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Properties of Green Cement Concrete with Alternative Cementicious Binders

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Abstract

The need to meet a sustainable development is now an important challenge to the cement industry. The production of OPC is responsible for about 7% of the world's CO_2 emissions, lead to the search for more environmentally viable alternative to cement. Some of those alternative materials are alkali-activated slag (AAS) and fly ash (FA), where AAS and FA are used not as a partial replacement to cement but as a sole binder in the production of concrete. The overall aim is to investigate the potential of mixture of alkali activated slag (100%) and the potential of mixture of alkali-activated slag (60%) + fly ash (40%) as the sole binder in producing concrete. The performance of mixture of alkali activated slag and fly ash as concrete with sodium hydroxide as alkali activator is studied. The activator are used at 4% Na_20 (by weight of slag) .The scope of the work covered three mixes: a normal strength OPC control mix, sodium hydroxide activated slag, sodium hydroxide activated fly ash+slag. The fresh concrete properties are studied were the setting time and workability in terms of slump, the engineering properties studied are compression test and split tensile test are measured at 1, 3, 7, 21 and 28 days , flexural strength and punching shear test are measured at at 12 and 28 days. The alkali activated slag + fly ash concrete (AAFS) with sodium hydroxide activator investigated was found to achieve very good workability which was higher or comparable with that of OPC/slag concrete.

Keywords: Alkali-activated slag, fly ash, Sodium Hydroxide.

Introduction

Concrete is one of the most widely used building materials in roads, buildings, bridges, and other infrastructures. On average, approximately 1ton of concrete is produced each year for every human being in the world. Because of this global extensive use, it is imperative to evaluate the environmental impact of this material correctly.

Now a day, a material's environmental impact is often equated with its effect on green house gas emissions (GHGs) and climate change. From this point of view, great variances of so called "green" concrete concepts have been developed over the years. Very often these concepts focus on partially replacing the cement, the concrete constituent responsible for the highest co_2 emissions, by other materials. Worldwide the cement industry alone was estimated to be responsible for 7% of all anthropogenic co_2 generated. Since this branch of industry exits almost no other GHGs, it is held accountable for only about 3% of the total GHG emission generated by human activities.

However, the implementation of these 'green' concepts implies that certain parameters in the mix design need to be changed to obtain a sufficiently workable, strong and desirable concrete. Moreover, the specific application and the environment in which the concrete will be used need to be considered. A more correct environmental evaluation takes into account all differences between the 'green' and traditional concrete. Carbon dioxide is among these green house gases (*Malin, 1998*).

Co_2 load values for each cementitious material used in this study.

Cementitious material	Co_2 load(Tons)
Portland cement	0.92
Fly ash	0.00
100 Grade slag	0.15
120 Grade slag	0.20

Portland cement clinker is made from calcinations of limestone and siliceous material where de-carbonation occurs according to reaction:

