A PROJECT REPORT

ON

STUDY ON ACID ATTACK ON CONCRETE CONSISTING OF GROUND GRANULATED BLAST-FURNACE SLAG, GRANULATED BLAST FURNACE SLAG, LIME AND RECYCLED COARSE AGGREGATE

Bachelors of Technology

In

Civil Engineering

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CERTIFICATE

This is to certify that the project topic titled **"STUDY ON ACID ATTACK ON CONCRETE CONSISTING OF GROUND GRANULATED BLAST-FURNACE SLAG, GRANULATED BLAST FURNACE SLAG, LIME AND RECYCLED COARSE AGGREGATE''** has been successfully delivered by **Ankur Singhal, Aman Prasad, Nishant Behera, Sachin Ambastha, Swetapadma Mohanty** of 8th semester **Civil Engineering** for the partial fulfillment of the requirement of Bachelor Degree in Civil Engineering, **Veer Surendra Sai University of Technology** during the year 2020 -21.

I highly appreciate their endeavor and sincerity in the project work.

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DECLARATION

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honestly and integrity and have not misrepresented or fabricated any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the university and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

With the increase in greenhouse gas emissions & the exposure of concrete structures to such environments, leaves the concrete quite susceptible to acid attack. Acid attack is caused by reaction between an acid and the calcium hydroxide portion of cement paste, producing a highly soluble calcium salt by-product. These are easily removed from the cement paste, thus weakening the structure as a whole. The presented paper aims to study the acid attack on concrete consisting of ground granulated blast furnace slag (GGBFS) and lime as substitutes of cement and granulated blast furnace slag (GBFS) and recycled coarse aggregate (RCA) as substitutes of natural coarse aggregate (NCA) and natural fine aggregate (NFA) respectively. The physical properties of the above substituting materials are studied.

CONTENTS

1. INTRODUCTION

1.1 Background

Due to increase in the levels of GHG emissions from various sectors of human activities, the world is pushed towards the vulnerabilities of global warming and climate change. Concrete, containing cement, coarse aggregate, fine aggregate & water, has contributed a significant 8% of global CO_2 generation. The production of each ton of OPC releases about 0.73–0.99 tons of carbon dioxide. Overall, 5–7% of global greenhouse gas emissions are related to the production of OPC Apart from that, it also accounts for the usage of substances that are already scarce and expensive.

Moreover, as the world traverses on the path of urbanization & development, environmental problems like depletion of natural resources & sustainable waste management, become key issues of concern. Activities like rehabilitations, reconstruction & demolition of existing concrete structures produce huge amount of construction & demolition waste every year, which needs to be channelized towards proper & efficient utilization.At present, many countries around the world are facing extreme shortage of landfills to dispose of massive quantities of different construction and demolition wastes (CDW). In developing countries, rapidly growing urbanization along with construction and demolition of infrastructures has increased the rate of CDW generation. In these countries, the major portion of CDW is sent to landfills due to the absence of proper recycling norms, which creates environmental and social complications. In 2018, it was estimated that 40 major countries around the globe, generated more than 3 billion tons of CDW. CDW can be converted into recycled aggregates using suitable crushing techniques. The substitution of conventional/natural aggregates with recycled ones especially coarse recycled concrete aggregate (RCA) can be very helpful in solving the environmental issues.

This calls for the attention towards exploring new substitutes of ingredients of concrete without compromising the desired physical properties. So the objective of present study is to prepare a sustainable concrete & to study the effect of acid attack on it by using ground granulated blast furnace slag (GGBFS) and lime as substitutes of cement and granulated blast furnace slag (GBFS) and recycled coarse aggregate (RCA) as substitutes of natural coarse aggregate (NCA) and natural fine aggregate (NFA) respectively.

1.2 General

Durability of concrete is one of the important properties of concrete that shows its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration, and will retain its original form, quality, and serviceability when exposed to its environment. Resistance to acid attack is crucial to determine the durability of the concrete.When it comes to resistance to different types of chemicals, the durability of concrete is quite influenced by its manufacturing process (curing methods, finishing, etc.) and the materials that are used. It is well known that concrete deteriorates when exposed to chemical attack under acidic environments. Concrete structures may be subjected to acidic environments under variety of conditions such as acid spills, acid rains, drainage sewers, chemical factories, hot springs, industrial effluents, etc. In above cases, the acid that affects concrete may be different. Also, the duration of attack may range from few seconds to years. And concrete being alkaline in nature is susceptible to the acid attack on its exposure to its surroundings. The spectrum of aggressive acidic media is wide. Acidic attack usually originates from industrial processes, but it can even be due to urban activity. Even natural exposure conditions may cause acid attacks. Free acids in natural waters are rare. Exceptions are carbonic waters and sulfurous and sulfuric acids in peat waters. Soils may contain huminous acids. Several organic and inorganic acids may occur in shallow regions of sea-water as a consequence of bacteriological activity. Significant quantities of free acids in plants and factories may be found. In these cases, the concentration of acid, which comes in contact with concrete structures, may reach to high values.In actual environment, the acid exposed on concrete is not a pure acid but a diluted or type of mixed acid. Concrete is susceptible to acid because of its alkaline nature. The components of the cement paste break during contact with acids. Acids such as nitric acid, hydrochloric acid and acetic acid are very aggressive as their calcium salts are readily soluble and removed from attack front. The effect of acid is mainly during the transformation of concrete from fresh state to hardened state.

Need for Study of Acid attack on Concrete Structures becomes necessary in following cases:-

- Acid spills in Battery Storage factories on concrete floors.
- Sulfuric acid attacks in Sewer pipes.
- Industrial effluents flowing through concrete channels.
- Paint manufacturing industries.
- Chemical Laboratories.
- Food Processing Industries.
- Fertilizer manufacturing and Storage plants.
- Leather Tanning Industries, etc.

So, cubes of concrete mixes with 0%, 50% and 75% replacement of NFA & NCA with GBFS & RCA were casted. Their resistance to acid attack was studied and compared with that of the conventional concrete made up of cement, NCA & NFA.

GGBFS, also known as ground granulated blast furnace slag, is a by-product obtained from iron manufacturing process. This when incorporated in concrete improves its properties such as workability, strength & durability. It helps in reduction of voids in concrete thereby reducing permeability significantly & making them more stable chemically. All this contributes to the enhancement of overall durability.

GBFS, called as granulated blast furnace slag, is also a by-product generated from iron & steel-making process. In our study this is used as a substitute for natural fine aggregates, i.e, sand. Being environment friendly, it also imparts better cohesion among the concrete mix. RCA, referred to as recycled coarse aggregates, are prepared through screening, crushing & sieving of waste pieces of concrete (from construction & demolition waste). Being an alternative to natural coarse aggregates, it reduces energy consumption & environmental pollution.

