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Replacing Part of Cement with Waste Material -Review

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Abstract:- Concrete is an important building material that is indispensable in our daily lives. Due to the scarcity of natural materials, the cost of construction using traditional materials is very high today. Concrete consumption and construction costs are increasing rapidly every day. Cement has excellent adhesion and is ideal for concrete. On the other hand, cement production consumes a large amount of energy and emits a large amount of greenhouse gas (CO2). So, experts searched for a cost-effective and environmentally friendly alternative to cement. The overall goal of this research is to find waste wood with desirable properties when mixed with concrete. Industrial by-products such as ground granulated blast furnace slag, silica fume, glass powder, rice husk ash, Meta-kaolin, and fly ash provide excellent binding characteristics to concrete that can be used in place of cement. Using these materials not only reduces cement consumption but also helps to ensure proper disposal. This study explores the impact of various substitutes for cement, some of which can be used as substitutes. If the strength of the newly produced eco-friendly cement is higher than that of ordinary concrete, it will be suitable for future construction work.

Keywords: *Eggshell Powder, Rice Husk Ash, Glass Powder, Fly Ash, GGBS, Machinery By-Products, Metakaolin, Silica Fume.*

I. INTRODUCTION

Cement is a binder, a chemical compound that can harden to bind different materials together. Cement is one of the main ingredients in concrete and is destroying the environment at an alarming rate. For every ton of cement produced, approximately 0.9 tons of CO_2 is discharged into the atmosphere. CO_2 is a greenhouse gas that is responsible for much of the world's warming. As a result, we can conclude that concrete is the backbone of infrastructural development and is the building block of any country's progress. Today's construction industry is unsustainable for many reasons, Concrete is widely used in the construction industry. Because the material is in such great demand right now, there is a need to discover substitutes for it in concrete. Cement is an essential raw material in the production of concrete. Efforts to limit the use of Portland cement in concrete are getting a lot of attention due to environmental concerns. As industrial waste accumulates daily, industries are under pressure to find a solution for its disposal, and the utilization of waste material in concrete can also help to reduce natural resource usage. The waste investigated in this study includes glass powder, fumed silica, fly ash, rice husk ash, eggshell powder, Meta-kaolin, and ground granulated blast furnace slag.

II. LITERATURE REVIEW

A. Silica-Fume

Silica fume is a shapeless polymorph of silicon dioxide. It's collected as a by-product of manufacturing silicon metal or ferrosilicon alloys. Fumed silica is gray or white in color, and its particles are much smaller than regular cement particles. Utilizing silica fume as a partial cement replacement aims to increase the concrete's strength. Silicon's fume large specific surface area is one of its recognized features. It's a great pozzolanic material, hence it's used in high-performance concrete. Fume silica concrete is extremely strong and durable. Fumed silica is commonly used as an additive or a partial replacement for cement in concrete.

Malviya et al (2020) Investigated the strength characteristics of concrete using silica fume as a partial substitute. Different cubes, cylinders, and beams were made for the study by substituting cement with 0%, 5%, 10%, and 15% silica fume. The results reveal that substituting silica fume with cement significantly impacted compressive, flexural, and split-tensile strength. The compressive strength of concrete increases rapidly with increasing silica fume content and reaches an optimum value attains at 10% substitution. After 10%, it begins to decline.

Srivastava et al (2014) Studied the effects of silica fume in concrete and concluded that adding silica fume to concrete improves its compressive and bond strength. Fumed silica concrete has the same tensile strength, Flexural strength, and modulus of elasticity as conventional concrete.

Shanmugapriya and Uma (2013) Conducted a test on concrete with a mean strength of 60MPa, a w/c ratio of 0.32, and a CONPLAST SP-430 super-plasticizer. The optimum dosage for maximum concrete performance was calculated to be 7.5% silica fume by weight. The material's tensile strength,

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compressive strength, and flexural strength increased by 20%, 15%, and 23% respectively.

Amudhavalli and Mathew (2012) Examined M35 concrete with partial substitution of cement by silica fume ranging from 0% to 20%. Since silica fume has a higher surface area than cement, we found that the consistency improved as the amount of silica fume increased. In the range of 10-15% silica fume replacement level, the optimum 7 and 28 days compressive and flexural strength was attained. Flexural strength seems to be more affected by silica fume than split tensile strength. When the cement was replaced with 10% silica fume, the weight loss and compressive-strength percentage were lowered by 2.23 and 7.69, respectively, when compared to other mixes.