$$CaCO_3 \rightarrow CaO + CO_2$$

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The total emission of CO_2 per kg of cement clinker produced is 0.53 kg from the de-carbonisation of calcite, plus 0.33 kg from the burning process plus 0.12kg from the generation of electrical power required, making a total of 0.98kg. Therefore, for every ton of cement clinker produced, an approximately equal amount of carbon-dioxide is released into the atmosphere (*Davidovits, 1991*). The world cement industry contributes some 7% to the total man-made CO_2 emission (*Malhotra, 1999*). This leads to the search for more environmentally viable alternatives to Portland cement. One of these alternative materials is alkali-activated fly ash slag (AAFS), in which ground granulated blast-furnace slag (GGBS) is used not as a partial replacement for cement but as a sole binder itself in the production of concrete. This will produce an environmentally friendly concrete. The use of slag cement has advantages due to its excellent cementitious properties over ordinary Portland cement (OPC), but the disadvantage of the low early strength has limited its use. Various studies had investigated ways to enhance the reactivity of the slag. One of the economic ways of activation is alkali activation. The alkali that is going to be used in this dissertation is sodium hydroxide (NaOH) along with small additions of lime. There are many slag like granulated blast-furnace slag, electro thermal furnace phosphorous slag and steel slag but GGBS is generally used. Slag has latent hydraulic properties. If GGBS is placed in water alone, it dissolves to a small extent but a protective film deficient in Ca_2^+ is quickly formed, which inhibits further reaction. The reaction continues if the P^H is kept sufficiently high. The pore solution of a Portland cement, which is essentially one of alkali hydroxides, is a suitable medium. The slag can be similarly activated by OH^- ions supplied in other ways such as addition of sodium hydroxide or silicate (*Taylor, 1997*). Study the properties of alkali activated slag(AAS) and alkali activated slag+ fly ash(AAFS) concretes using , sodium hydroxide as activator including the fresh concrete properties(setting time and workability at 5 minutes in terms of slump) and Engineering properties(compressive strength, split tensile strength punching shear strength, flexural strength). All the engineering properties are studied at curing conditions (normal water curing conditions).

Materials

Cement: Ordinary Portland cement conforming to IS 12269 – 2002 was used for the concrete mix and Specific gravity was found to be 3.5.

Fine Aggregate: The fine aggregate used in the work was obtained from a nearby river course. The fine aggregate that falls in zone –II was used. The specific gravity was found to be 2.60.

Coarse aggregate: Crushed coarse aggregate of 4.75mm size passing and 10mm retained proportion and 10 mm passing-20mm retained proportion was used in the mix. Uniform properties were to be adopted for all the prisms for entire work.

Slag: The ground granulated blast-furnace slag (GGBS) used was obtained from the Toshali cements pvt. Ltd., it complied with BS: 6699-1992.

Fly ash: The most widely used supplementary cementations material in concrete is a byproduct of the combustion of pulverized coal in electric power generating plants. During combustion, the coal's mineral impurities (such as clay, feldspar, quartz, and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gases. In the process, the fused material cools and solidifies into spherical glassy particles called Fly ash.

Sodium Hydroxide Pellets: Sodium hydroxide pellets. It is 97 % pure. The pellets are used to make solution of required dosage in water.

Water: Potable water supplied by our colleges was used in the work.

Moulds: Specially made wooden specimens are used for casting prisms. Standard cast iron cube and cylinder were used for casting of cubes, cylinders.

Vibrator: To compact the concrete, a plate vibrator and as well as needle vibrator was used and for compacting the Test specimens, cubes, cylinders and prisms.

Casting: The moulds were tightly fitted and all the joints were sealed by plaster of Paris in order to prevent leakage of cement slurry through the joints. The inner side of the moulds was thoroughly oiled before going for concreting. The mix proportions were put in miller and thoroughly mixed. The prepared concrete was placed in the moulds and is compacted using needle & plate vibrators. The same process is adopted for all specimens. After specimens were compacted the top surface is leveled with a trowel.

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Curing: The NSC specimens were removed from the moulds after 24 hours of casting and HSC specimens were removed after 48hours of casting, the specimens were placed in water for curing.

Mix Design

Alkali Solutions Preparation: Alkali solutions were prepared as activators for fly ash-slag concrete. The alkali solution consists of a sodium hydroxide pellets. The activator was prepared firstly by mixing the sodium hydroxide pellets in to water, stirring until all the pellets dissolved. Considerable care was necessary while handling the solution not only due to its high alkalinity and potential of harm, but because after preparation the solution released a very high amount of fumes. After preparation, the solution was handled carefully. This procedure was necessary to avoid using the activator while it was still warm. The water/ solid binder ratios were kept constant at 0.43. The term "solid" means a sum of the weight of slag, dissolved solids present in the solution (Na_2O).

