IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Performance Evaluation of Slag Based Alkali Activated Concrete by using Non-Conventional Aggregates

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Abstract— **Increasing urbanization and industrialization is raising burden on existing natural resources used in construction industry which is leading to severe environmental issues. Using industrial waste materials in construction can be one alternative to curb this problem. Geopolymer concrete (GPC), known as the next generation of concrete, is more durable and environment friendly as compared to conventional concrete. The current investigation presents the effect of waste foundry sand (WFS), a by-product of foundry industries. This review discusses the synthesis of alkali-activated binders from blast furnace slag, quarry dust and fly ash, the natural sand was replaced by WFS in the range of 0% to 100%. Tests on hardened concretes, to study, compressive strength, split tensile strength and flexural strength, were conducted to assess the strength. Addition of WFS lowered the workability of GPC. Tests were carried out on 0%, 50% and 100% WFS replacement for finding the optimal percentage again tests were carried out on 10,20,30&40 percent, 20% WFS gained highest strength and compressive split tensile and flexural strengths and that can be used for application purpose.**

Keywords: aggregates, strength, WFS, ggbs, concrete.

I. Introduction

In present scenario most of the construction done by concrete, so proportion of concrete is important factor for strength as well as durability. Concrete is a single most extensively used man-made material in the world. Ordinary Portland cement is one of the main ingredients used for the production of concrete it has been used for the construction of buildings, bridges, dams, pavements, tunnels, waste containment system. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and global warming. Hence, it is inevitable either to search for another material or partially replace it by some other material like Alkali Activated Slag that is GGBS.

AAS concrete has been found to own some superior properties as compared to OPC concrete, namely, low heat of association, high early strength, and glorious sturdiness in aggressive surroundings.

Ground coarse furnace scoria may be a by-product from the blast-furnace of iron and it's terribly useful within the concrete production. These operate at a temperature of concerning 1500 degrees centigrade and area unit fed with a rigorously controlled mixture of ore, coke and stone. The ore is reduced to iron and therefore the remaining materials from a scoria that floats on prime of the iron. This scoria is sporadically broached off as a liquefied liquid and if it's to be used for the manufacture of GGBS it should be apace quenched in massive volumes of water. The conclusion optimizes the building material properties and produces granules the same as coarse sand. This coarse scoria is then dried and ground to a fine powder. This powder is employed as a replacement to cement.

This severely impacts durability concrete near the surface. Good curing can help mitigate the appearance of unplanned cracking. Being practical, curing methods can enhance sustainability of concrete by reducing the need for resource intensive conditioning treatments. Curing conditions affect the strength development rate, as strength gain is significant in the curing phase. Improper curing leads to carbonation at early stage and reduces pH levels. In this regard, certain measures have to be introduced to ensure better quality of curing process in order to secure high quality of concrete. The three main functions of curing are retaining water in concrete during the early hardening process, reducing the loss of water from the surface of the concrete and most importantly accelerating strength gain using heat and additional moisture. It was found that thermal curing concrete increases rate of strength gain.

Typical highway engineering applications include Portland cement concrete (PCC), soil and road base stabilization, flow able fills, grouts, structural fill and asphalt filler Aggregates make up about 70–80% of a concrete mix. As the natural granite quarries for aggregates are gradually decreasing, there would be the need for alternative materials to be used as natural aggregates in concrete. Waste foundry sand is rich in silica content owes its black color to coating of burnt carbon over particles. Several authors have studied the use of WFS in various civil engineer- ing applications such as sand replacement in concrete, as highway embankment filling, soil stabilization, mortar making, brick blocks, pavement blocks etc. Addition of WFS in concrete as partial substitute (20–30%) to natural sand has improved the mechanical as well durability properties of conventional as well as special concretes such as self-compacting concrete (SCC) and geopolymer concrete. Some authors have observed strength enhance- ment on replacement by WFS upto 50–60% as well at 80% replacement level of WFS, upto 70% of strength of reference concrete (0% WFS) was achievable. Most of the research on WFS in concrete is limited to conventional concrete only and that too its use as partial replacement to normal sand. The aim of this study the feasibility of using the waste foundry sand as fine aggregate in making concrete. The paper evaluates the technical and environmental characteristics of the concrete with the main concern of recycling and adding economic value to the waste foundry to be used as alternative cheaper materials for concrete aggregates.

