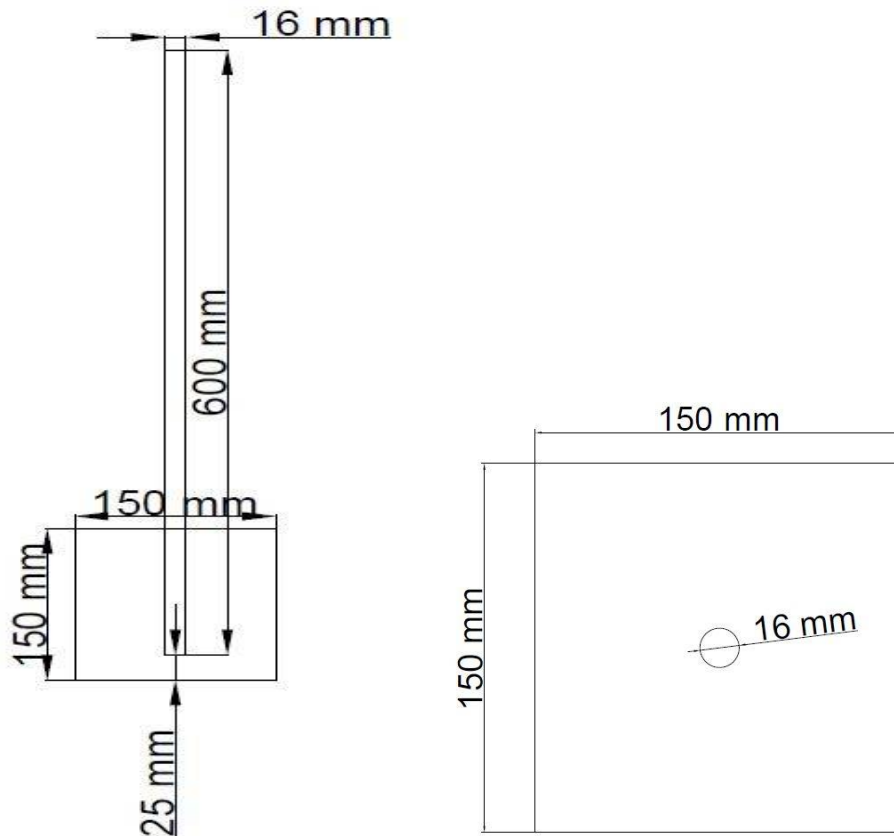


Fig3. Specimen of pull-out test

For pull out tests conducted, cubes of size 150mm x 150mm x 150mm into which steel re-bars of 16mm diameter is inserted at Centre of the specimen with a cover of 25mm from bottom face are used for this study.

Process of casting:

For an alkali activated slag concrete, chemical mixture of sodium hydroxide with water is to be prepared 24 hours prior to the casting of specimens to reach the desire strength. So as per design mixes required amounts of NaOH is mixed with stated amount of water in a container. The container is to be kept closed until the time of usage.

For achieving the better mix of chemicals, hand mixing procedure is opted for alkali activated slag concrete while conventional concrete is mixed by using the general concrete mixer. The pre-prepared sodium hydroxide solution and sodium silicate solution are to be mixed at the time of hand mixing.

For the slant shear specimens in order to investigate adhesive failures, they should have half of the specimen with different age. So to achieve the desired purpose after casting half of the specimen before 28 days, the other half is casted on the specimen with different angles of interaction making it a specimen with different ages. To achieve good bond strength the contact surfaces are roughened using steel brushes.

Tests conducted:

Different types of tests are conducted on different types of specimens in order to procure better results. Compressive strength, slant shear strength and pull-out tests are chosen to acquire required data. These tests are to be conducted by using compressive testing machine and universal testing machine.