Dilip Kumar et al (2012) Investigated the qualities of low/medium strength concrete. They found that silica fume provides strong particle bonding. When 10% of the cement was replaced with silica fume, the compressive strength was higher than conventional concrete. At 10% cement replacement with silica fume, split tensile strength, and flexural strength were also improved. Fumed silica concrete can be used in areas at risk of chemical attack, frost exposure, and other factors.

B. Eggshell Powder

Egg shells are agricultural wastes produced by chick hatcheries, fast food restaurants, bakeries,etc. Which can contaminate the environment and require proper treatment. The innermost layer, the maxillary third layer, grows on the egg's outermost membrane and acts as a base for the palisade layer, which is the eggshell's thickest section. The vertical layer's top layer is wrapped up in an organic cuticle. The eggshell's primary components are magnesium carbonate (Lime), calcium, and protein. Dried egg shells were used as a source of calcium in animal nutrition. It's a fine-grained powder with the right proportions that is sieved to the appropriate size before being mixed into concrete or mortar.

Humdullah et al (2020) The effect of eggshell powder as a partial cement substitute on the freshness and hardening properties of concrete were investigated. At the percentage of 0%, 2.5%, 5%, 7.5%, and 10%, the cement was partially substituted with eggshell powder (by weight of cement). The impact strength, energy absorption, load-slip parameters, and ultimate bond strength of the resulting concrete were investigated. Initial and final cure time, slump, density, and compressive strength are measured. The eggshell powder content had no measurable effect on the weight of the concrete block. When compared to the reference mix, the 2.5% eggshell powder produces the best results.

Mohamed Ansari M et al (2016) Research on eggshells as a substitute for cement. The effect of replacing eggshell powder in cement and experimental results are described in this article. The compression test was performed on a cube specimen that had been substituted with 10%, 15%, and 20% eggshell powder in Portland pozzolana cement (PCC) accordingly. Compression tests were performed on 150mm cubic samples on day 7 and repeated on day 28. Results obtained after the successful completion of the project, show that eggshell powder can be used as a cement substitute. The findings show that using 10-15% eggshell powder as a substitute is advantageous, and after that increasing the percentage of eggshell powder reduces compressive strength.

Doh Shu Ing et al (2014) Studied ESP as a potential filler in concrete. In this experiment, five different eggshell powder percentages were added to an M25 concrete mix for cement. The most common materials used were superplasticizers, Portland cement, river sand, crushed sandstone, and eggshell powder. The results of the slump of eggshell concrete in the experiment ranged from 65 to 75mm, representing the average level of work. As the eggshell powder concentration rises from 0% to 10%, the flexural strength increased.

K. Uma Shankar J et al (2014) Research on the effective use of using eggshell powder, GGBS, and sawdust ash as industrial waste. The aim of this study was to see if eggshell powder, granular blast furnace slag, and sawdust ash could be used as cement substitutes in certain applications. The research results are very promising as a result of the trials. The cement sample consisted of 50% GGBS, 20% eggshell powder, and 10 % sawdust ash.

C. Glass-Powder

Glasses are non-crystalline, amorphous materials, mostly supercooled liquids. Glass can be produced very uniformly in a wide variety of shapes and sizes, from microscopic fibers to large pieces, with great uniformity. Glass is mainly composed of limestone, soda, sand, and other chemicals alumina, iron, chromium, cobalt, and lead. Glass has long been used as an aggregate in the construction of roads, building, and walls. Waste glass generated on-site was collected and crushed to produce glass powder. Glass trash is a very tough substance. Glass powder must be ground to the right size before being put into concrete.

Amurutha et al (2021) Investigated the compressive strength and flow tests on mortar and concrete that were carried out by adding 0 to 25 % ground glass to the mixing, with the water/ binder ratio remaining constant at all substitution levels. The addition of glass leads to a slight increase in mortar flow, as well as a small effect on the workability of the concrete. The Concrete block samples were prepared and tested for strength in the same way as they prepared mortar samples. It was found that the compressive strength of mortar and concrete made from recycled glass was higher compared to control samples. Replacing 10% with waste glass has proven compelling in terms of costs and environmental impact.

Kalakada and Doh (2018) Focus on the experimental investigation of recycled waste Glass Powder (GP) as a pozzolanic cement. Particle sizes of 75m and 150m were chosen for the ongoing investigation. Workability, density, compressive, and tensile strengths were tested at glass-powder replacement levels of 0 %, 20 %, 40 %, 60 %, and 80 % by weight of cement. Test results show that using GP as a partial replacement for cement is reasonable for low-strength and lightweight applications. In addition, GP can be used for tasks that require high machinability.