II. LITERATURE REVIEW

BM Mithun, MC Narasimhan [2015]: This is the paper to study the performance of alkali activated slag concrete mixes incorporating copper slag as fine aggregate for the experiments to determine strength and other characteristics. For the conduction of the experiment the materials are used such as cement GGBFS, alkali solution, aggregates, super plasticizer with these materials mix design was prepared. Alkali activated slag concrete mixture containing 25% 50% 75% 100% of copper slag a volume replacement for river sand were prepared. With 0.4% w/c ratio and 0.6% dosage of super plasticizer for conventional concrete. 7 days results of OPCC was 41.5 MPa and 100% ACS mix was about 50.7 MPa Compressive strength is almost similar of both OPC and AASC, in terms of water absorption AASC has reduced water absorption compared that of OPC, chloride permeability is also lower hence better at corrosion protection. Hence, we can say that AASCs with sand/CS show higher tensile strength properties than those of OPCC mix of similar compressive strength. Replacing CS even up to 100% showed no marked loss in strength parameters.

Nitendra Palankar et.al [2015]: Studied possibility of use of alkali activated binders for use in concrete pavements. Alkali activated slag concrete (AASC) and alkali activated slag fly concrete (AASFC) are prepared and the properties are compared with ordinary Portland cement concrete (OPCC). Materials such as cement of OPC 43 grade were used. GGBFS and fine aggregate was used for the alkali solution liquid sodium silicate and sodium hydroxide flakes in combination with portable tap water was used, water binder ratio was kept at 0.4, mix design was prepared with 100% GGBFS as binder and samples were prepared and are let to curing (air curing) at room temperature while OPCC specimens were cured in water tank.

Compressive strength test was conducted on the samples. It can be noted that the alkali activated binders display high early strength (3 days – 7days) as compared to that of conventional OPC concrete. The AASC achieve the highest strength of 67.4 Mpa at 90 days of curing as compared to other mixes. In terms of flexural strength, the AASC achieved the highest strength of 6.93mpa. The AASC and AASFC mixes attained a compressive strength in range 50-60 MPa with flexural strength in the range 6-7mpa at 28 days of curing. AASC and AASFC being air cured lead to the saving of water required for curing which otherwise is a key issue in rigid pavements

Nitendra Palankar et.al [2015]: Studied the effect of steel slag coarse aggregates on mechanical properties and fatigue behaviour of Alkali activated slag fly ash concrete mixes. In these investigation OPC 43 grades was used, and steel slag coarse aggregates is being used. Alkali activators used were combination of sodium hydroxide flakes and liquid sodium silicate along with potable water, crushed granite aggregates with maximum size of 20mm and locally available sand as coarse and fine aggregates was used respectively. Superplasticizer used was sulfonated naphthalene formaldehyde (SNF) was used for OPC mix for achieving good workability and mix was prepared, water binded ratio was of 0.4 with o.4% of super plasticizer. AASFC mixes the incorporation of steel slag had bit less workability due to angular shape of steel aggregates. Cubes were casted and tests were carried out on AASFC on 3, 7, 28, 90 days of curing Strength of AASFC had the replacement of normal aggregates with steel slag resulted in the decreases in the compressor strength of AASFC mixes. Mix with 100% steel slag attained 87% of composite flexural strength also decreases at all age; elastic modules also decrease Factual fatigue performance of Alkali activated slag concrete mixes incorporating copper slag as fine aggregate