Mix Design Procedure: The proportioning of a concrete mixture is based on determining the quantities of the ingredients which, when mixed together and cured properly will produce reasonably workable concrete that has a good finish and achieves the desired strength when hardened. This involves different variables in terms of water to cement ratio, the desired workability measured by slump and cement content and aggregate proportions. The mix is designed to target strength of 31.8 Mpa, of M30 Grade. Mix design is done according to Indian standard recommended method of concrete mix design IS 10262-2009.

Alkali-Activated fly ash + Slag Mixes: The alkali-activated fly ash-slag concrete mixes are mixed based on the second OPC control mix having the w/c ratio of 0.43. The activator dosage chosen in the recommended Na_2O range was 4% of Na_2O by weight of slag in case of Sodium hydroxide activator. The mixture calculations were made to calculate the required amount of activator by weight, which will provide the chosen dosages. In case of NaOH is considered as part of the binder content and the water in the activator is also taken as part of the total mixing water.

Mix Notations: The notation for the mixes is as follows:
CM: PC control mix with w/c=0.43.
SH₄: Sodium hydroxide-activated slag concrete mixture with Na_2O content of 4% by weight of slag of solid binder content with w/c=0.43 with 100%GGBS & 10%recycled aggregate.
SF₄: Sodium hydroxide activated fly ash + slag concrete with 2.5% N_2O by weight of fly ash+ slag and w/c=0.43 with 60%GGBS+40% Fly ash , and with 4% of lime.

Properties of Concrete

Setting Time: The test was carried out in accordance to IS4031 (part 5)1988 using the vicat's apparatus. The apparatus consists of steel needle which acts under a prescribed weight of 300 ± 1 g to penetrate the mortar. The penetration was repeated for every 10 min and during the interval the sample was kept in a chamber under a controlled temperature (20 ± 2)ºC and 90% relative humidity. Two different needles were used to determine the initial and final setting. The initial set needle was a right cylinder of diameter 1.13 ± 0.05 mm. The initial setting time was recorded when the sample is sufficiently stiff so that the needle penetrates no deeper than 4 ± 1 mm from the bottom. The final set needle is a similar needle with an attachment that helps to identify when it penetrates the mortar to a depth of only 0.5 mm. The setting values are related to many variables such as cement composition and temperature and the typical data on setting of different types of cement are shown below.

Table 1 Typical setting Time of Cement, Slag Mixes

cement type	Initial Set (h: min)	Final set (h: min)
OPC of 53 grade	2:30	5:12
SF_4(sodium hydroxide activated with 60 % slag, 40 % fly ash)	0:25	1:25
SH_4(sodium hydroxide activated slag)	0:25	2.00

Results and Discussion: The results in table 1 show that the OPC mix with higher w/c ratio had longer setting time compared to the other OPC control mix. Among the mixes of the same w/c ratio and binder content the addition of fly ash + slag prolongs the setting time. The sodium hydroxide activated slag mortar and 4 % Na_2O dosage has shorter setting time of all the mixes and NaOH activated slag mortar exhibited longer setting times (Initial and Final) among AAFS mortar mixes. Setting of sodium hydroxide activated as shown in the above table. The setting time of the activated with by NaOH is lower as compare to OPC is found to be 2hours 30minutes.Final setting time was also found to less in the case of alkali activated with NaOH.

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Workability: The workability of concrete describes the homogeneity and the ease of mixing, handling, placing, compacting and finishing of the concrete (or mortar). Workability or rheology of fresh concrete is the term traditionally been used in concrete technology to embrace all the necessary qualities. According to Tattersall (1991), the fresh concrete must be of a suitable composition in terms of quality and quantity of cement, aggregate and admixtures and must also be capable of: flowing into all corners of the mould or formwork to fill it completely, being compacted to expel as much entrapped air as possible, being mixed satisfactorily, being transported satisfactorily and providing a good surface finish.

Workability Tests: There are different tests for the workability of concrete that are adopted in concrete practice. The use of any test is chosen based on the following inter-dependent factors:
The concrete type: Properties and the desired level of workability of concrete, w/c ratio and use of admixtures. The test used is slump test.