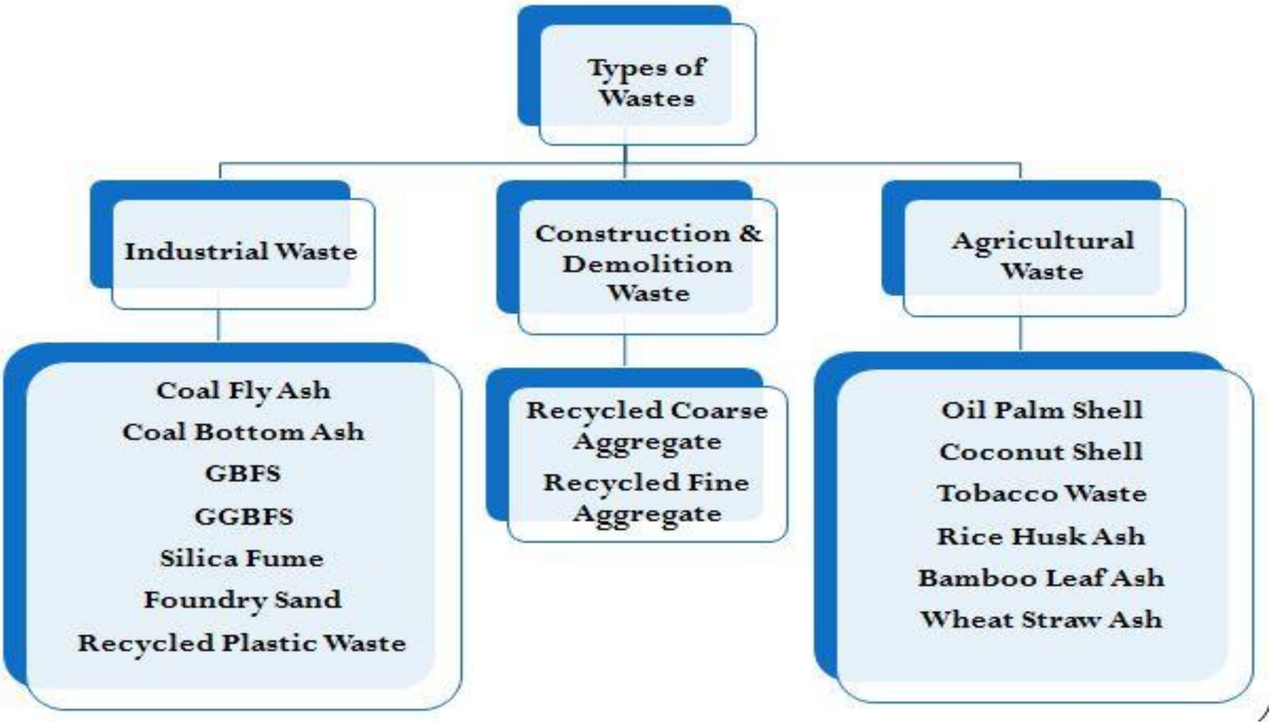
2. SUSTAIANABLE CONCRETE

Sustainable Concrete is defined as the concrete that uses less energy in its production and produces less carbon dioxide than normal concrete. It is also known as green concrete or ecofriendly concrete.

Utilization of these materials as Green Concrete is the only option to reduce the disposal concern. The Green Concrete is made from the eco-friendly waste materials and ushers in a revolution in the concrete industries by its technology. The waste products can be reused directly as a partial substitute of cement and save the energy consumption during the production of cement. Some waste materials are having pozzolanic properties. Pozzolans is a material rich in silica and alumina which itself possess little or no cementing property, but in the presence of water, it chemically reacts with calcium hydroxide at ordinary temperature to form the cementitious properties. The complete process of cement manufacturing, right from crushing and transport of lime stone, heating of kilns and crushing is all polluting.

Cement production is the second largest industrial emitter of carbon dioxide in the world, and creates devastating environmental impacts. With production expected to increase, especially in developing countries, innovation is urgently needed to find a sustainable alternative.

Wastes which can replace the main Constituents of Concrete



3. DURABILITY TEST ON CONCRETE

The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality, and serviceability when exposed to its environment.

When designing a concrete mix or designing a concrete structure, the exposure condition at which the concrete is supposed to withstand is to be assessed in the beginning with good judgment. The environmental pollution is increasing day by day particularly in urban areas and industrial atmospheres. It is reported that in industrially developed countries over 40 per cent of total resources of the building industries are spent on repairs and maintenance. In India, the money that is spent on repair of buildings is also considerable.

3.1 Acid Attack

Concrete is not fully resistant to acids. Most acid solutions will slowly or rapidly disintegrate portland cement concrete depending upon the type and concentration of acid. Certain acids, such as oxalic acid and phosphoric acids are harmless. The most vulnerable part of the cement hydrate is $Ca(OH)_2$, but C-S-H gel can also be attacked. Silicious aggregates are more resistant than calcareous aggregates. Concrete can be attacked by liquids with pH value less than 6.5. But the attack is severe only at a pH value below 5.5. At a pH value below 4.5, the attack is very severe. As the attack Dark reaction rim on aggregate proceeds, all the cement compounds are eventually broken down and leached away, together with any carbonate aggregate material. With the sulphuric acid attack, calcium sulphate formed can proceed to react with calcium aluminate phase in cement to form calcium sulphoaluminate, which on crystallization can cause expansion and disruption of concrete. If acids or salt solutions are able to reach the reinforcing steel through cracks or porosity of concrete, corrosion can occur which will cause cracking

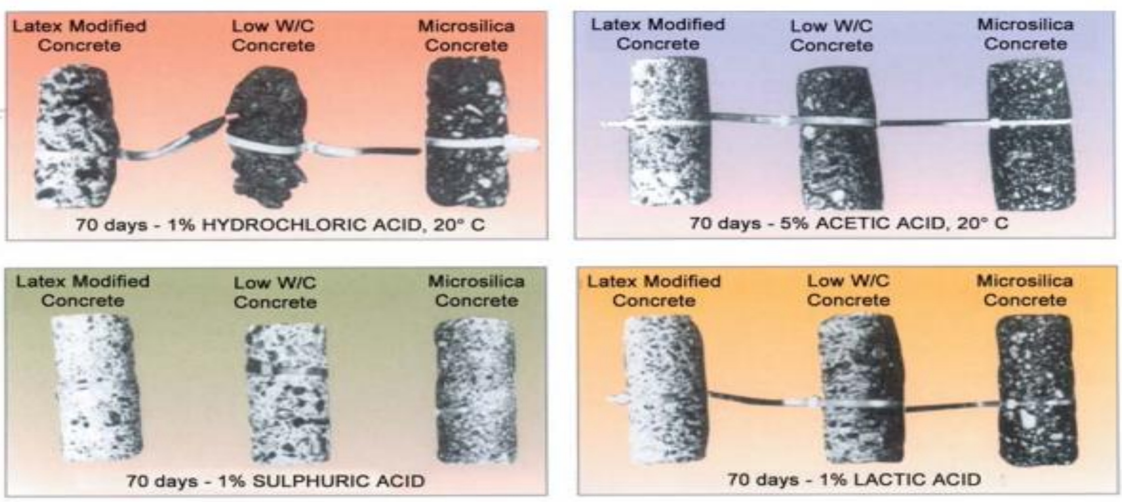
When it comes to resistance to different types of chemicals, the durability of concrete is quite influenced by its manufacturing process (curing methods, finishing, etc.) and the materials that are used. It is well known that concrete deteriorates when exposed to chemical attack under acidic environments. Concrete structures may be subjected to acidic environments under variety of conditions such as acid spills, acid rains, drainage sewers, chemical factories, hot springs, industrial effluents, etc. In above cases, the acid that affects concrete may be different. Also, the duration of attack may range from few seconds to years.

Deterioration of Concrete Structure The spectrum of aggressive acidic media is wide. Acidic attack usually originates from industrial processes, but it can even be due to urban activity. Even natural exposure conditions may cause acid attacks. Free acids in natural waters are rare. Exceptions are carbonic waters and sulfurous and sulfuric acids in peat waters. Soils may contain huminous acids. Several organic and inorganic acids may occur in shallow regions of sea-water as a consequence of bacteriological activity. Significant quantities of free acids in plants and factories may be found. In these cases, the concentration of acid, which comes in contact with concrete structures, may reach to high values. In actual environment, the acid exposed on concrete is not a pure acid but a diluted or type of mixed acid. Concrete is susceptible to acid because of its alkaline nature. The components of the cement paste break during contact with acids. Acids such as nitric acid, hydrochloric acid and acetic acid are very aggressive as their calcium salts are readily soluble and removed from attack front. The effect of acid is mainly during the transformation of concrete from fresh state to hardened state.

Major sources of Sulphur are

- Source water has high sulphur content, both as sulphate or sulphide, and form hydrogen sulphide, H_2S.
- The hydrogen sulphide gas comes out of the solution and forms sulphuric acid in the air space. Sulphuric acid is highly reactive and reacts with calcium compounds to form gypsum which causes the concrete to soften, ultimately leading to roof collapse.
- Organic matter

  + SO_4^{2-} S^{2-} + H_2O + CO_2S^{2-} + $2H^+$ H_2SH_2S + $2O_2$ H_2SO_4



Effect of different acids on concrete

3.2 Acid Attack – Mechanism

Concrete being very alkaline in nature, is extremely susceptible to acid attack. The mechanism for this process is very simple. The products of cement hydration are shown below.

CS + H $\rightarrow$ C-S-H + CH

Calcium Silicate + Water $\rightarrow$ Calcium Silicate Hydrate + Calcium Hydroxide

Acid attack is caused by the reaction of an acid and the calcium hydroxide portion of the cement paste which produces a highly soluble calcium salt by product. These soluble calcium salts are easily removed from the cement paste thus weakening the paste's structure as a whole. This basic reaction is shown below.