Rakesh Sakale et al (2016) Experimental effects on compressive strength, tensile strength, workability, and flexural strength of replacing glass powder in concrete with cement at different dosages of 10, 20, 30, 40% by volume were investigated. It can be seen that the compressive, flexural, and split tensile strengths of concrete initially increase, reach a maximum of about 20%, and then decreases as the proportion of cement replaced by glass powder increases.

Mirzahosseini et al (2015) Investigated how the performance and microstructural parameters of cementitious systems containing glass cullet as an SCM were affected by a mixture of glass types and particle sizes. At a curing temperature of 50°C, the findings show that mixed glasses can boost reaction rate and show pozzolanic capabilities, especially when particles of green and clear glass with a diameter of fewer than 25 m are used. Linear addition can account for the simultaneous effect of glass fragment size and type (surface area) on the reaction rate of glass powders exhibiting this surface area has a large effect on glass-cullet reactivity. On the other hand, Cementitious systems with mixed glass types and sizes exhibited different performance characteristics.

Raghavendra et al (2015) Study on compressive strength, tensile strength, and water absorption of concrete mix M40 grade replacing 20% used glass powder in cement and a part of foundry waste in fine aggregate. The test results showed a decrease in strength on the 7^{th} and 14^{th} days, but an increase in strength on the 28^{th} day. High strength values were discovered at a 40 % replacement level in strength parameters, with the proportion attaining its maximum at M40.

D. Fly-Ash

Fly ash is a material with many components. It's the leftover residue after coal is burned, and it's collected on an electrostatic precipitator or in a baghouse. When powdered coal was used to generate electricity, it combines with flue gases. Fly ash is a by-product of coal combustion that is made up of fine particles that are carried out of the boiler with the flue gases. In Portland cement concrete, fly ash is utilized to increase the concrete's performance. Free-state calcium oxide produced during cement hydration combines with fly ash silicates to form strong and durable cementitious compounds that improve concrete properties.

Saini and Soni (2014) Compressive strength, tensile strength, and versatile modulus of fly ash concrete were measured at 80, 100, and 120˚C. The percentage ratio of fly ash in the cement was calculated as 30%, 40%, and 50% by weight. The compressive-strength, split tensile strength and modulus of elasticity of concrete with a cement replacement of up to 30% were comparable to those of concrete without fly ash, whereas those of concrete with a cement replacement of more than 30% were lower than those of concrete with no cement replacement. When compared to room temperature, the compressive strength of fly-ash concrete was reduced to 120°C.

Wankhede and Fulari (2014) Investigated the impact of fly ash on concrete qualities and found that when 10% and 20% of cement was replaced with fly ash, the compressive strength increased, however when 30% of cement was replaced compressive strength declined. It was also found that the excessive addition of fly to concrete increases slump loss.

Patil et al (2012) Explored the compressive strength of concrete using fly ash to partially replace cement. From 5% to 25% of the cement is substituted by fly ash, with each percent rising by 5%. For concrete that does not replace cement with fly ash, the rate of development of compressive strength peaks after 60 days. Up to the age of 21 days, concrete with 5% fly ash has the fastest rate of compressive-strength development, after which it slows down. The maximum strength is obtained after 90 days with a 10% fly-ash injection. Therefore, when fly ash replaces some of the cement, the initial strength development rate of concrete slows down but eventually reaches the required maximum strength.

Sigrun Kjaer Bremseth (2010) Discussed the advantages and disadvantages of using fly ash in concrete. The ability to resist alkali-aggregate reactions is one of fly ash concrete's greatest advantages, but air-entrainment and slow strength build-up are its greatest drawbacks.

Bargaheiser and Butalia (2007) Evaluation of advantages of high-capacity fly ash concrete for structural corrosion damage. Concrete Corrosion in concrete is caused by the penetration of carbon dioxide and chlorides into concrete. Fly ash in concrete reduces carbon dioxide emissions, gives a more sustainable design and longer service life for infrastructure, slows the intrusion of moisture, oxygen, chlorides, carbon dioxide, and harsh chemicals in concrete, and inhibits corrosion in reinforced concrete structures.

E. Ground Granulated Blast Furnace Slag

GGBS, or ground granulated blast furnace slag, is made from molten iron slag, a by-product of steel and iron production. Iron slag from the blast furnace is soaked in steam to make a granular glass item, which is then dried and ground into a fine powder. This fine powder is called blast furnace slag fine powder.

