

AN EXPERIMENTAL INVESTIGATION OF THE IMPACT OF DIFFERENT INDUSTRIAL BY-PRODUCT ON THE STRENGTH CHARACTERISTICS OF CONCRETE

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ABSTRACT

The study on the effect of using three different industrial by-product silica fume, bottom ash, and steel slag aggregate partial replacements for Cement, natural sand and Coarse aggregates in concrete. Through a series of experimental investigations, the researchers assess the optimal percentage of replacement for these materials by conducting compressive strength tests on cube and cylindrical specimens. Additionally, reinforced concrete beams are cast using the blended fine aggregate to analyze their behavior under flexural loading. The study includes determining ultimate strength, load-deflection characteristics, crack patterns, ductility, and flexural rigidity of the concrete beams. The outcomes are compared with control concrete beams to draw conclusions on the feasibility of substituting natural river sand with using three different industrial by-product silica fume, bottom ash, and steel slag aggregate in concrete production. An experimental investigation has been carried out to explore the possibility of using three different industrial by-product silica fume, bottom ash, and steel slag aggregate as a partial replacement of Cement, natural sand and Coarse aggregates in concrete. The goal of the current study is to determine the impact of replacing steel slag, bottom ash, and silica fume with coarse aggregate, fine aggregate, and, cement respectively, on the performance of HPC. Here, M30-grade High Performance Concrete using three different industrial by-product silica fume, bottom ash, and steel slag aggregate was attempted.

Keywords: Concrete, industrial by-products, Silica Fume (SF), Bottom Ash (BA) , and Steel Slag (Ss), durability studies, Compressive and Split tensile strength.

1. INTRODUCTION

“A review on partial replacement of using three different industrial by-product silica fume, bottom ash, and steel slag aggregate as a partial replacement of Cement, natural sand and Coarse aggregates in concrete most widely used man-made construction material in the world. Its most important quality is its versatility and the ability to design the concrete of any required properties according to the environment. Human development in today’s scenario is impossible without the excessive use of concrete. Cement is the most important component of concrete. Unfortunately, the production of cement results in emission of many greenhouse gases such as CO₂ in atmosphere, which are responsible for global warming. Hence, the researchers are currently focused on use of waste material having cementing properties, which can be added in cement as partial replacement of cement in concrete, without compromising on its strength and durability, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Meta kaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement in concrete due to its inherent cementing properties. The main objective of this experimental study is to reduce the percentage of the cement in the concrete. using three different industrial by-product silica fume, bottom ash, and steel slag aggregate as a partial replacement of Cement, natural sand and Coarse aggregates in concrete . The optimum proportion of replacement was found by conducting tests on mechanical properties like Compressive strength test and Split tensile strength test. In this experiment the strength and durability of M30 concrete is determined by curing the specimens at 7days, 28 days age.

Role of Admixtures and By-products

For decades, efforts have been made to develop concrete that possesses specific desired qualities, such as high compressive strength, high workability, and high performance and durability parameters, in order to meet the demands of building complex structures. In order to control setting and early hardening, increase workability, or provide additional properties, a substance other than water, aggregates, or cement is used as an ingredient in concrete. To counteract the detrimental effects of calcium hydroxide produced during the hydration of cement in concrete, mineral

admixtures such as fly ash, silica fume, metakaolin, and GGBS are used. When added to concrete, mineral admixtures can cause the pozzolanic reaction, which can make concrete dense and impervious. Calcium hydroxide consumption increases concrete's durability. As a result, using the right amount of mineral admixtures increases the quality of concrete by

- Lowering the heat of hydration and thermal shrinkage
- Increasing the water hardness
- Reducing the alkali-aggregate reaction
- Improving the chemical resistance
- Improving the corrosion resistance
- Improving the early strength, workability and extensibility
- Improving the rate of strength development

Pozzolana is a substance that exhibits cementitious properties when mixed with calcium hydroxide (lime). Pozzolans are occasionally added to Portland cement concrete mixtures in order to improve the material's long-term strength and other characteristics and, in some cases, lower the cost of the raw materials. The granular material that results from the rapid cooling (quenching) of molten iron blast furnace slag by immersion in water is known as ground granulated blast-furnace slag. It is a granular product with a high cementitious nature that hydrates like Portland cement when ground to cement fineness. the finely divided byproduct of coal that has been ground or powdered. Fly ash, which has pozzolanic properties and is typically mixed with cement, is collected from the chimneys of coal-fired power plants. In many of the voids surrounding the hydrated cement particles, a pozzolanic reaction between silica fume and the calcium hydroxide (CH) results in the production of additional calcium silicate hydroxide (CSH). In addition to improved compressive, flexural, and bond strength, this additional CSH gives the concrete a much denser matrix, mostly in places that would have remained as tiny voids vulnerable to the intrusion of potentially harmful materials.