Acid X + CH $\longrightarrow$ CX + H

Acid + Calcium Hydroxide $\longrightarrow$ Calcium Salt + Water

More aggressive acids such as hydrochloric, acetic, nitric, and sulfuric acids produce calcium salts that are very soluble. Less aggressive acids such as phosphoric and humic acids produce calcium salts with a lower solubility. These low soluble salts can act as a partial inhibitor to the overall process by blocking tiny passage in the cement paste through which water flows. This reduces the amount of calcium salts that enter into solution and retard the overall process.

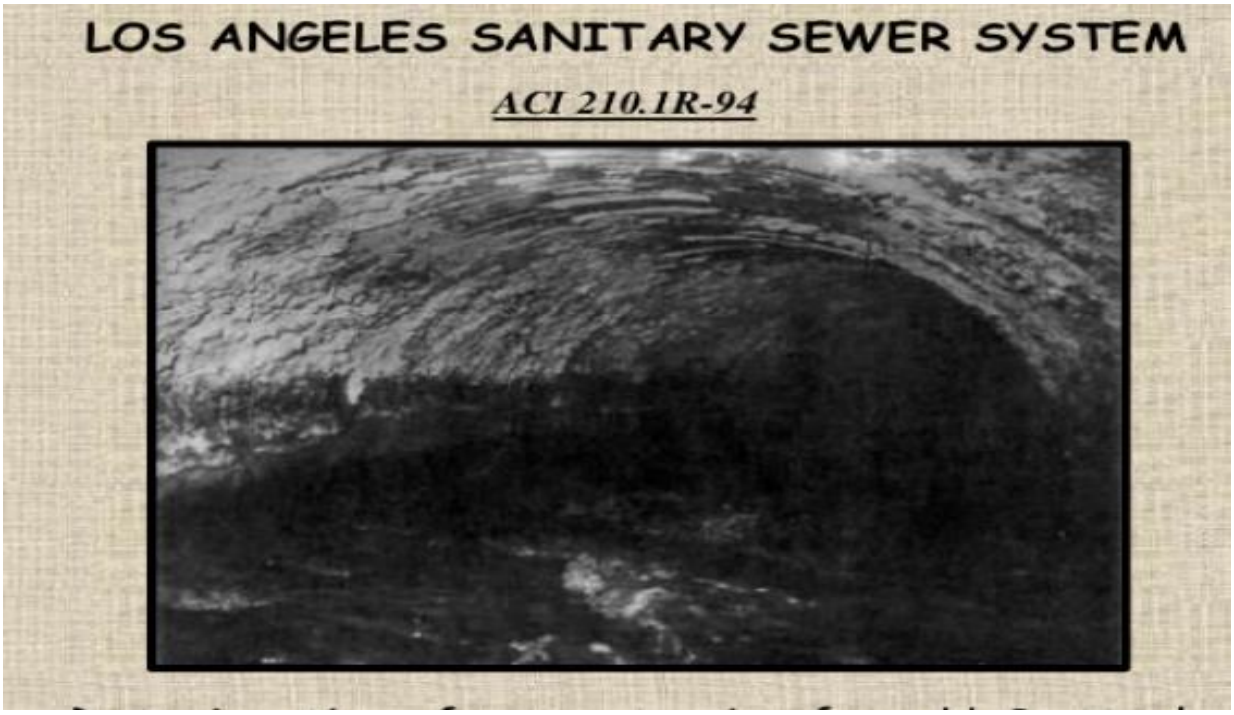
A more aggressive and destructive case of acid attack occurs when concrete is exposed to sulfuric acid. The calcium salt produced by the reaction of the sulfuric acid and calcium hydroxide is calcium sulfate which in turn causes an increased degradation due to sulfate attack. This process is illustrated below.

$$H_2SO_4 + Ca(OH)_2 \longrightarrow Ca(SO)_4 + 2H_2O$$

Acid + Calcium Hydroxide $\longrightarrow$ Calcium Sulfate+ Water (calcium sulfate product contributes to sulfate attack)

The dissolution of calcium hydroxide caused by acid attack proceeds in two phases. The first phase being the acid reaction with calcium hydroxide in the cement paste. The second phase being the acid reaction with the calcium silicate hydrate. As one would expect the second phase will not begin until all calcium hydroxide is consumed. The dissolution of the calcium silicate hydrate, in the most advanced cases of acid attack, can cause severe structural damage to concrete.

Following image showing LOS ANGELES SANITARY SEWER SYSTEM (ACI 210.1R-94) Deterioration of concrete pipe from H_2S attack.



3.3 Prevention.

The acid attack on concrete can be minimized by providing due consideration to concrete porosity. Lesser the porosity, lesser will be the chances of acid attack on concrete. In another way, the concrete resistance to acids can also be provided by giving its surface an acid resistant coating.

Acid resistant Concrete.

In general it can be said that all high performance concrete mixtures showed a better resistance against acid attack than the reference ordinary type concrete that was tested in comparison.

The main trends seen in the acid attack results include:

- Using fly ash in combination with micro silica fumes resulted in an improved acid resistance. The reason for the performance was a denser packing of the cement paste and aggregates due to the fly ash. The micro silica fume reacts pozzolanically and transforms the calcium hydroxide chemically and by that decreases its content in the binder matrix. This also increases the acid resistance. Without fly ash, the micro silica fume alone can result in micro cracks, which will increase the path for acid intrusion. The fly ash releases alumina ions and above a certain level of ion content the shrinkage is lower and therefore less cracks will occur. This was confirmed by the observation that using micro silica alone resulted in a lower acid resistance.

- Using air entrainment resulted in an increased acid resistance because the entrained micro air voids improved the workability and the ability of the concrete to be packed denser. In other words, the concrete is more homogenous. Furthermore, the air voids block micro capillaries and prevent the acid from invading the concrete through these canals.

- Using extra fine blast furnace slag did not provide any improvement to the acid resistance. It can be assumed that the combination of fly ash and Silica fume is more effective than the use of extra fine blast furnace slag alone. The reason for this is probably that the slag does not change the amount of calcium hydroxide in the concrete.

- To produce a dense concrete like in high performance concrete is favourable for the durability under acid attack. The dense matrix slows down the speed of the acid penetration and the dissolution of the matrix itself. The damage development is delayed.

4. OBJECTIVE

Objective of the current proposal is to develop sustainable concrete by using recycled coarse aggregate (RCA), granulated blast furnace slag (GBFS) and ground granulated blast furnace slag (GGBFS) as substitutes of natural coarse aggregate (NCA), natural fine aggregate (NFA), lime and cement, respectively and study the effect of acid on it.

The objective of the work is as follows

- Characterization of GBFS, GGBFS and RCA
- Mix Proportioning and casting.
- To investigate the strength at different mix proportioning
- To investigate the effect of acid on different mix proportion
- An extensive literature survey pertaining to chemical attack of materials specifically acids on concrete.
- Determination of effect of acids on compressive strength of concrete through experimentation.
- To study the effect of acid attack on concrete by varying following things: -Duration of attack. Concentration of acids.

5. SCOPE

- It helps to find out strength of sustainable concrete, so we can construct different structure using sustainable concrete such as
- ➢ Acid spills in battery storage factories on concrete floors.
- ➢ Sulfuric acid attacks in Sewer pipes.
- ➢ Industrial effluents flowing through concrete channels.
- ➢ Paint manufacturing industries.
- ➢ Chemical Laboratories.
- ➢ Food Processing Industries.
- ➢ Fertilizer manufacturing and Storage plants.
- ➢ Leather Tanning Industries, etc.

- To reduce burden on the existing scarce natural resources.
- To decimate environmental pollution.

6. MATERIALS

6.1 Binders

The binding materials used in this investigation were 43 grade Ordinary Portland cement in an agreement to IS: 8112 and GGBFS collected from Jindal Steel and Power Limited, Angul, India. Standard tests have been conducted in laboratory for determinationof various physical and mechanical properties of the binders as per BIS specifications.

❖ GGBFS (Ground Granulated Blast Furnace Slag)

The ground granulated blast furnace slag (GGBFS) is a by-product of iron manufacturing which when added to concrete improves its properties such as workability, strength and durability. It is white in appearance. The difference in mineralogical composition in GGBFS comparison to Portland cement is shown in the table below.