S. Arivalagan (2014) Determination of effective factor of M35 hardened concrete with GGBS as a partially replacing cement. For various ratios of GGBS substitution of cement, the slump, compressive-strength, flexural-strength, and split-tensile strength of concrete are experimentally determined. The concrete strength at 28 days increases when 20 % of the cement is replaced with GGBS. In comparison to OPC concrete, adding GGBS of approximately 40% cement by weight resulted in normal workability.

Ramezanianpour et al (2013) Explore the impact of supplanting cement with GGBS on the compressive quality and sulfate resistance of concrete. Percentages of cement replacement of 35%, 42.5%, and 50% were considered. The concrete was immersed in a 5% sodium sulfate solution for 180 days and 270 days, and compressive strengths were measured. After 270 days of presentation, concrete with 50% substitution of cement by GGBS showed an increment in resistance to sodium sulfate arrangement, but concrete with 35% substitution levels appeared a drop in resistance. The lower the w/c ratio, the higher the compressive resistance.

V.S. Tamilarasan et al (2012) Looked into the workability of M20 and M25 grade concrete with halfway substitution of cement by GGBS. Replacing levels were established in 5 percent increments from 0 to 100%. Various tests, such as the flow test, slump test, compaction-factor test, and Vee-Bee densitometer test, were used to examine the qualities of concrete. The workability of concrete improved by up to 45% replacement level in M20 concrete grade and around 50% replacement level in M25 concrete grade, according to the findings. The workability of M25-grade concrete was also found to be better than that of M20-grade concrete.

Pavia and Condren (2008) The durability of GGBS concrete when susceptible to magnesium sulfate solution and silage leachate was investigated. For different values of GGBS incorporated in the concrete, properties such as porosity, permeability, capillary suction, mass loss, water absorption, and compressive strength were studied. When concrete is exposed to leaching cycles and salt crystallization, the durability parameters of the concrete increase with increasing GGBS content. As a result, a concrete blend utilizing GGBS as a halfway substitution for cement can be utilized viably in rural silos.

F. Meta-kaolin

Meta-kaolin is a dehydroxylated version of kaolinite (clay mineral). It's a non-crystallized amorphous material made up of lamellar particles. Meta-kaolin is an excellent pozzolanic element that can improve the durability, strength, and other mechanical properties of concrete.

Suryawanshi et al (2015) Studied the effects of Meta-kaolin and super-plasticizer on M35 concrete grade. Meta-kaolin was used to substitute cement in 4%, 8%, 12%, and 20%. The w/c ratio was 0.43 in all cases, and compressive strength was measured on day 3, day 7, and day 28. The compressive strength improved until 12 % of the cement was replaced, at which point it began to decline. Replacing cement with meta-kaolin, improved compressive strength by more than 10%. The use of meta-kaolin affects workability, which can be offset by the use of superplasticizers.

Devi (2015) Compressive, tensile, flexural strength and durability parameters of concrete with quarry dust fine aggregate were evaluated using metakaolin as a partial cement substitute. Meta-kaolin is used in varying amounts ranging from 5% to 20% as a cement substitute in concrete. Meta-kaolin is added to quarry concrete to improve rheological properties such as workability, segregation, compaction, and bleeding. The optimal proportion of cement to be replaced by meta-kaolin was 15%, which improved the corrosion resistance and strength of concrete at all ages. Meta-kaolin also reacts with calcium hydroxide to improve the pore structure of concrete.

Nikhila and Chaitanya Kumar (2015) The halfway substitution of cement with MK in concrete M70 grade has been considered at concentrations of 0%, 10%, 15%, 20%, 25%, and 30%. A mixed design was created using Erntroy's empirical Shacklock method. Specimens are evaluated for durability studies with 0.5% and 1% concentrations of H_2SO_4 and HCL, respectively. At 15% replacement, cubes, cylinders, and prisms are examined for temperature investigation. The specimens were heated to temperatures of 100°C, 200°C, 300°C, 400°C, and 500°C for 3 hours at each temperature. The usage of Meta-kaolin Concrete (MKC) has increased concrete's performance in a variety of situations.

Patil and Kumbhar (2012) Investigated properties such as workability, compressive strength, and durability of high-performance concrete M60 grade containing Meta-kaolin. Different amounts of meta-kaolin and appropriate water reducers were added to the concrete. The best workability and compressive strength were found when meta-kaolin was added up to 7.5 % by the weight of cement. When 7.5 % meta-kaolin was applied, the compressive strength increased by 7.73 % after 28 days. Concrete is attacked by chloride and sulfate, and it was concluded that adding meta-kaolin to the mixtures improves the chemical resistance of the concrete.