Mithun B. M. et.al [2015]: Studied the mechanical properties and fatigue characteristics of new class of alkali activated slag concrete (AASC) mixes incorporations copper slag (CS) as fine aggregates for these investigation materials such as concrete of oxide OPC was used. Preparation of this mix GGBFS was used for aggregates locally available granite chips of maximum nominal size of 20mm were used as coarse aggregates for fine aggregates, CS was used as fine aggregate, alkali solution mixture of liquid sodium silicate and sodium hydroxide was used as the binder. Mix design was prepared and samples were casted then let to curing and are tested. Average 90 days flexural strength of 7.05mpa, 7.6mpa and 7.65mpa was obtained for OPC, ACS-50 and ACS-10 Respectively It is observed that the AASC achieve the highest strength of 67.4 Mpa at 90 days of curing, as compared to other mixes, in term o flexural strength. Mixes with sand/CS fine aggregate display higher flexural strengths then surface to OPCC. In terms of fatigue characteristics, it can be seen that AASC mixes displayed higher fatigue lives as compared to OPCC. We can conclude by saying that the` flexural strength of AASC mixes with sand/CS is higher compared to OPCC of similar compressive strength. For concrete Pavements**.**

Mithun.B.M., MatturC.Nalasimhan [2014]: studied the effect of increasing the dosage of sodium oxide (4-8%) and activate modulus of the alkaline solution on workability and strength characteristics of self-cured alkali activated concrete. materials such as GGBFS and cement of 43 grade was used as alkaline solution which is mixture of sodium hydroxide and sodium silicate solution is commonly used as alkaline activator, river sand of zone-2 and crushed aggregated of 20mm max size were used as fine and coarse aggregate with specific gravity of 2.69 and 2.64 respectively Mix was prepared with desired wet/dry binder (c) ratio at 0.45. Cubes were casted and kept for air curing for 24 hours and specimens were tested. From the test results it can be observed that there is no significant difference in strength between mixes prepared with potable and de-ionized water. Hence it can be concluded that use of potable water or preparing alkali solution will not significantly affect the strength of AASC mixes. The compressive strength of AASC mixes are higher at both early and later ages. Such strength or exceeding that of OPC concrete of the same w/b ratio.

Nitendra Palankal et.al [2015] [6]: Studied the development of alternative binders material to ordinary Portland cement (OPC) as this is huge emission of greenhouse gases associated with production of OPC. There's a need to reduce it hence this investigation was conducted to check the strength and other characteristics of OPC-43 grade was used, binder fly ash(FA) and GGBF's were blended and used an alkali solution was prepared combines sodium hydroxide(NaOH) flakes and liquid sodium silicate along with potable water aggregates of maximum size 20mm were used as coarse aggregates ,super plasticizer CONPLAST SP 430 was used to improve the workability of conventional concrete further mix design was prepared samples were containing 0%, 50%, and 100% steels slags coarse aggregates and standard OPC conventional concrete cubes were prepared. Slump cone test was carried out and from the slump tests results; it can be observed that all the concrete mixes attained the target slump values for which they were targeted. Development up to 90 days of curing. The result of the compressive strength of all concrete mixes at 28th day achieved average strength of 50 MPa the incorporation of steel slag coarse aggregates in GGBFS-FA geopolymer mixes yielded slightly lower fresh and mechanical properties. GGBFS-FA geopolymer mixes with steel slag coarse aggregates recorded slightly lower compressive strength along with lower tensile strength and modulus of elasticity as compared to GGBFS-FA geopolymer with granite aggregates; due to the presence of a thin layer of calcite on the aggregate surface thus leading to a weak aggregate– paste interface.

Wei Yao et.al (2019): Fly ash and Ground granulated blast furnace slag are the waste material used as the binding material by replacing ordinary Portland cement. The alkaline activators used in mortars are sodium silicate solution and sodium hydroxide solution. The mortar sample was carried out trails on 7, 28- and 56-days curing. For finding the dynamic strength specification of rock, dynamic compressive and tension tests were carried out with the help of split Hopkinson pressure bar system. They have determined that with increase in load rate the dynamic compressive and tensile strength was increased.