Table-1 Composition of GGBFS and Portland Cement

Mineral	**GGBFS**	**Portland Cement**
CaO	30-50%	55-66%
SiO_2	28-40%	20-24%
Al_2O_3	8-24%	0-8%
MgO	1-18%	5%

Advantages of using GGBFS in Concrete

- GGBFS in concrete increases the strength and durability of the concrete structure.
- It reduces voids in concrete hence reducing permeability
- GGBFS gives a workable mix.
- The structure made of GGBFS constituents help in increasing sulphate attack resistance.
- The penetration of chloride can be decreased.
- The heat of hydration is less compared to conventional mix hydration.
- The alkali-silica reaction is resisted highly.
- These make the concrete more chemically stable

- Gives good surface finish and improves aesthetics
- Lower chances of efflorescence

- **LIME**

It is a good binding material for concrete. It also acts as plasticizer making the mortar slower to harden and more flexible. Lime is manufactured from limestone or chalk (calcium carbonate) which is crushed and then heated in a kiln to around 1,000°C. This converts the calcium carbonate into calcium oxide (quicklime) which is reacted with water (slaked) to produce a fine powder.

Advantages of using lime in concrete

- Increases workability of concrete
- Gives fresh and aesthetic finish to the structure
- Provides high water retention that allows for maximum early curing of the cementitious materials
- Enhances durability

6.2 Aggregates

Locally collected siliceous type river sand and 20 mm crushed granite type aggregate were used as NFA and NCA, respectively. Sand is replaced with GBFS which is the by-product of iron and steel industries. GBFS is collected from Tata Steel Plant of Jajpur.

Similarly, 20 mm granite type aggregate with attached cement mortar obtained by crushing 10 years old precast railway sleepers from NALCO, Angul, India, was used as RCA. The grading analysis of natural fine aggregate (NFA) and coarse aggregates (NCA and RCA) were done in accordance to IS: 2386.

- **GBFS (Granulated blast-furnace slag)**

- Granulated blast-furnace slag (GBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) into water from a blast furnace in water or steam, to produce a glassy, granular product.
- It has maximum size of about 6mm.
- It typically has a density of about 60 - 70% of natural sand.

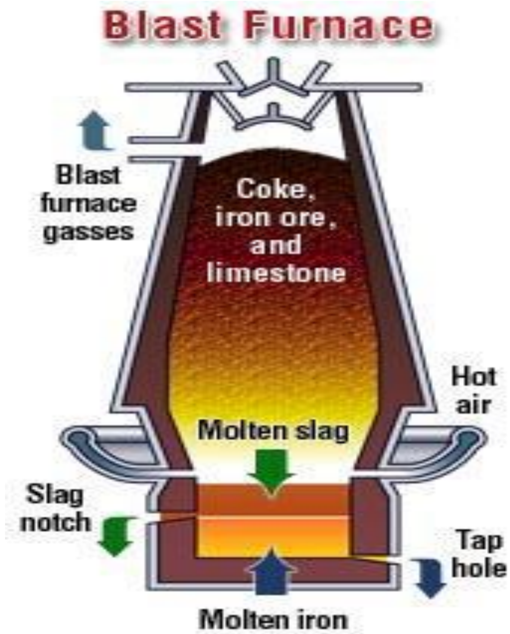


Fig. 1 Sources of GBFS (Suresh and Nagaraju,2015)

Ground Granulated Blast furnace Slag (GGBS) is a by-product from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimises the cementitious properties and produces granules similar to coarse sand. This granulated slag is then dried and ground to a fine powder.

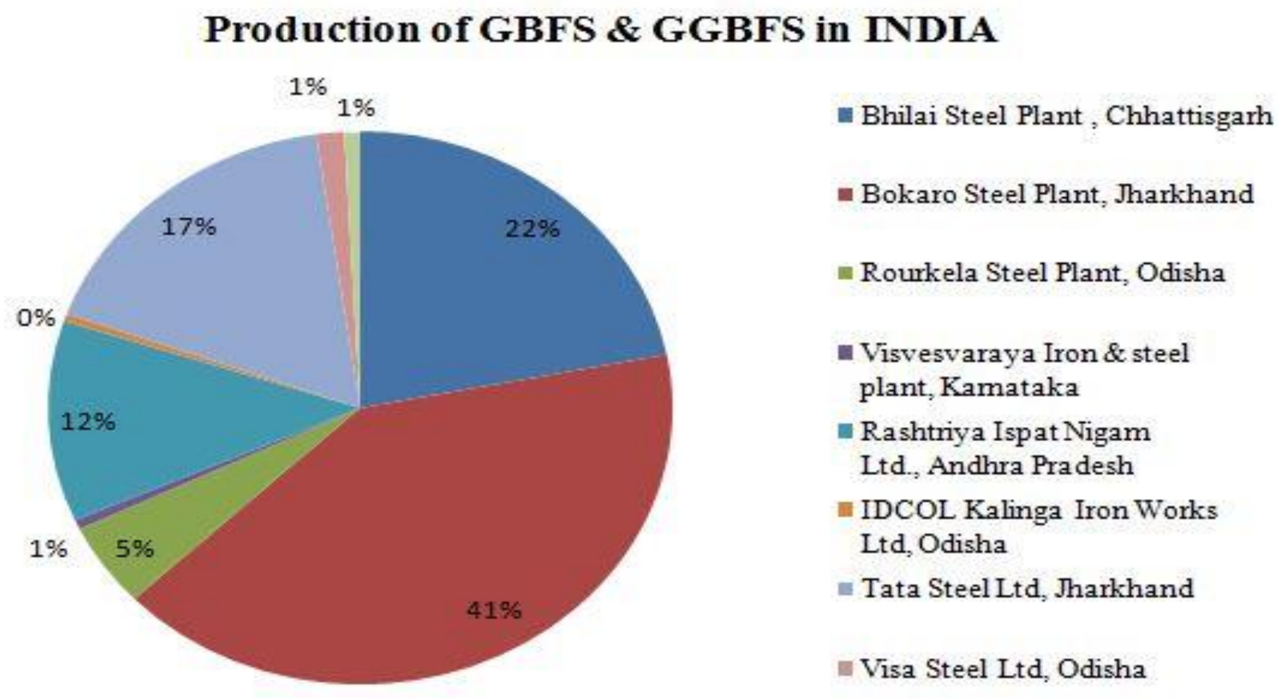


Fig. 2 Pie Chart of GGBS and GGBFS production

Utilizing RA (Recycled aggregate) in construction industries is a step forward to build sustainable environment because it reduces the use of natural aggregate which is decreasing day by day as it is a non-renewable resource. Construction and demolition is an on-going process which develops concrete waste and it should dispose properly otherwise it will contaminant the soil, water as well as the environment. In addition to this problem there is another big issue about land space. To dispose these wastes, a large land area required which is a big issue now a day. Hence, to overcome these issue researchers planned to reuse this concrete waste.

❖ RCA (Recycled Coarse Aggregate)

The recycled aggregate which are used are of processed recycled aggregate. The steps adopted for processing recycled aggregate is as follow:

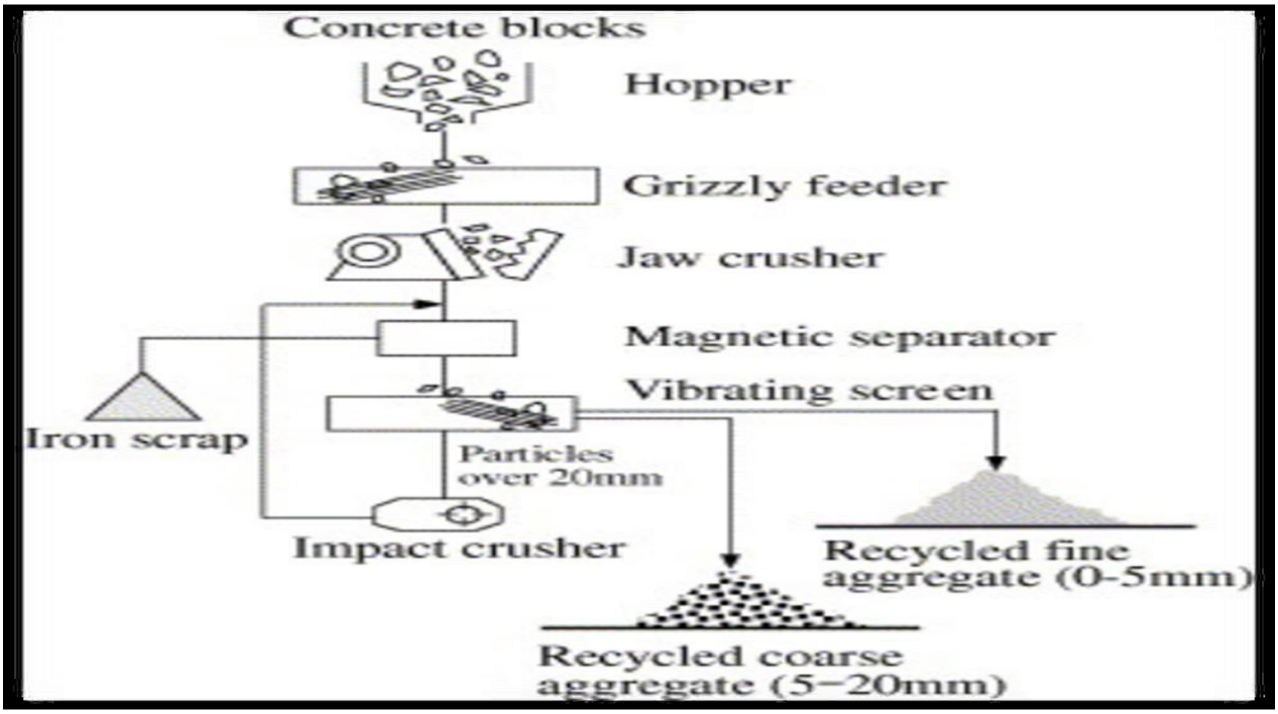


Fig. 4 Method of processing recycled aggregate (Etxeberria et al.)

7. LITERATURE REVIEW

By using industrial as secondary raw materials, the concrete industry can play an important role in sustainable development. Ground blast-furnace slag, lime is used as an additive as a binder. Ground granulated blast-furnace slag acts as replacement of sand and recycled coarse aggregate act as replacement of natural coarse aggregate.

- Sowmya.et.al. (2000) [1], some tests were conducted using the recycled aggregates to studyand compare the results with the naturally available aggregates. The tests were conductedon the aggregates which weren't subjected to any prior treatment. The impact value forrecycled aggregate was obtained as 35% and that for natural aggregate as 29.9%. Theabrasion value for recycled aggregate was obtained as 47.4% and that for natural aggregates 29.6%. Water absorption of recycled aggregate (4.2%) was found to be higher when compared to the natural aggregate (0.4%). It was found that the compressive strength of concrete made from the recycled aggregate is about 76% of the strength of concrete made from natural aggregate for normal strength concrete (M20). Flexural strength of recycled aggregate concrete is almost 85% and 80% of natural aggregate concrete.

- Amnon.et.al (2002), [2] concrete having a 28-day compressive strength of 28 MPa wascrushed at ages 1, 3 and 28 days to serve as a source of aggregate for new concrete,simulating the situation prevailing in precast concrete plants. The properties of therecycled aggregate and of the new concrete made from it, with nearly 100% ofaggregate replacement, were tested. The properties of the concrete made with recycledaggregates were inferior to those of concrete made with virgin aggregates. Effects ofcrushing age was moderate: concrete made with aggregates crushed at age 3daysexhibited better properties than those made with aggregates of the other crushing ages.

- Limbachiya.et.al. (2004),[3] the report aimed at examining the performance of Portland Cement Concrete produced with natural and coarse aggregates. The study showed that because of the attached cement paste in RCA, the density of these materials is about 3-10% lower and water absorption is about 3-5 times higher than the correspondingnatural aggregates. The results also indicate that for RCA samples obtained from four different sources, there was no significant variation in strength of concrete at a givenRCA content

- Shailendrakumar.et.al. (2004), [4] in this paper, the author found the relationship betweensplit tensile strength and compressive strength for RCA concrete as well as controlledconcrete. The recycled concrete aggregate used was that passing through IS sieve 40mm and retained on IS sieve 4.75mm. For controlled concrete the natural stone chips of the same nominal size were used in making concrete. If required a dose of super-plasticizer [Conplast SP 430 (M)] was also added to ordinary tap water to obtain desired degree of workability.In this study, 3 mixes were prepared i.e. replacement of natural aggregates by 0%, 50%and 100% RCA. The strength was tested at 28 days maturity of casted concrete. It wasobserved that recycled concrete aggregate has lower value of specific gravity andmoderately high values of water absorption, crushing value, impact value and abrasionvalue. Furthermore, similar to concrete containing natural aggregate, tensile strength ofrecycled aggregate concrete containing recycled concrete aggregate mainly depends on compressive strength.

- Chaurpagar.et.al. (2004),[5] the author investigated physical andmechanical properties of RCA with and without steel fibers and polymer againstcontrolled concrete. Specimens (cubes/beams/cylinders) were prepared by varying theparameters like water cement ratio and volume of polymer (2.5%, 5.0%, and 10% by parts weight of cement) and constant 0.5% steel fiber by volume of concrete. RecycledAggregate and Natural Aggregate shows that the former has high specific gravity, highabsorption capacity and low fineness modulus. Resistance to mechanical actions suchas crushing strength, impact value and abrasion value of recycled aggregates aresignificantly higher than that of conventional aggregates. There is a marginal increasein the compressive strength due to the addition of polymer-steel fiber in recycledconcrete. There is significant increase in split tensile strength and flexure strength at 90days in polymer steel fiber recycled aggregate concrete as compared to conventional as well as recycled aggregate concrete. Area under stress strain curve is higher, shows the high toughness properties of concrete indicate that polymer concrete is more suitable for the earthquake resisting structures. It is observed that there is an improvement in the ductility with addition of 10% polymer & 0.5% steel fiber in the concrete as compared to recycled aggregate concrete as well as conventional concrete.

- Choudary.et.al. (2006), [6] the author investigated workability and strength properties ofRCA. The recycled aggregate concrete is made by mixing 60% of recycled aggregateswith 40% of crushed stone chips. The aggregates used for concrete batching aremaintained at saturated surface dry conditions. The workability of the recycledaggregate concrete is slightly lower than that of conventional concrete. Thecompressive strength of the recycled aggregate concrete is slightly lower than that ofthe conventional concrete and recycled concrete aggregate or recycled withconventional concrete can be used in normal plain and reinforced concreteconstruction. The recycled and conventional concrete containing 60% of recycledaggregate and 40% of crushed natural stone chips occupies almost an intermediateposition is terms of workability and strength consideration between the others types ofconcrete. So from an economic and performance point of view, this type of concrete issuitable only next to conventional concrete.

- Casuccio.et.al(2007)- [7] studied the failure mechanism in tension and compression of RAC. 3 series of concrete with compressive strength levels 18,37 and 48 MPa and each series having three concretes with varying in the type of coarse aggregate were analyzed. Flexural tests on notched beams of 105mm height and 75mm width and uniaxial compression tests on standard cylinders were conducted. The test results indicated increase in bond strength and reduction in stiffness when NA was replaced by RCA which increases the elastic compatibility between concrete phases and modifies fracture process. Concrete having RCA as normal concrete has lower energy of fracture and size of fracture.

- Abbas.et.al (2009)- [8] compared the durability of structural grade concrete made with RCA proportioned with equivalent mortar volume (EMV) and traditional method. In conventional mix design RCA is considered as a coarse aggregate and no consideration is given to the attached residual mortar but EMV gives due consideration to the attached residual mortar. The compressive strength of the specimen made by mix designed with EMV was higher than those made of mixes designed with conventional method but the difference was very less (2-5 MPa). The durability factor for EMV specimen was found to be 2-7% higher than conventional specimen, so specimen designed by EMV method exhibited better freeze and thaw resistance. The carbonation coefficient for EMV specimen was found to be 17% higher than conventional specimens. Thus EMV design method proved to be an efficient method of designing and produced concrete with higher strength and resistance and can be effectively used in structures in severe environment.

- Siddique et. al. (2010), [9] found that concrete containing GGBFS could possibly be used in applications involving elevated temperatures. There was no very significant deterioration of the mechanical properties of the concrete between 27 and 100 C. Reduction in the valuesof compressive strength, splitting tensile strength and modulus of elasticity remained lower than 40% of the initial value even after a temperature of 350 C was applied. At temperatures between 200 and 350 C, the mass loss is not very significant. The modification of the hydrates generates a degradation of the concrete microstructure. From the results it can be easily concluded that up to 20% GGBFS could be suitably used in concrete designed for nuclear structure.