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Vol. 6, Issue 8, August 2017

IV. RESULTS

Table 2. Bond strength between concrete and steel bars for different mixes

| Different types of mixes | Load applied for pull out(kN) | Bond strength (N/mm ²) |
|--------------------------|-------------------------------|------------------------------------|
| Mix1 | 41.0 | 6.525 |
| Mix2 | 55.25 | 8.79 |
| Mix3 | 59.3 | 9.44 |
| Conventional mix (M-20) | 43.25 | 6.88 |

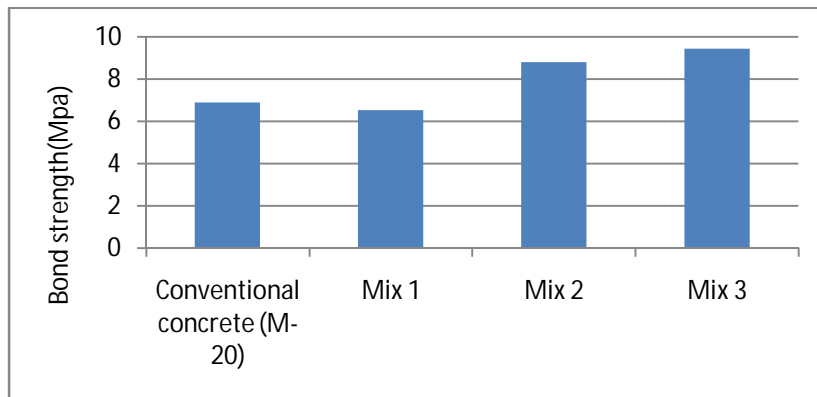


Fig4: Bond strength of different mixes

Table-2 and Fig 4 represents the Bond strength obtained at different failure load from pull-out test for different mixes.

Table3. Adhesive failures for different mixes

| Description | Type of test | Angle with respect to vertical axis | Conventional concrete (N/mm ²) | Mix 1 (N/mm ²) | Mix 2 (N/mm ²) | Mix3 (N/mm ²) |
|-------------|------------------|-------------------------------------|--|----------------------------|----------------------------|---------------------------|
| Cubes | Slant shear test | 45 degrees | 7.24 | 22.10 | 26.50 | 31.55 |
| | Bi-shear test | 0 degrees | 27.20 | 33.15 | 31.30 | 39.50 |

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Vol. 6, Issue 8, August 2017

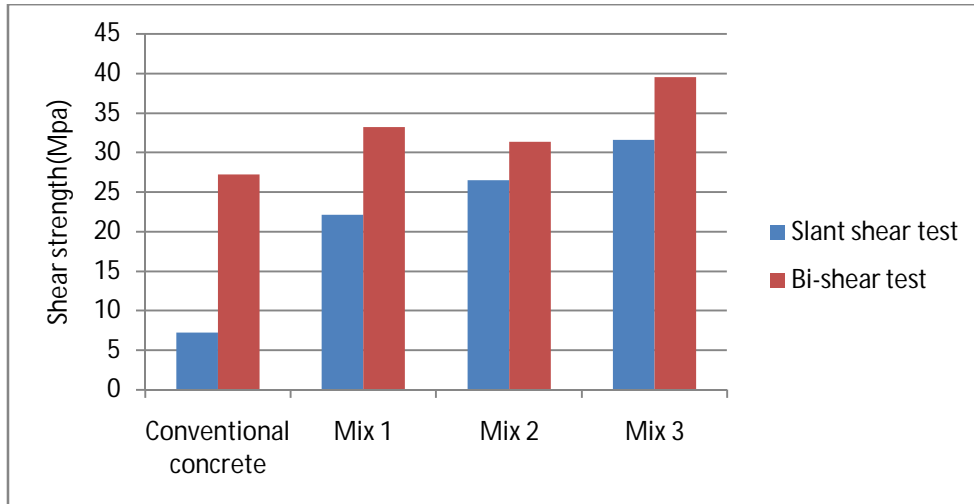


Fig.5: Slant shear strength and Bi-shear strength of different mixes

Table-3 and Fig.5 represent the Slant shear and Bi-shear strength obtained at different failure load from tests conducted for different mixes.