Ali a. Aliabdoet. al (2019): In this research paper the mechanical properties such as compressive strength, splitting tensile strength and modulus of elasticity are analysed. Five components such as sodium hydroxide (10, 12, 14M), alkaline solution content (0.4, 0.45, 0.5), curing temperature (30°,60°,90°C), curing time (1, 2, 3days), sodium hydroxide: sodium silicate mass ratio (1:1.75, 1:2.5, 1:3.5). the results obtain was with increase in sodium hydroxide: sodium silicate and sodium hydroxide molarity which increases all mechanical properties and increase in alkaline solution and curing temperature has badly affected the alkali activated slag concrete. They obtain 2 days is the best curing period

Nabeel A. Farhanet. Al (2019): In this research paper the material used are fly ash and alkali activated slag mixed with alkaline solution with aluminium silicate. They compared engineering properties such as workability, dry density, ultra-sonic pulse velocity, compressive strength, direct and indirect tensile strength, flexural strength, stress strain behaviour in compression and direct tension. And, micro structural study is carried out. The results obtain was dry density was lower than normal concrete, tensile strength was found to be equal when compressive strength of concrete was 35MPa while tensile strength of fly ash based geopolymer and alkali activated slag was found to be higher when the compressive strength was about 65MPa. Modulus of elasticity of FAGP and AAS was found to be lower than ordinary Portland cement. Microstructure of FAGP and AAS was found to be more compacted than OPC at 7days but less compacted in 28days of similar compressive strength

Robert J. Thomas et al (2015): In this paper they investigated on tensile strength, modulus of elasticity, Poisson's ratio, and stress strain relationship of alkali activated concrete (GGBFS). They found that AAC is shown to be stronger in tension and have lower Poisson's ratio than ordinary Portland cement. Young's modulus of elasticity varies linearly with alkali activated fly ash concrete while young's modulus of elasticity remains constant for activated GGBFS and alkali activated fly ash concrete exhibits similar stress strain behaviour to normal concrete. Whereas GGBFS concrete exhibits highly brittle behaviour compare to normal concrete. such as SEM, EDXand XRD analysis were also carried out, showi ng, denser morphologies clearly indicating effective activation of slag by the alkaline solution.

Manohar K M et al (2019): Studied the effect of utilization of natural aggregates by rap aggregates and cement by GGBS in alkali activated concrete pavement Cementitious binder material OPC 53-grade was used to produce the reference concrete GGBS was used as binder or alkali activated concrete, The RAP aggregates were used as fine and coarse aggregates, alkaline solution was prepared using sodium hydroxide(NaOH) flakes and liquid sodium silicate along with potable water aggregates Mix design is done for M40 grade geopolymer concrete The geopolymer concrete were prepared by replacing the cement with GGBS which is fully replaced with cement, and by replacing the RAP aggregates with natural aggregates with percentage variation 100%, 75%, 50%, 25%. In addition, taking activator modulus 1.25Compressive strength with Natural aggregate 48.23 MPa, 100% RAP(coarse aggregates) mix 34.90 MPa and 25% RAP mix 48.42 MPa Compressive strength with Natural aggregate 48.23 Mpa, 100% RAP(fine aggregates) mix 37.85 Mpa and 25% RAP mix 50.01 Mpa The workability of alkali-enacted concrete reduces by an increase in the RAP in case both RAP coarse aggregates and RAP fine aggregates replacement of 25% RAP coarse aggregates giving more strength than normal concrete which can be used for pavement construction and 50% RAP coarse aggregates which strength is near to normal concrete which can be used for low volume roads