Table 2. Slump at 5 Minutes for the Mixes

Activator	Slump (mm)
CM	135
SH_4	143
SF_4	138

Results and Discussion: The results from above Table show acceptably workable concrete with the Concrete Mix, having the lower slump than AAS and AASF concrete which has same w/c ratio. The addition of 4% lime by weight of slag resulted in loss of workability from collapse to 143,138 mm in terms of slump, which shows that due to the addition of lime slurry there exist losses of workability. This finding is in agreement with the work done by Chen and Liao, 1992. Among AAS and AASF concrete, sodium hydroxide activated slag concrete with the addition of hydrated lime has lower workability but is comparable with the workability of control mixes.

Engineering Properties

Compressive Strength: Compressive strength is an important criterion used to evaluate the quality of concrete. It is usually the value that the structural design of concrete is based on. This section gives details of the investigation carried out to evaluate the compressive strength of OPC, 60%Slag+40%fly ash and 100% slag concrete with NaoH activator 150x150x150 mm cubes were prepared according to mix procedure. The compressive strength is determined by following (IS456:2000) and two samples were tested for each different age and curing. Cubes from the mixtures were tested for 1, 3, 7, 21 and 28 days, and the average results are reported.

Table 3. Compressive Strength Developed for Different Mixes

Mix	1 day	3 days	7 days	21 days	28 days
CM	10.56	15.30	16.81	25.76	38.01
SH_4	8.85	11.71	15.31	20.80	29.85
SF_4	9.35	12.05	15.80	21.09	32.60

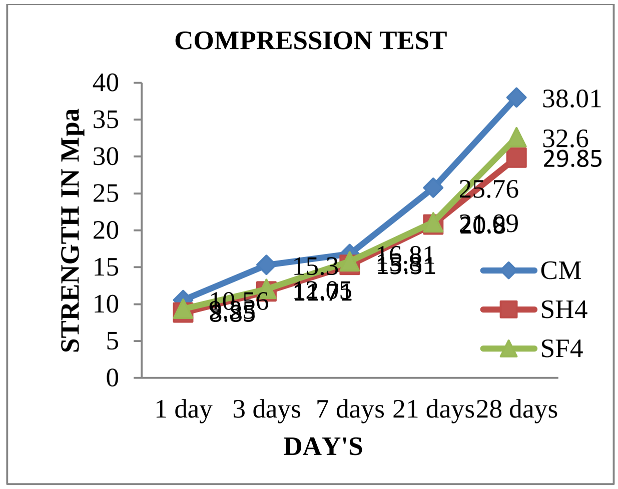

Figure 1. Result of Compressive Strength in Graphical Representation

Results on Compressive Strength: It can be seen in Figure 1. SF_4 (4%Na_2O) by weight of fly ash + slag achieved higher compressive strength 32.60 MPa at 28 days respectively in water curing in comparison with the other alkali mix. NaOH activated slag concrete mix with (4%Na_2O) by weight of slag has compressive strength 29.85 Mpa. According to split tensile test SF_4 mix achieved best result.

Splitting Tensile Strength: The splitting tensile strength of all mixes was measured using 100 mm Φ X 300 mm long cylinders. The test was performed as described by (IS 5816: 1999) and three samples were tested at each of the ages 1, 3, 7, 21and 28 days.