Table4. Compressive strength for different mixes

| Description | Type of test | Conventional concrete (N/mm ²) | Mix1 (N/mm ²) | Mix2 (N/mm ²) | Mix3 (N/mm ²) |
|-------------|----------------------|--|---------------------------|---------------------------|---------------------------|
| Cubes | Compressive strength | 31.11 | 46.96 | 41.78 | 53.03 |

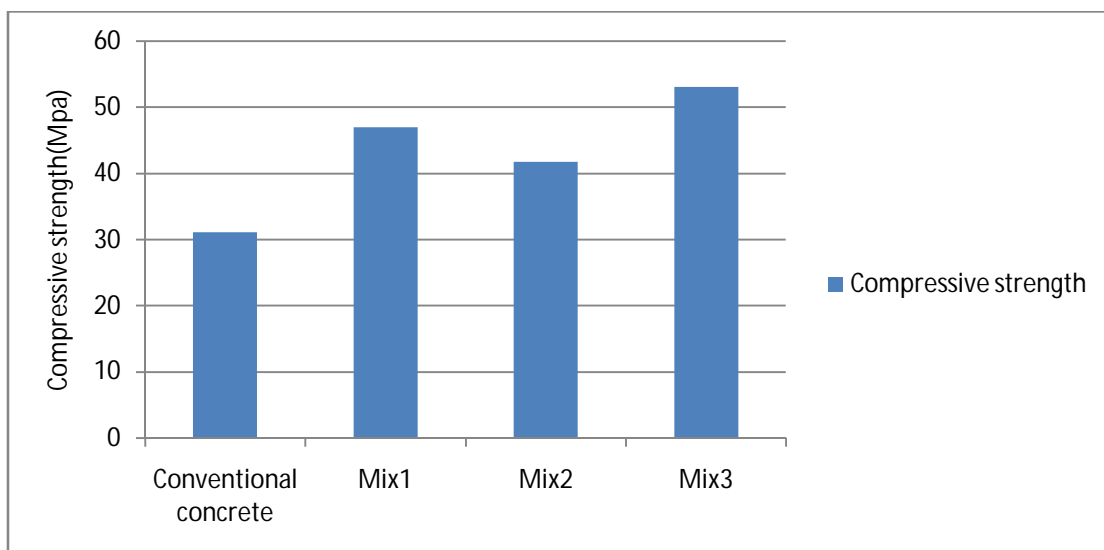


Fig 6: Compressive strength of different mixes

Table-4 and Fig.6 represent the compressive strength obtained at failure load from tests conducted for different mixes.

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V. CONCLUSIONS

- With regards to the bond strength between concrete and steel bars for different mixes mix 3 acquired the maximum strength of 9.44 N/mm². Mix 1 acquired the least bond strength of 6.525 N/mm². This is due to the presence of least amount of alkaline activators compared to the other mixes (Alkaline /GGBS is 0.4). Even conventional concrete acquired more strength than mix1. Alkaline/GGBS ratio and molarity of sodium hydroxide plays prominent role in bond strength between concrete and steel bars for different mixes.
- With regards to the adhesive failures of the mixes, the slant shear strength of mix 3 is the highest of all the mixes (31.55 N/mm²). The conventional concrete specimens acquired the least slant shear strength (7.24 N/mm²). The Bi-shear strength of mix 3 is the highest of all the mixes (39.55 N/mm²). The conventional concrete specimens acquired the least slant shear strength (27.20 N/mm²). But the mix 1 Bi-shear strength is higher than the mix 2, since the molarity may have notable influence on the Bi-shear strength. But the other factors like angle of interface and method of roughness also influences the slant shear strength.
- Now the compressive strength has acquired high strength at mix 3(53.03 N/mm²) and low strength at conventional concrete (31.11 N/mm²), Where mix 1 compressive strength is higher than the mix 2 which indicates the influence of molarity of the sodium hydroxide on compressive strength.

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