Nabeel A. Farhan et. al (2019): In this research paper the material used are fly ash and alkali activated slag mixed with alkaline solution with aluminium silicate. They compared engineering properties such as workability, dry density, ultra-sonic pulse velocity, compressive strength, direct and indirect tensile strength, flexural strength, stress strain behaviour in

compression and direct tension. And, microstructural study is carried out. The results obtain was dry density was lower than normal concrete, tensile strength was found to be equal when compressive strength of concrete was 35MPa while tensile strength of fly ash based geopolymer and alkali activated slag was found to be higher when the compressive strength was about 65MPa. Modulus of elasticity of FAGP and AAS was found to be lower than ordinary Portland cement. Microstructure of FAGP and AAS was found to be more compacted than OPC at 7days but less compacted in 28days of similar compressive strength

Manjunath R et al (2018): In this paper, an attempt has been made to develop self compacting, alkali activated slag concrete mixes, using steel slag sand as fine aggregate and EAF (Electric Arc Furnace) slag as coarse aggregate. The study investigates the properties such as compressive strength, splitting tensile strength and water absorption of these mixes. Development of Self-Compacting Alkali Activated Slag Concrete mixes (hereafter referred to as SCAASC mixes) was made with GGBFS (Ground Granul ated Blast Furnace Slag) as the binder, with its content varying between 700kg/m3 and 900kg/m3 of fresh concrete. The net W/B (water to binder) ratio of the mixes were varied between a narrow 0.47 – 0.48 range. The alkaline solutions had Na2O percentages in the range 7 – 9%, but a constant activator modulus was maintained at 1.0 in all the mixes. In order to optimize the number of trial mixes to be tested, A total of nine mixes were formulated using Taguchi orthogonal L9 array. Results showed the slump flow values for the mixes greater than 700mm, with their L–Box ratios and V-Funnel values ranging between 0.90 and 0.95 and 9 – 11s respectively, satisfying the EFNARC guidelines. Results also showed good cmpressiv e strengths (65–80MPa), split-tensile strengths (2–4MPa) and low water absorption values in the range of (2%–3%). The microstructural studies such as SEM, EDX and XRD analysis were also carried out, showing denser morphologies clearly indicating effective activation of slag by the alkaline solution.

III.EXPERIMENTS

OBJECTIVE:

The main objective of the study is to develop, manufacture and study the engineering properties of the hardened alkali-activated concrete produced by using industrial wastes. In order to achieve the same, the following objectives have been set.

1. Obtaining mix design of slag-flyash based alkali activated concrete mixes.

2. Studying mechanical properties of AA concrete incorporating non-conventional aggregates.

3. Developing AAC paver blocks and studying its performance in compression and tension.

4. Economic analysis of the AAC paver blocks comparing it with conventional locally available blocks

METHODOLOGY

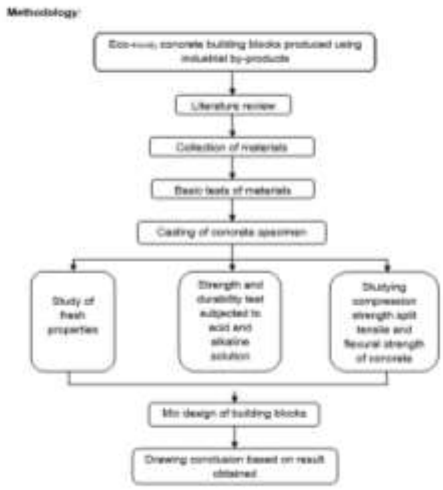
1. Preliminary tests on materials such as sieve analysis, specific gravity, water absorption test is conducted.

2. Alkali activated concrete mix design is madeby proportio ning various ingredients based on vast literature survey.

3. Alkali-activated concrete specimens are tested for compressive, split tensile, and flexural strength, and are tested after 28 days.