2. REVIEW OF LITERATURE

Avinash Kumar Padhy et al. (May 2022)

Compressive strength is an integral property of concrete that play a key role in the construction industry. The present works investigates the effect of triple blend of fly ash, silica fume and steel fibers on the compressive, split tensile and flexural strength of concrete. fly ash (fa) and silica fume (sf) are introduced as a partial replacement for cement for various additions of steel fibers by volume of concrete. a replacement level of 0% fa with 0 %, 5%, 10%, 15% sf in place of cement for 0% addition of steel fibers by volume of concrete is used for the preparation of first set of samples. second set of samples were prepared with the change in fly ash proportion to 20%, keeping replacement levels of sf unchanged for 0% inclusion of steel fibers and the last set of samples were prepared with 40% fa replacement percentage without any change in the replacements of sf for the same 0% steel fibers. Likewise, the same combinations of fa and sf were repeated for 0.5% and 1% steel fibers and tested for various strength results after 28 days curing. Later, it is seen that an optimum mix of 20% fa with 10% sf for 1% inclusion of steel fibers, produced the maximum compressive strength of 81.20 n/mm² and maximum flexural strength of 8.40 n/mm².

Hardeep Singh (2022)

“Effect of Silica Fume on Steel Slag Concrete “ In India, the production of steel slag is about 12 million tons in the steel industries and we can use in our concrete as a waste material. Concrete is the most commonly and widely used building material used in all around the world. Concrete is the mixture of cement, sand, aggregates (fine and coarse), and water. The utilization of concrete is continuously increasing due to which there is a great effect on natural resources. There are many numbers of byproducts (like, steel slag, silica fume, fly ash, etc.) that are produced during the production or the manufacturing of material like steel, silicon metal, etc. In the present study effect of silica fume on steel slag concrete has been carried out on M25 grade of concrete by varying percentage of steel slag i.e. 45%, 50% and 55% and constant value of silica fume i.e. 10%. From the study it has been observed that the compressive strength decreases while increases the percentages of steel slag. Therefore, up to 45% replacement of steel slag with the fine aggregates and 10% replacement of silica fume with cement give best result and after that the strength will decreases.

Henok Abera et al. (August-2021)

For the construction of various structures, the most commonly used material is cement concrete. however, it has a number of disadvantages, including low tensile strength, brittleness, and crack propagation in an unstable state and low fracture resistance, shrinkage, and increased heat of hydration evolution as well as an increase in cost. under stress, the rapid propagation of micro fractures results in poor tensile strength and brittle collapse of the material. due to these flaws, a novel concrete composite material with steel fibres and partial fly ash replacement has been developed with enhanced structural qualities. steel fibers added to ordinary cement concrete improve structural qualities such as fracture

resistance, impact resistance, thermal shock resistance, wear, fatigue resistance, spalling resistance, and compressive, flexural, tensile, shear, bond strength, ductility, and toughness.

Beata Figiela, et al (August, 2021)

The main aim of the article is to analyze the state of the art in short steel fiber-reinforced geopolymers, taking into consideration also waste fibers. steel fibers are currently the most widely applied additive to composites in the building industry. The work is dedicated to the usage of short steel fibers and the mechanical properties of geopolymer composites. research methods applied in the article are a critical analysis of the literature sources, including a comparison of the new material with other, traditional concrete materials used in similar applications, especially in the construction industry. the results of the research are discussed in a comparative context. They indicate that the addition of fibers is an efficient method not only for improving compressive and flexural strength, but also mechanical properties such as fracture toughness. the potential applications in the construction industry as well barriers and challenges for the effective application of geopolymer materials reinforced with steel fibers are presented. further research directions are discussed.

Babar Ali et al. (November 2021)

Which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Demands for high-strength concrete (HSC) have been increasing rapidly in the construction industry due to the requirements of thin and durable structural elements. hsc is highly brittle. Therefore, to augment its ductility behavior, expensive fibers are used. These negative drawbacks of hsc can be controlled by incorporating waste materials into its manufacturing instead of conventional ones. Therefore , this study assessed the performance of HSC produced with different quantities of waste tire steel fiber (WSF) and fly ash (FA). WSF was used at two doses, namely, 0.5% and 1%, by volume in HSC, with low-to-medium volumes of FA, that is, 10%–35%. However, test results of CPD showed that WSF produced insignificant changes in chloride permeability of HSC. Furthermore, when made with fa, wsf-reinforced HSC yielded very low chloride permeability. Both WSF and FA contributed to the improvement in the AAR of HSC. WSF was highly useful to tensile properties while it showed minor effects on compressive properties (FCM and ECM). Optimum ductility and durability can be achieved with HSC incorporating 1% WSF and 10%–15% FA.