Table 4. Split Tensile Strength Developed for Different Mixes

Mix	1 day	3 days	7 days	21 days	28 days
CM	0.372	0.895	2.31	2.55	2.80
SH_4	0.257	0.545	1.75	2.12	2.43
SF_4	0.251	0.498	1.68	2.23	2.56

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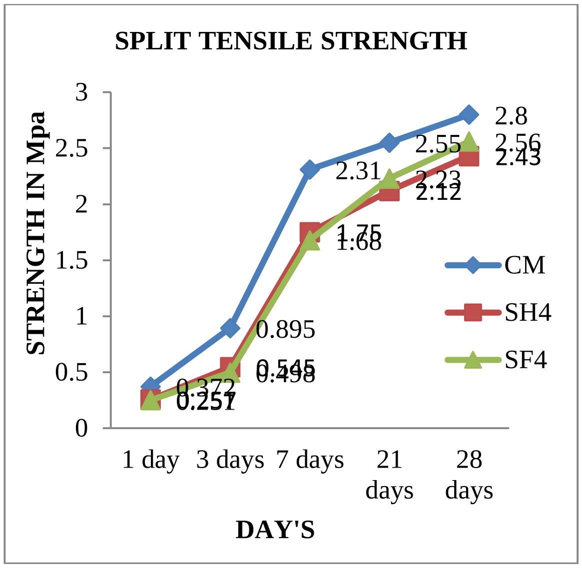

Figure 2. Result of Split Tensile Strength in Graphical Representation

Results on Split Tensile Strength: The results in above table show that among AAS concrete mixes, SF_4 showed the highest value of tensile strength around 2.43 Mpa at 28 days followed by SH_4 (2.43 Mpa). According to split tensile test SF_4 mix achieved best result.

Flexural Strength: Concrete as we know is relatively strong in compression and weak in tension, which leads to failure mostly in tension. Therefore, the knowledge of tensile strength of concrete is of importance. Direct measurement of tensile strength of concrete is difficult.While a number of investigations involving the direct measurement of tensile strength have been made, beam tests are found to be dependable to measure flexural strength property of concrete. The flexural strength of concrete mixes was measured according to I.S.9399:1979. Samples of 150x150x750 mm were cast in order to perform the flexural strength tests and one sample was tested for each curing at the age of 12 day. The flexural strength was calculated considering that the specimens were placed in a three-point load frame, with total free span of 0.6m and the point load will be act at center.

Table 5. Flexural Strength Developed for Different Mixes

Mix	*12 days*
CM	18.2
SH_4	12.32
SF_4	12.38

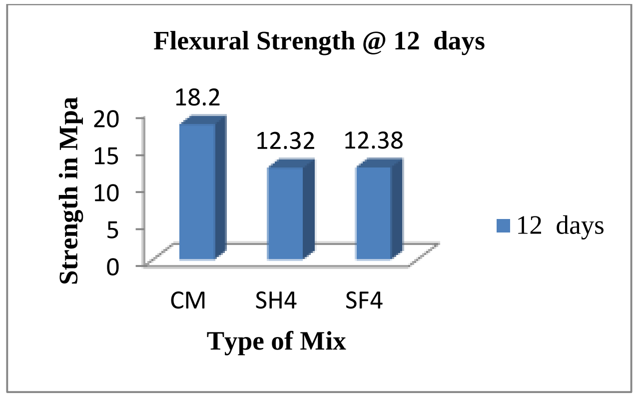

Figure 3. Result of Flexural Strength in Graphical Representation

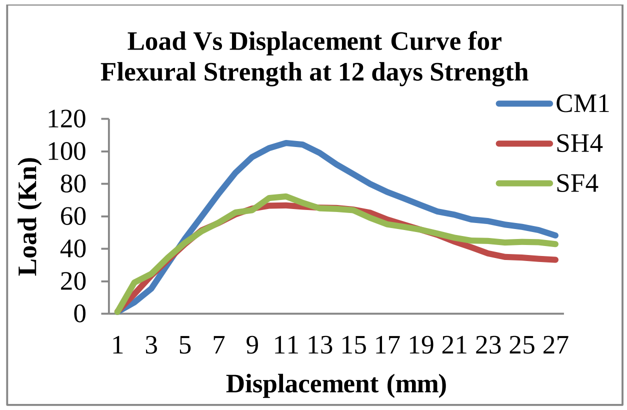

Figure 4. Load Vs Displacement Curve for Flexural Strength at 12 Days Strength

Results and Discussion: The highest flexural strength is shown by concrete mix where the lowest flexural strength is shown by NaOH activated concrete mix (SF_4). In the figure even the values for each curing and mix at 12 days are presented. Almost AAFS concrete shows comparable values of flexural strength with concrete mixes.