4. Obtaining the behavior of standard masonry blocks under compression, and flexure.

5. The obtained results are discussed and conclusions are derived.



MATERIALS USED

The materials used in the study are:

1. Fly ash (FA)

2. Waste foundry sand (WFS)

3. Ground Granulated Blast Furnace Slag (GGBS)

4. NaOH flakes

5. Sodium Silicate solution (LSS)

6. Coarse aggregate (CA)

7. Fine aggregate (FA)

8. Water (W)

FLY ASH

Fly ash, one of the sources materials for geopolymer binders, is available abundantly worldwide, and yet its use to date is limited. One of the efforts to produce more environmentally friendly concrete is to partially replace the amount of OPC in concrete with by-product materials such as flyash. An important achievement in this regard is the development of high-volume fly ash (HVFA) concrete that uses only approximately 40% of OPC, and yet possesses excellent mechanical properties. The fly ash used in this study was collected from UPCL power plant, Padubidri. It falls in the category of class F grade. Fly ash is a very fine, light gray and dust like material which results from burning of powdered coal in suspension.

WASTE FOUNDRY SAND

Due to ever increasing quantities of waste materials and industrial by-products, solid waste management is the prime concern in the world. There are several types of industrial by-products and waste materials. The utilization of such materials in concrete not only makes it economical, but also helps in reducing disposal concerns. One such industrial by-product is waste foundry sand (SFS). Waste foundry sand is a by-product of ferrous and nonferrous metal casting industries. Foundries successfully recycle and reuse the sand many times in a foundry. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as waste foundry sand.

GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

Blast furnace slags are the most widely investigated and probably the most effective CRM (cement replacement material) used for concrete manufacturing. Blast furnace slag is a by-product of the iron manufacture. Specific gravity of GGBS used is 2.88.

ALKALI SOLUTION	Per 1 m³
Water	88 KG
NaOH	9.987 KG
Sodium silicate	67 KG

SODIUM HYDROXIDE (NAOH) AND LIQUID SODIUM SILICATE SOLUTION (LSS)

Sodium silicate is the common name for compounds with the formula (Na2SiO2) No. These materials are available in aqueous solution and in solid form. The pure compositions are colorless or white. The Sodium silicate for this project was procured from local suppliers. Sodium Hydroxide flakes with 97%,98% purity in the form of flakes is commercially available which can be dissolved in water and liquid sodium silicate solution to have required concentration as per the modular ratio.

FINE AGGREGATES

The locally available quarry dust, passing through 4.75 mm and retained on 0.15 mm was used in this experimental work which was collected from a quarry at Parapady.

CONCRETE MIX DESIGN PROCEDURE

The w/c ratio of 0.55 was used. From the available literature, the mix is prepared for geo-polymer concrete with activator modulus of 1.25. The following step by step procedure is used while mixing the ingredients for masonry blocks.

1. A mix proportion of 0.55:1:4:5 (Alkaline liquid: Binder: fine aggregates: coarse aggregate) is used.

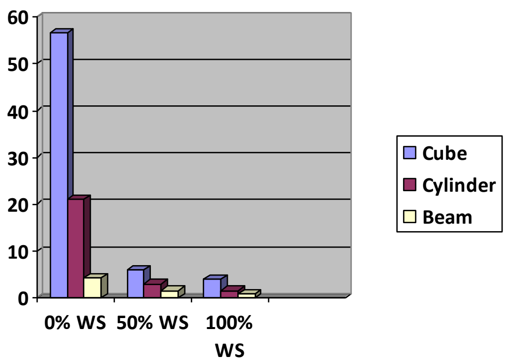
2. Binder, quarry dust and jelly crusher aggregate of size less than 10mm are mixed with appropriate amount of water in a machine operated concrete mixing machine.