G.H.L.S.Sai Kumar et al. (2021)

Self compacting concrete which is highly flow able achieves compaction by itself without using mechanical vibration techniques. the research focused on self compacting concrete (scc) modified by a mineral admixture with the inclusion of steel fibers. the flow properties and strength properties were studied to arrive the ideal fiber content which attains the self- compacting effect. mineral admixture used is fly ash and steel fibers are rippled having aspect ratios of 27.7 and 44.44 with 0.45mm as diameter and varying lengths of 12.5mm and 20mm respectively. the dosage of steel fibers in scc varies as 0%, 1%, 2% and 3% by weight of cement and the mixes are designated as scc0, scc1, scc2 and scc3 respectively. Results indicated that the flow properties are adversely affected due to the incorporation of fibers and the l-box blocking ratio acceptance limits were failed beyond 1% fiber content. modified scc mixes achieved better strength properties than control scc and mixes with 2% fiber dosage attained higher strength values.

Hemn Qader Ahmed et al. (January 2020)

This is an open access article distributed under the creative commons attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. a construction system with high sustainability, highdurability, and appropriate strength can be supplied by geopolymer concrete (gpc) reinforced with glass fibre-reinforced polymer (GFRP) bars and carbon fibre-reinforced polymer (CFRP) bars. few studies deal with a combination of gpc and frp bars, especially Sfrp bars. The present investigation presents the flexural capacity and behaviour of fly-ash- based gpc beam reinforced with two different types of frp bars: six reinforced geopolymer concrete (RFRP) beams consisting of three specimens reinforced with gfrp bars and the rest with CFRP bars. The beams were tested under four point bending with a clear span of 2000 mm. The test parameters included the longitudinal-reinforcement ratio and the longitudinal- reinforcement type, including GFRP and CFRP. Ultimate load, first crack load, load- deflection behaviour, load-strain curve, crack width, and the modes of failure were studied. The experimental results were compared with the equations recommended by aci 440.1r-15 and csa s806-12 for flexural strength and mid span deflection of the beams.

Esakkiraj. P et al. (July 2020)

Concrete is most frequently used composite material. Concrete is homogeneous mix of fine aggregate, coarse aggregate and binding medium of concrete paste .due to `high demand of cement co2 emission is very high, it leads to global warming. so in this project high volume fly ash concrete was incorporated. fly ash is the waste material obtained from thermal power plant. in this paper we investigated about high volume fly ash in different percentage of replacement 55, 60, 75 percentage. layered pavement is incorporated with steel fiber in a different aspect ratio (15, 30, 40).layered

pavement will give good thermal expansive properties. by varying fly ash content and steel fibers aspect ratio of different mixes were arrived hardened properties of these nine mixes were arrived such as compression test, split tensile test and flexural test.

Anil Kumar, et al. (September-2018)

This paper describes the applications and feasibility of steel fiber and fly ash in the concrete industry. this paper also helps in to identify the desired percentage of steel fiber and fly ash in the concrete mix. many literature reviews have been studied deeply to carry out the proposed dissertation work in a scheduled manner and to achieve the project related goal. to find out the effect of steel fiber and fly ash on the strength concrete the compressive, tensile and flexural test will be conducted with the concrete mix. the final result will be compared with the control mix to find out the effect of steel fiber and fly ash on the strength properties of concrete M30.

A. Shyam, et al. (March 2017)

In the recent past, there have been considerable attempts for improving the properties of concrete with respect to strength and durability, especially in aggressive environments. High performance concrete appears to be better choice for a strong and durable structure. A large amount of by-product or wastes such as fly-ash, copper slag, silica fume etc. are generated by industries, which causes environmental as well as health problems due to dumping and disposal. Proper introduction of silica fume in concrete improves both the mechanical and durability characteristics of the concrete. This paper present literature review on replacement of Cement by Silica Fume which includes current and future trends of research.

Rooban Chakravarthy et al. (November 2016)

fly ash substitution to cement is a well-recognized approach to reduce co2 emissions. although fly ash concrete is prone to brittle behavior, researchers have shown that addition of fibers could reduce brittle behavior. previous research efforts seem to have utilised a single type of fiber or two types of fibers. in this research, three types of fibers, steel, polypropylene, and basalt as 0%, 0.50%, 0.75%, and 1% by volume of concrete, were mixed in varying proportions with concrete specimens substituted with 50% fly ash (class f). all specimens were tested for compressive strength, indirect tensile strength, and flexural strength over a period of 3 to 56 days of curing. test results showed that significant improvement in mechanical properties could be obtained by a particular hybrid fiber reinforcement combination (1% steel fiber, 0.75% polypropylene fiber, and 0.75% basalt fiber). the strength values were observed to exceed previous research results. workability of concrete was affected when the fiber combination exceeded 3%.thus a limiting value for adding fibers and the combination to achieve maximum strengths have been identified in this research.