Conclusion

Overall it can be concluded that AASF concrete has a great potential and presents a viable alternative to OPC to help in decreasing the effect on the environment in terms of energy conservation and less CO_2 emissions. From Load vs. displacement curve in flexure test results, the CM mix gives the higher load carrying capacity but less ductility whereas SF_4 mix shows lower load carrying capacity but very high ductility. AASF concrete shows good ductility than traditional concrete. So AASF concrete is good to use where ductile designs are needed i.e., in seismic prone areas.

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References

[1] *Radlińska, A., Yost, J.R. Salera, M.J. (2013) 'Material Properties of Structurally Viable Alkali-Activated Fly Ash Concrete', ASCE Journal of Materials in Civil Engineering; 25(10), 1456–1464.*
[2] *Maochieh Chi. (2012) "Effects of dosage of alkali-activated solution and curing conditions on the properties and durability of alkali-activated slag concrete", Construction and Building Materials, cited in Elsevier Science Direct.*
[3] *E. Acevedo-Martinez, L.Y. Gomez-Zamorano (2012) "Portland Cement-Blast furnace slag mortars activated using water glass", Construction and Building Materials, cited in Elsevier Science Direct.*
[4] *Dali Bondar, C.J. Lynsdale, Neil B. Milestone (2011) "Effect of type, form, and dosage of activators on strength of alkali-activated natural pozzolans", Construction and Building Materials, cited in Elsevier Science Direct.*
[5] *Dali Bondar et.al.(2010) "Effect of type, form, and dosage of activators on strength of alkali-activated natural pozzolans", Cement & Concrete Composites* ***33 (2011)***.
[6] *Saud Al-Otaibi (2008) "Durability of concrete incorporating GGBS activated by water-glass", Construction and Building Materials, cited in Elsevier Science Direct.*
[7] *Bougara, Lynsdale, Ezziane (2007). "Activation of Algerian slag in mortars", Construction and Building materials, cited in Elsevier Science Direct.*
[8] *Atis CD., Bilim C., Celik O. (2007) " Influence of activator on the strength and drying shrinkage of alkali-activated slag mortar", Construction and Building Materials, cited in Elsevier Science Direct.*
[9] *Sato R, Maruyama I, Sogabe T, Sogo M. (2007) Flexural behavior of reinforced recycled concrete beams. J Adv Technol.*
[10] *Vladimir Zivica, 2006. "Effects of type and dosage of alkaline activator and temperature on the properties of alkali-activated slag mixtures", Construction and Building Materials, cited in Elsevier Science Direct.*
[11] *Saud, A. O. (2002). "Performance of alkali-activated slag concrete", The University of Sheffield, Sheffield.*
[12] *Van Jaarsveld, J.G.S., Van Deventer, J.S.J., and Lukey, G.C. (2002). "The effect of composition and temperature on the properties of flyash-and kaolinite- based geopolymers." Chemical Engineering Journal, 89, 63-73.*
[13] *Bakharev, T.; Sanjayan, J.G.; Cheng, Y.B. (2001). "Resistance of alkali-activated slag concrete to carbonation", Cement and Concrete Research, 31, 1277-1283.*
[14] *Bakharev, T.; Sanjayan, J.G.; Cheng, Y.B. (2001). "Resistance of alkali-activated slag concrete to carbonation", Cement and Concrete Research,* ***31***, *1277-1283.*
[15] *Bakharev, T.; Sanjayan, J.G.; Cheng, Y.B. (2000). "Effect of admixtures on properties of alkali-activated slag concrete." Cement and Concrete Research,* ***30(9)***, *April 2001.*

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