3. After 5 minutes of proper mixing, the mix is filled in the molds.

4. It is then vibrated and compacted.

5. Procedure is repeated for casting other samples.

MIX DESIGN OF AKKALI SOLUTION

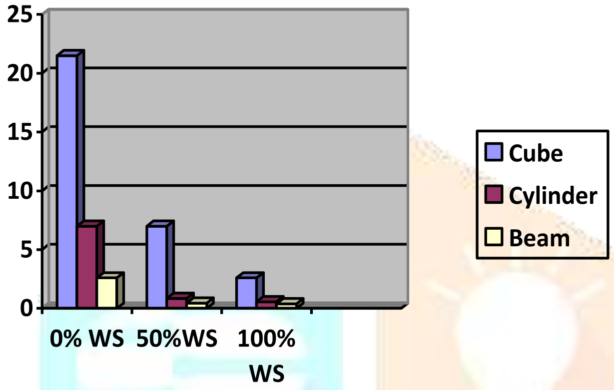


MIX DESIGN

MIX DESIGN	Per 1 m³
GGBFS	330 KG
FLY ASH	44 KG
GLASS POWDER	66 KG
ALKALI SOLUTION	129.85 KG
WATER	88 KG
COARSE AGGREGATE	1105 KG
FINE AGGREGATE	670 KG

7 DAYS TEST RESULTS

Sample	0% WS (N/mm²)	50%WS (N/mm²)	100% WS (N/mm²)
Cube	**21.5**	**7**	**2.6**
Cylinder	**2.43**	**0.86**	**0.456**
Beam	**2.75**	**0.56**	**0.4**



28 DAYS TEST RESULTS

Sample	0% WS (N/mm²)	50% WS (N/mm²)	100% WS (N/mm²)
Cube	**56.6**	**21**	**4.17**
Cylinder	**6**	**2.94**	**1.48**
Beam	**4**	**1.51**	**0.78**

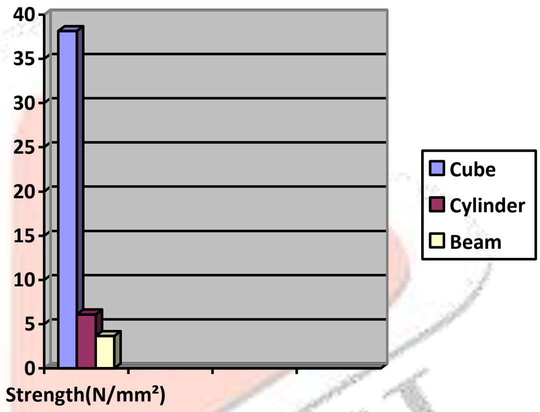
After 7- & 28-days test results with 0%, 50% and 100% waste foundry sand and quarry dust as the replacement we did test for 10% 20% 30% and 40% to find out optimal percentage of replacement

waste sand	Strength
10% waste sand	19.3 N/mm²
20% waste sand	24 N/mm²
30% waste sand	20.4 N/mm²
40% waste sand	20.96 N/mm²

Above are the test results of 10 20 30 and 40 percent waste foundy sand, we got 20% as optimal percentage and conducted 7-days and 28-days test

20% WASTE SAND 28 DAYS TEST RESULTS

Sample	Strength (N/mm²)
Cube	**38.16**
Cylinder	**6.10**
Beam	**3.65**



From the above results we can see that 20% waste sand showed better results, hence that percentage is optimal for application purpose.

CONCLUSION

The experimental study has been carried out on alkali activated concrete by using industrial wastes like fly ash, ggbs, quarry dust and waste foundry sand. the result of the experimental study has been found, and it can be concluded that the samples obtained can be used as a construction material with higher strength and durability. The specific conclusions are as follows.

1. From the experiment the average compressive strength of the samples for 20% waste foundy sand is 38.16 Mpa.

2. The compressive strength, results obtained for AAC samples were higher than the conventional concrete samples produced using OPC cement.

3. Behavior of alkali activated concrete was similar to that of conventional concrete when the when the reinforcement is introduced.

4. The alkali activated concrete produced can be used in the production masonry blocks and paver block which will consists better strength then conventional blocks.

5. The alkali activated concrete proved to be 20% economical than the conventional concrete.

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