Irfaz Ur Rahman Najar , et al. (2016)

Cement is the mainly use construction material in recent trend cement concrete is replace by admixtures such as, slag, fly ash, silica fume to increase the characteristics strength of high performance of concrete in order to decrease the shrinkage and creep and to increase tensile strength, fibres are added. strength properties studies involve compressive strength flexural strength tensile strength and abrasion. standard cubes 15cm x 15cm x 15cm, standard cylinders 15cm dia x 30cm height and standard beam 10cm x 10cm x50cm were considered in the research. the study bring that the use of waste material like silica fume, fly ash with steel fibres develop the strength properties of concrete, which is otherwise unsafe to the environment and thus may be used as a fractionally replacement of cement.

3. MATERIALS USED

3.1 Ordinary port land cement (OPC) Ordinary port land cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is of three types, 33 grades, 43 grades, 53 grades. One of the important benefits is the faster rate of development of strength. Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag in suitable proportion and grinding the mixture to get a thorough and intimate mixture between the constituents. This type of cement can be used for all purposes just like OPC. It has lower heat of evolution and is more durable and can be used in mass concrete production.

3.2 Fine Aggregate Fine aggregate most of which passes through a 4.75 mm. IS sieve and contains only that much coarser material as is permitted by the specifications. Sand is generally considered to have a lower size limit of about 0.07 mm. Material between 0.06 mm and 0.002 mm is classified as silt, and still smaller particles are called clay. The soft deposit consisting of sand, silt and clay in about equal proportions is termed loam.

3.3 Coarse Aggregates - In this study, coarse aggregates of size 40 mm and 20 mm conforming to specifications as given in IS: 383- 1970 is used. Pycnometer test is carried out to find the specific gravity of aggregates. Sieve analysis has been done to find the fineness modulus of aggregate.

3.4 Silica fume Certain materials used in civil engineering replace cement with Silica fume, a binding agent. This article covers the methods for testing the properties of Silica fume as well as its physical and chemical features.

It is possible to distinguish between different mixes of Silica fume used in construction by their physical attributes. The quality of Silica fume is governed by several significant aspects. The physical properties of good Silica fume are predicated on:

- Fineness of Silica fume (10 micron to 11 micron)
- Specific gravity (Relative density) of Silica fume (2.20 to 2.3)

3.5 Bottom ash- Bottom ash is a non-combustible residue left over after the combustion process in a power plant, boiler, furnace, or incinerator. It's the coarser part of coal ash, making up about 10% of the waste, and settles at the bottom of the boiler instead of floating into the exhaust stacks. Bottom ash is made up of inert materials like sand, stones, and ash from burnt material, as well as metals that are embedded in the residual waste. It has an angular texture and a color that ranges from gray to black, with grain sizes that can be as fine as sand or as coarse as gravel.

3.6- Steel Slag- In the Basic Oxygen Furnace process, hot liquid metal from a blast furnace is combined with scrap metal and fluxes such as lime (CaO) and dolomitic lime (CaO.MgO). High-pressure oxygen is injected into the converter, which reacts with impurities like carbon, silicon, manganese, phosphorus, and some iron. These impurities are oxidized and form liquid oxides that combine with the added fluxes to create steel slag. Once the refining operation is complete, the liquid steel is tapped into a ladle for further processing while the slag remains in the furnace.

Electric Arc Furnaces operate differently but also produce steel slag as a result of melting scrap metal using electric arcs. The slag produced in this method can vary significantly based on the type of scrap used and operational conditions.

3.7 Water- Concrete is a composite material made primarily of four key ingredients: cementitious material, fine aggregates, coarse aggregates, and water. Among these components, water plays a crucial role in the formation and strength of concrete. The following sections will detail the importance of water in concrete, the effects of excess water, and considerations regarding water quality.

						
Cement (OPC)	Fine Aggregate	Coarse Agg.	Silica fume	Bottom ash	Steel Slag	Water

Figure no 1; Ingredients of Mix Concrete

4. CONCLUSION

The concrete mix made using steel slag, bottom ash, and silica fume with coarse aggregate, fine aggregate, and, cement respectively, on the performance of HPC showed good physical properties of concrete mixes.

The workability of concrete increased with the addition of steel slag, bottom ash, and silica fume with coarse aggregate, fine aggregate, and, cement respectively, on the performance of HPC.

Comparative analysis to nominal concrete with multi bended Mix concrete, Mix designation of nominal concrete Mix Compressive Strength Increase in strength at 7 days ,14 & 28 Days.

Comparative analysis to nominal concrete with multi bended Mix concrete, Mix designation of nominal concrete Mix Splitting Tensile Strength Increase in strength at 7 days & 28 Days.

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