- S.C. Kou.et.al. (2012) [10]studied the effects of incorporating Class F fly ash in the concrete mix design to mitigate the lower quality of recycled aggregates in concrete. The effects of incorporating Class F fly ash in the concrete mix design to mitigate the lower quality of recycled aggregates in concrete. The carbonation depth was increased with an increase in the replacement ratio of coarse natural aggregate by recycled aggregate. It can be concluded the relatively poorer durability properties of recycled aggregates concrete can be adequately compensated by the use of fly ash, either as a replacement or addition of cement, in the concrete mix design.

- Grist et al. (2015), [11] the purpose of this investigation was to ascertain the technical feasibility of producing a structural strength concrete using hydraulic lime as an alternative cementitious binder to CEMI.The maximum $f_{cm,28}$ of the four lime-pozzolan concretes was 35.7 MPa by curing the resulting concrete in water. The $f_{cm,28}$ of the equivalent air-cured concrete was 21.5 MPa, 40% lower. Further work is needed to investigate the long term strength of lime-pozzolan concretes. Lime-pozzolan concretes have been seen to be less stiff than CEMI concretes of equivalent strength, The carbonation resistance of lime-pozzolan concretes has been observed to be low in comparison to CEMI concretes, across all w/b ratios. Increase in w/b ratio increases the rate of carbonation. The least drying shrinkage was seen observed in lime-pozzolan concrete (II), incorporating 25% SF and 25% GGBS, which was within the range of shrinkage measurements for the CEMI reference concrete [0.35-0.65] at all w/b ratios. It was seen that the production of lime-pozzolan concretes at low w/b ratios results in the strongest and most durable concrete. It has been possible to provide the results of comparative testing on equivalent CEMI-concretes, it has been seen that the lime-pozzolan concretes tested, exhibited only moderate strengths and tolerable durability in comparison with the reference CEMI-concretes.
- Kubissa.et.al(2015) [12] – carried out experimental investigations to improve the gradation of the natural aggregates which are undesirable due to the presence of high share of 2-4mm fraction (about 70%) by adding recycled coarse aggregates. They conducted experiment on two series of concrete obtained by using two different cements and different proportions of RCA. 7 concrete blocks of series I having w/c ratio 0.45 and 4 concrete blocks of series II having w/c ratio 0.5 were made. In series I a part of the NA was replaced with RCA by 0,5,10,20,30,50 and 100% whereas in series II the replacement percentage was 50,75 and 100%. The compressive strength for series I concrete was found to be increased by 19.4% also for series II concrete the increase in compressive strength was found to be 17.3. The water absorption was also found to be increased by 12.3% for series I concrete and 8.3% for series II concrete. Thus good quality of RCA must be used to ensure water resistance of the concrete.
- Gaurav Singh et al (2015) [13] , in this study, the compressive strength of concrete increases with increase in GBFS percentage up to a certain percentage and after that it decreases. The most optimum percentage of GBFS to be used in normal conditions considering both strength and economy factor is from 40% to 50% and for marine conditions it’s from 50% to 60%.The long term strength development of GBFS concrete is almost double of normal concrete in both normal and marine conditions .Based on these findings it can be stated the GBFS can be used as a replacement to natural sand provided that it is used judicially. It is one of the promising solutions towards sustainable infrastructure without compromising strength and economy

- Acharya and Patro (2016) [14] , carried out experimental study to assess the potential of ferrochrome ash(FA)and lime as a partial substitute of cement in concrete production. It was found that workability got reduced with increase in inclusion of FA. Highest compressive strength development was observed in the mix having 7% lime and 10%FA whereas the lowest development was found in the mix having 7% lime and 40% FA. Thus the maximum replacement of OPC by FA was found to be 40%. Petrography study revealed that inclusion of FA and lime enhanced the bond strength due to homogeneity of the mix and reduced the micro gaps as degree of hydration is more in such mixes. The flexure strength was also found to be increased and the maximum replacement of OPC was found to be 47%. Inclusion of FA and lime lead to decrease in sorptivity of the mix. Concrete mixes with FA and lime suffered less loss due to sulphuric acid and magnesium sulphate attack. The error in compressive strength obtained from nondestructive test was in permissible limit when compared to destructive test thus the result of both the tests can be compared. The above results conforms the use of FA with lime as supplementary cementitious material.

- Dimitiou.et.al(2017), [15] highlighted the effect of RCA on concrete and suggested a treatment method to improve the properties of RCA. The field RCA was treated by placing it in a modified concrete mixer which was rotated at a speed of 10 rpm for 5h and water was added in to the mixer during rotation. After rotation the aggregates were sieved to discard the aggregates with size lower than 4mm. 7 of concrete mixtures were made in which there was replacement of NA with different types of RCA while 4 concrete mixtures were made in which there additional replacement of cement with different mineral admixtures like was replaced with RCA. The replacement with RCA resulted in loss of compressive strength when compared to control mixture by 16.8%,34.1%,13.8% for RL100,RF100, RT100.The mixtures having mineral admixtures also exhibited decrease in compressive strength but the 56-day strength was quite similar to the mixture without admixture. The flexure strength was found to be decreased by 19.6%,23.7%,16.7% for RL100, RF100, RT100 whereas water absorption and sorptivity was found to be increased. The mixture with RCA had lower durability due to lower density. Simple treatment of RCA can lead to production of better-quality concrete mixture.

- R.K. Majhi.et.al. (2017) [16] , experimented on the use recycled coarse aggregate (RCA) and ground granulated blast furnace slag (GGBFS) as replacement of natural coarse aggregate (NCA) and ordinary Portland cement (OPC) for developing sustainable concrete. The test results obtained in the present investigation show that the workability increases with the use of RCA or GGBFS or both of these two. The concrete mix with 50% RCA and 40% GGBFS achieves values of these properties closer to those of the concrete mix without RCA and GGBFS. Finally, the concrete mix with 50% RCA and 40% GGBFS is considered as the optimum mix which is satisfying the target mean strength of the mix design and producing sustainable concrete by saving 40% of cement and 50% of NCA and utilizing maximum waste products such as GGBFS and RCA. The effectiveness of GGBFS in RAC increases with the age of concrete in comparison to NAC and is more at 90 days with respect to 7 and 28 days.

- N.S. Amorim et al.(2017), [17] according to the results obtained in this study it can be concluded that the 15% replacement of the coarse natural aggregate by the coarse recycled aggregate was efficient to withstand the expansion stresses of the water, presenting a greater durability factor and not suffering substantial loss of stiffness or physical wear; The use of the recycled aggregate as an alternative way to air incorporation was effective, presenting a durability factor, at the end of the cycle, higher than that presented by the reference mixture. The low water/cement ratio ensured a satisfactory behavior (F_d> 80%) for all concretes tested, according to ASTM C 666; For structures subjected to freeze-thaw cycling, the mechanical strength of the concrete is not of great relevance, since it is possible to obtain a concrete with less mechanical resistance, but more durable. The loss of concrete stiffness caused by the appearance of internal fatigue cracks can lead to a decrease in the interconnection between the capillarity pores and/or to increase their diameter, reducing suction power and absorption. Specific studies are required for the application of the recycled aggregate generated in each region or country, in order to havea better control of the properties of this material, in order to prevent possible damages, when incorporated to the concrete submitted to the freezing-thawing cycle, since the aggregates are quite heterogeneous.

- Mahdi et al (2018), [18] the effect of incorporating recycled concrete aggregate (RCA), rice husk ash (RHA) and steel fibers on the mechanical behavior and durability of concrete were investigated As the percentage of RCA increased, the compressive strength and splitting tensile strength decreased, and properties of concrete related to water transport of water absorption, chloride diffusion and acid attack decreased. The difference between the compressive strength of RHA concrete with control mix increased as concrete aged The RHA improved the resistivity against acid because of the lower calcium hydroxide content of RHA concrete. RHA also reduced the chloride diffusivity of concrete. The durability of RCA concrete increase with incorporating RHA. Meanwhile, concrete was less durable with an increase in the RCA in the mix due to the existence of adhered mortar in RCA concrete. The RHA mitigated the inferior performance of the recycled aggregate concrete. These findings demonstrate that RHA is a good replacement for cement. This is because it improves the microstructure of concrete and improves the bond between concrete and fibers.