Badogiannis et al (2002) High-purity commercial meta-kaolin and a manufactured meta-kaolin were used to replace a certain amount of cement in the concrete. Specific properties such as air permeability, adsorption, durability, strength development, chloride permeability, and porosity are evaluated and compared for both forms of metakaolin. Commercial meta-kaolin and manufactured meta-kaolin were found to give identical results in terms of concrete strength and durability. Compared with ordinary Portland cement concrete, meta-kaolin had higher 28-day and 90-day strength and pore size, lower chloride permeability, adsorption, and gas permeability.

G. Rise Husk Ash

Rice Husk Ash (RHA) was a term used to describe an agricultural by-product produced by burning of husk at temperatures below 800°C. The procedure yields around 25% ash with amorphous silica content of 85% to 90% and alumina content of about 5%, making it very pozzolanic. RHA is the result of rice husk burning. The most important sediments are the silicates, which are eventually lost when the chaff loses a significant portion of its evaporative constituents after consumption. The nature of the wreckage is affected by the shape of the rice husks and the temperature at which it is consumed, and the amount of time it is consumed. About 25 kilograms of RHA are produced for every 100 kilograms of husks used in the heater.

Sai Kumar and Raju (2017) A study on the use of rice husk ash in various proportions (i.e., 0%, 5%, 10%, 15%, 20%, and 25%) instead of cement. Using the M25 grade, the intensity on days 7 and 28 is determined according to code requirements. The idea for adopting RHA is that it is economical and has pozzolanic properties. He explained that RHA is fungible in the range of 0% to 15% and its use in concrete could help to solve the RHA disposal problem.

Anil Kumar and Suraj Baraik (2016) researched M20 concrete design mix with 0%, 15%, 30%, 45, and 60% replacement of mine sand for laboratory tests such as deflection, flexural strength, tensile strength, compressive strength, permeability gap, and acid attack. The effect on the concrete of partially replacing cement with fly Ash and rice husk ash has been the subject of extensive research. He also mixed the two ashes to partially replace for cement and river sand with mine sand and conducted studies. Maximum strength is achieved by combining 7.5% Rice Husk Ash + 22.5% Fly-ash with 60% quarry sand.

Kashyap et al (2015) Investigate the properties of concrete where 5 to 20% of the cement has been replaced by rice husk ash (RHA). mixed concrete M30 was used in this study. The highest level of strength is achieved when 10%of OPC is replaced by RHA. The use of RHA instead of OPC leads to a 7% to 10% reduction in the cost of concrete manufacture.

Obilade (2014) Studied the usage of rice husk ash as a partial replacement for cement in the range of 0% to 25%. They discovered that the ideal percentage of rice husk ash is between 0% and 20% based on their research. As the percentage of rice husk ash replacement rises, the compacting factor values, bulk densities, and compressive strengths of concrete start decreasing.

C. Marthong (2012) The effect on concrete properties of partial replacement of different OPC qualities by RHA was investigated. The percentages of OPC replaced with RHA were 0%, 10%, 20%, 30%, and 40%, respectively. Concrete's compressive strength, water absorption, shrinkage, and durability were primarily investigated. Research shows that replacing up to 20% of OPC with RHA can be used as a partial replacement of cement with good durability and compressive strength.

III. CONCLUSIONS

We live in a constantly changing world and are always looking for more comfort and convenience. However, it has an adverse impact on the ecosystem as resources are depleted and pollution occurs on many natural resources. Using waste as a partial substitute for concrete manufacturing has a huge impact on the environment, resulting in a cleaner and more peaceful environment. As a result of the literature survey mentioned above, it is possible to consider various ways of maximally substituting a portion of cement with waste. Partial replacement of concrete material with locally accessible waste can be cheaper than conventional concrete, as well as a method of reducing waste disposal problems generated by various industries. We're seeking to create cost-effective, environmentally friendly concrete that has all the desired qualities and strengths that can be achieved with conventional concrete materials. According to the research of many scholars, there are many opportunities to improve the properties of concrete and reduce the amount of cement used. Concrete properties are individually affected by each of the seven alternatives discussed in this study. In order to boost concrete's strength, workability, and durability, it will be necessary to replace all of the cement in the concrete with an appropriate combination of cement substitutes. Furthermore, new alternatives must be found to overcome the disadvantages of the previously described alternatives. By turning industrial waste into a valuable substance, we can reduce the amount of waste we create. In this way, a pollution-free environment can be achieved.

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