- Bao.et.al(2019) [19] - investigated the transport behavior of water and chloride in RAC prepare with grounded blast furnace slag (GBFS). The mix proportion of mixture was designed with two water to binder ratios of 0.33 and 0.39 and sand ratio was set as 40%. The replacement ratio of RCA 0%,30%,50%,100% was selected. 100mm cubes and 100mm x 50mm cylinder were casted for each concrete mixture. The qualities of RCA and water binder ratio significantly affect the water absorption of RCA specimens. The water absorption of RAC samples increased with increase in RCA content. The chloride diffusion constant was found to be increased with increase in RCA content. The penetration depth between water and chloride ion in RAC with different replacement ratios exhibited a linear relationship. It was found that the chloride transport process lags behind the water migration for the absorption tests of RAC due to filter effect of adhered new and old cement paste.

- Babar Ali.et.al. (2020), [20] conducted study on concrete having RCA, fly ash & glass fiber. It found that mechanical and durability performance of RAC is enhanced by combined incorporation of glass fiber (GF) and fly ash (FA). In this study, specimens were exposed to 4% H_2SO_4 solution and mass loss was taken as measure of degradation of each mix at 28, 56, 90, and 120-days of exposure. RCA, having more porosity and high CH content (present in old mortar) than NCA, is more vulnerable to acid attack than NAC. Issue of poor mechanical and durability performance of RCA concrete can be addressed by simultaneous incorporation of GF and FA. Best mix considering sustainability, mechanical and durability performance had 50%RCA, 20%FA with 0.5%GF.
- Ch. Srinivasarao.et.al. (2020) [21] , investigated the effect of mechanical properties such as compressive, Flexural and split tensile strength and durability aspects such as water permeability, rapid chloride permeability, when Granulated blast furnace slag is used (GBFS) as a fine aggregate, with partial and fully replacement of River Sand (RS) and Manufactured (MS) sand in M40 standard grade of concrete with a constant W/C of 0.40. It has been observed that concrete made with 50% of river sand and 50% (GBFS) is nearer to Zero percent replacement in OPC, PPC, and PSC Concrete. It is observed that the average coefficient of permeability is less at 50% replacement of MS by GBFS in OPC, PPC and PSC concrete and the permeability of PSC concrete is comparatively less than OPC and PPC. On the other hand, it is also observed that the average coefficient of permeability is low at 50% replacement of RS by GBFS in OPC, PPC and PSC concrete of M 40 grade.

- Rajib K. Majhi.et.al. (2020), [22] studied the effect of inclusion of hydrated lime on the strength, durability, physical and non-destructive characteristics of recycled aggregate concrete (RAC) containing high-volume ground granulated blast furnace slag (HV-GGBFS). It concluded that the concrete mix 50% RCA + 60% GGBFS + 7% lime can be considered as the optimum mix for M25 grade concrete because it fulfills the requirements of M25 grade concrete by utilizing high-volume of wastes. The RAC mixes with HV-GGBFS and appropriate dose of lime show superior resistance against sulphate and acid attack as compared to NAC. This improvement is the consequence of formation of secondary hydration products such as CSH and ettringite and filling effect of GGBFS and lime particles, which is supported by the improvisation in the strength and micro-structural characteristics of RAC with HV-GGBFS and lime.

- Faisal et al. (2020) [23] Hydration of concrete slowdowns when GGBFS is added toit, thus leads to lower hydration of heat.Incorporating GGBFS in concrete considerably increases setting time (both initial and final).GGBFS tends to improve the microstructure of concrete as its percentage increases, uponstudy of micro-structure it revealed that with longer curing period concrete incorporating GGBFS reduces void ratio considerably thus making concrete more denser in its micro- structureform.Early strength whether compressive or flexural both are reduced due to slow hydration but with increased curing period strength both compressive and flexural are increased considerablyduetofurtherformationofC-S-HgelbyGGBFS with increasing GGBFS content, the impact on early strength increases but ultimate strength is increased by considerableamount.GGBFS utilizes the calcium hydroxide and other compounds that tend to increase the possibility of attacks of different chemicals like chlorides, sulphates, etc. and also makes the structure of concrete less porous, thereby lowering permeability and water absorption of concrete. Inclusion of GGBFS in concrete makes concrete more resistant to chemical attacks thus is responsible for increasing the durability of concrete.
- Rekha et al. (2020), [24] an experimental investigation was conducted to study. The incorporation of fly ash and copper slag in the concrete to economical concrete. But the replacement of cement with fly ash effectively filled the pores in the concrete.So it turns down the penetration of CO2 through the voids presentin the concrete. The concrete made with copper slag generally gives a higher rate of corrosion than the control concrete. Butit varies from low to moderate. So it is insisted that the bars embedded in the concrete should be coated with anti-corrosivecoating in the coastal areas. In every trial, if it mixed with fly ash, the corrosion of steel reinforcement gets down because of the reduction in permeability of concrete. The resistance against abrasion is checked for all twenty-four mixes incorporated with copper slag and fly ash.

8. CRITICAL REVIEW

- In the presence of H_2SO_4, research revealed that the microstructure of concrete is exposed to some inner pressure which may lead to expansion of pores and cracks.

- Gypsum is believed to be one of the main causes of expansion during sulfuric acid attacks. It is well known that a low w/c brings low porosity which normally leads to more durability.

- However, researches revealed that H_2SO_4 solution showed greater degradation for low w/c ratio than for high w/c ratio samples.

- According to the limited number of previous studies, the concrete specimens in sulfuric acids with low concentrations will undergo some initial expansion and also gain weight due to ettringite formation and acid absorption, respectively.

- Also, it has been observed that the low pH of the sulfuric acid solutions completely governs the attack process and does not allow other reactions to take place.

- It was found that the compressive strength of concrete made from the recycled aggregate is about 76% of the strength of concrete made from natural aggregate for normal strength concrete (M20).

- Highest compressive strength development was observed in the mix having 7% lime and 10%FA. Concrete mixes with FA and lime suffered less loss due to sulphuric acid and magnesium sulphate attack.

- 20% GGBFS could be suitably used in concrete designed for nuclear structure without significant deterioration of the mechanical properties of the concrete between 27 and 100 C.

- Compressive strength of concrete increases with increase in GBFS percentage up to a certain percentage and after that it decreases. The most optimum percentage of GBFS to be used in normal conditions considering both strength and economy factor is from 40% to 50% and for marine conditions it's from 50% to 60%.

- The concrete mix with 50% RCA and 40% GGBFS is considered as the optimum mix which satisfies the target mean strength of the mix design and produces sustainable concrete by saving 40% of cement and 50% of NCA.

- Concrete mix 50% RCA + 60% GGBFS + 7% lime can be considered as the optimum mix for M25 grade concrete and shows superior resistance against sulphate and acid attack as compared to NAC.

- GGBFS utilizes the calcium hydroxide and other compounds that tend to increase the possibility of attacks of different chemicals & makes the concrete less porous, thereby lowering permeability and water absorption. Inclusion of GGBFS in concrete makes it more resistant to chemical attacks thus is responsible for increasing the durability of concrete.

9. EXPERIMENTAL PROCEDURE

9.1 MATERIALS PROPERTIES:

❖ **BINDERS-**

For the preparation of concrete mix, Ordinary Portland cement (OPC-43 grade) meeting the requirements of IS: 8112 was considered as the main binder. Similarly, GGBFS and hydrated lime obtained from local market of Sambalpur, India was used for partial replacements of OPC in the present work. The physical and mechanical properties of OPC, GGBFS and lime were determined as per the provisions of Bureau of Indian Standards.

Table-2 The physical properties of cement are given below

Properties	OPC 43 Grade
Sp. gravity	3.13
Consistency (%)	32
Fineness (%)	3.5
Initial setting time (min)	56
Final setting time (min)	282
Soundness (mm)	2

Table-3. Properties of GGBFS

Properties	**Values**
Sp. gravity	2.82
Fineness (%)	3.5

❖ **AGGREGATES-**

Siliceous sand sourced from the nearby river bed was considered as natural fine aggregate (NFA) for concrete preparation. Similarly, granite aggregates of 20 mm nominal size were regarded as NCA. Further, RCA was sourced by crushing the 9 years old demolished railway sleepers into 20 mm nominal size. Moreover, the NFA is conformed to Zone-II. The resistance to mechanical actions such as abrasion, impact and crushing of RCA is also less with respect to NCA. However, the properties of RCA and NCA have satisfied the specified requirements of IS: 383.

Table-4. Physical Properties of NFA and GBFS:

Properties	**NFA**	**GBFS**
Loose bulk density (Kg/m^3)	1417	1182
Compact bulk density (Kg/m^3)	1612	1339
Specific gravity	2.6	2.49
Water absorption (%)	0.8	1.83
Free surface moisture	Nil	Nil
Grading zone	2	2
Fineness modulus	2.88	2.68

Particle Size Distribution of GBFS and Sand

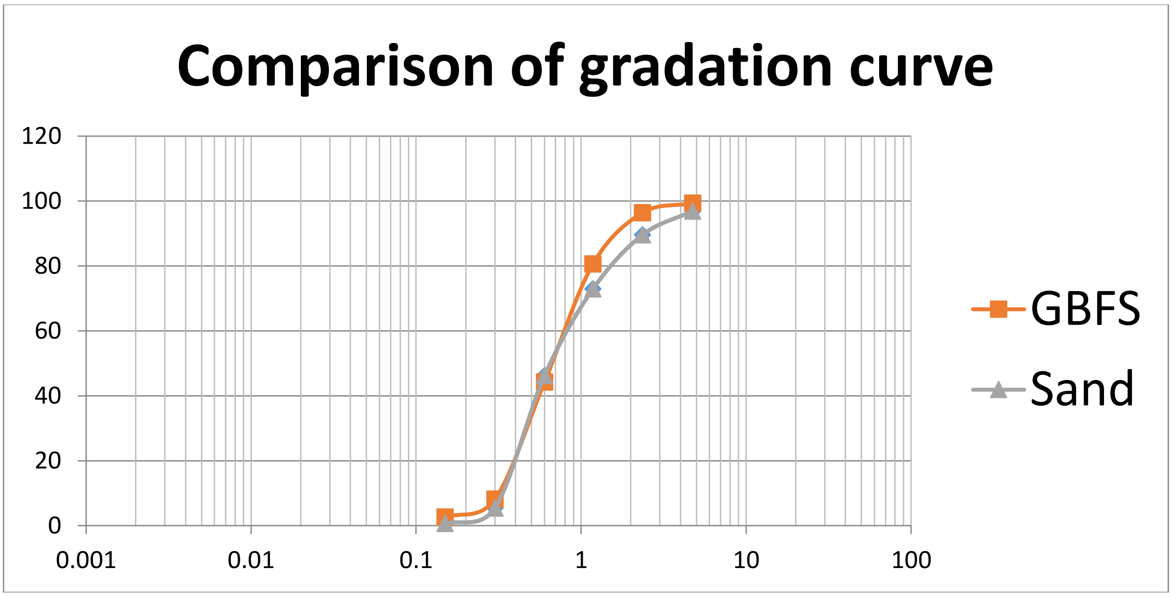


Fig . 3 Gradation Curve Analysis

❖ NCA (Natural Coarse Aggregate)

Table- 5. Physical Properties of NCA

Properties	10 mm	20 mm
Loose bulk density (Kg/m^3)	1512	1529
Compact bulk density (Kg/m^3)	1678.2	1653.6
Specific gravity	2.78	2.82
Water absorption (%)	0.3	0.15
Fineness modulus	4.92	6.78

Table- 6 Physical Properties of RCA

Properties	Value
Loose bulk density (Kg/m^3)	1311
Compact bulk density (Kg/m^3)	1450
Specific gravity	2.53
Water absorption (%)	4
Fineness modulus	7.14

❖ WATER-

Normal municipal supply water fulfilling the specifications of IS: 10500 was used for the preparation of concrete mix.

9.2MIX DESIGN:

In this study, a nominal mix proportion of 1:1.62:2.85, comprising 1 part cement, 1.62 parts fine aggregate, 2.85 parts coarse aggregate was used. Then nine concrete mixes were prepared to explore the effect of GGBFS, lime, GBFS & RCA on the acid resistance of concrete. The mix design procedure given by IS: 10262 is based on minimum void and maximum density of concrete. Here, contents of binders (OPC, GGBFS & lime) were kept constant for the 9 concrete mixes. The proportion of aggregates (NCA, RCA, NFA, GFBS) were varied as shown in the table. The calculation is made on the basis of absolute volume of the ingredient materials. The sum of volumes of all the ingredients for every mix is made to 1 m3 design considers the saturated surface dry (SSD) condition of all the ingredients. Accordingly, extra water has been added based on water absorption capacity of the ingredients in order to maintain the workability in a particular range, i.e. 75 ± 5 mm. This has also been verified by conducting various trial tests.

Table-7 Mix Design

Mix	**Replacement Of NFA & NCA**	**OPC**	**GGBFS**	**Lime**	**NFA**	**GBFS**	**NCA**	**RCA**	**Water**
C:0-0	0% , 0%	390	0	0	705	0	1256	0	185
GRL:0-0	0% , 0%	133	211	23	705	0	1256	0	209
GRL:0-50	0% , 50%	133	211	23	705	0	628	529	209
GRL:0-75	0% , 75%	133	211	23	705	0	314	793	218
GRL:50-0	50% , 0%	133	211	23	353	334	1256	0	195

GRL:50-50	50% , 50%	133	211	23	353	334	628	529	213
GRL:50-75	50% , 75%	133	211	23	353	334	314	793	222
GRL:75-0	75% , 0%	133	211	23	176	506	1256	0	198
GRL:75-50	75% , 50%	133	211	23	176	506	628	529	215
GRL:75-75	75% , 75%	133	211	23	176	506	314	793	224

It is to mention that as per IS 456 the concrete to be used in RCC works should possesses medium degree of workability i.e. slump value of 50–100 mm. Moreover, the W/B should be less than 0.5 for M25 grade concrete under moderate exposure condition from durability point of view. Considering the above criteria provided by IS 456 the slump value in the range 75 ± 5 mm and the W/B ratio 0.48 were chosen. Hence, in order to fix the workability of all the mixes within 75 ± 5 mm slump and to satisfy the saturated condition of the aggregates, the extra water based on absorption of the aggregates was adjusted during mixing of ingredients. Table 7 presents the quantities of materials in kg required for 1 m3 concrete in each mix.

9.3 CASTING & CURING:

In the first stage of mixing, the quantity of aggregates and binders mentioned in the mix design (Table 7) for a particular type of concrete were mixed thoroughly for 2 min in a mini laboratory concrete mixer. Then water was poured into the dry mixture and the mixing process was continued for another 4–5 min to have a homogenous concrete mix. However, when lime was added to the concrete blend, the mixing time was extended for another 2 min. After getting a homogenous fresh concrete, its slump was measured using a standard slump cone. Further, the moulds of 150mm size were lubricated and the fresh concrete was placed and compacted within the mould as per BIS guidelines. Cubes of size 150 mm were cast for determination of acid resistance. After duration of 24 ± 1 h, the hardened concrete specimens de-moulded and cured in water at 25 ± 2 C.

9.4 TEST PROCEDURE:

The evaluation of resistance to acid attack was carried on 150 mm size cubical specimens after 28 days & 56 days. The water-cured cube specimens of 150 mm size were immersed in sulphuric acid solution (pH maintained below 7) having 1% concentration.The cubes were weighed using an electronic balance prior to immersion in sulphuric acid solution for assessment of weight loss. The cubes were tested after 28 and 56 days of exposure to sulphuric acid solution. The effect of acid attack on strength loss was assessed by testing the compressive strength of concrete cubes at respective test ages and comparing them with water cured concrete specimen of same age. The percentage of strength loss was then calculated. Similarly percentage of weight loss was also assessed comparing the weight of specimen prior to exposure and after exposure at different test ages. This percentage loss in the mass and strength were used to indicate the resistance of the specimens against acid attack.

10. REMARKS AND CONCLUSION

From this research work it can be concluded that because of growing levels of CO_2 in environment and need to channelize the demolition wastes in efficient manner, sustainable concrete is a welcome alternative. The addition of GGBFS & lime as partial replacement for OPC; GBFS for NFA & RCA for NCA helps to reduce GHG emissions (mostly from manufacturing of cement) and makes the use of by-products from industries and demolition sites. Previous studies on effect of each substitute, either individually or in combination with other materials, on concrete have yielded positive impact on their durability and hence on their resistance to acid attack. Further investigation shall show the combined effect of GGBFS, lime, GBFS & RCA, in varied quantities, on the concrete structure regarding their ability to sustain acid attack due to exposure to H_2SO_4 solution.

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