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A Review on Usage of Waste Materials as Replacement for Natural Sand in Concrete

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ABSTRACT:

The three essential components of any construction industry are cement, sand, and aggregate. Sand is a key component in mix design and is used extensively in the preparation of concrete and mortar. River sand is in short supply these days due to environmental concerns and river erosion. Finding a new alternative material to replace river sand is necessary to prevent excessive river erosion and environmental harm as the lack of river sand will have an impact on the construction industry. In order to address environmental concerns related to sand mining and promote sustainability, it is imperative that alternative materials be used in place of sand in concrete. It also encourages the creation of creative and effective building techniques. When investigating substitute materials, it's crucial to pay close attention to the unique characteristics and performance specifications of the concrete mix for every application. An overview of the various replacements for natural sand in concrete preparation is provided in this paper. The focus of the paper is mainly on the mechanical, physical, and strength aspects of materials and concrete.

Keywords: River sand, Alternative material, Sustainability, natural sand, Strength.

I. INTRODUCTION

Sand acts as a natural barrier against erosion, which stabilizes riverbanks. Sand particles contribute to the soil's cohesiveness, limiting excessive erosion and the loss of rich topsoil. It filters the water naturally by capturing sediments and other contaminants. Concrete made from industrial waste materials contributes to environmental sustainability by minimizing the quantity of waste dumped in landfills. The total cost of producing concrete can be decreased by obtaining certain waste materials for little or no money. It makes it possible for water to seep through, aiding in the replenishment of groundwater aquifers. This is crucial for preserving rivers' base flows and sustaining ecosystems during dry spells. Riverbeds and banks may deteriorate as a result of excessive and uncontrolled sand extraction from rivers for industrial and construction uses. Historically, river sand has been used extensively in construction to create mortar and concrete. It gives the structures excellent workability, durability, and strength provides a natural barrier against erosion, aiding in the stabilization of riverbanks. In order to stop excessive erosion and the loss of rich topsoil, sand particles aid in binding the soil together. In order to lessen the reliance on river sand, the construction industry is investigating sustainable practices and alternative materials. Sand replacement in concrete refers to the substitution of alternative materials for all or a portion of the conventional sand. The selection of a replacement material is contingent upon a number of factors, including cost, availability, technical specifications, and environmental factors. This paper reviews the certain industrial waste materials are Crumb rubber, Crushed glass powder, Precious slag balls, Bottom ash, Copper slag, Quarry sand, Foundry sand, Ground granulated blast furnace slag (GGBS), Fly ash (Class F), Crushed palm oil clinker, Saw dust, Marble powder, Ferrochrome slag and Imperial smelting furnace slag.

Bottom ash –

An average of 226 million metric tonnes of ash are produced annually by burning coal in indian thermal plants. More water can be absorbed by the porous structure of bottom ash than by natural sand. Therefore, adding bottom ash to the concrete mix raises the water requirement of the mixture.

Copper slag –

Currently, the world produces 33 million tonnes of copper slag annually, with India producing 6 to 6.5 million tonnes of that total. To achieve the necessary performance, strength, and durability in mortar and concrete, 50% copper slag can be substituted for natural sand. These concretes have demonstrated a 20% increase in strength over traditional cement concrete of the same grade level.

Crumb rubber –

India does not have a comprehensive plan for the approximately 275,000 tires that are disposed of annually, according to data submitted for an NGT case. Furthermore, approximately 3 million used tires are imported for recycling. In order to reduce the amount of sand used and preserve raw material resources, self-compacted concrete (SCC) can benefit from the partial replacement of fine natural aggregates with crumb rubber (CR) made from waste tires.

Crushed glass waste –

Waste glass and glass powder have all been successfully used as partial substitutes for fine and coarse aggregates in concrete, according to studies that have been published in a number of papers. The results show that adding waste glass particles to concrete can increase its tensile strength, workability, flexural strength, and compressive strength. Three million tonnes of glass waste are produced in India alone each year; only 35% of this is recovered, with the remainder frequently ending up in landfills or being recycled into aggregates for construction.

Precious slag balls –

India's steel mills will produce 12 million tons of steel slag waste annually by 2030, up from the current 19 million metric tons. It is a novel material that can be made by quickly cooling the slag that is produced during the Slag Atomizing Technology (SAT) steel-making process. According to the Ministry of Environment, PS Ball is an eco-friendly material.

Quarry sand –

Each crusher unit produces between 20 and 25 percent of its total output as quarry dust waste. If compressive strength is a concern, replacing sand with quarry dust should ideally range from 55% to 75%. He goes on to say that 100% sand replacement is possible if fly ash another industrial waste is added.

Foundry sand –

The foundry industry produces about 100 million tons of Used Foundry Sand annually worldwide. For every ton of iron or steel casting produced, about one ton of foundry sand is used. The concrete made with waste foundry sand can be made to be strong, lightweight, and inexpensive by partially replacing fine aggregate with it.

Ground granulated blast furnace slag (GGBS) –

A by-product of the blast furnaces used to produce iron is ground granulated blast furnace slag, or GGBS. India is a producer of 7.8 million tons of slag from blast furnaces. 100% glassy slag granules are produced by quenching the molten slag with a high-power water jet in the blast furnace.

Fly ash (Class F)–

The by-product of coal-fired power plants called fly ash is made up of tiny particles that rise with the flue gases. In the industrial context, fly ash is typically used to describe the ash left over after burning coal; India produces roughly 75 million tonnes of fly ash annually. Class "F" fly ash is typically generated through the burning of bituminous or anthracite coal.

Saw dust –

A waste product or by-product of woodworking processes like sawing, sanding, milling, and routing is sawdust, also known as wood dust. It is comprised of tiny wood chips. These figures show that sawdust production in India amounts to about 18 million tons per year.

Crushed palm oil Clinker –

After burning the solid waste from palm oil mills to produce electricity, palm oil clinker (POC) is the waste by-product that remains. POC aggregate is lighter by nature, so it can be used to make lightweight mortar or concrete. Not only would this help the construction industry by replacing aggregate, but it would also be a very effective way to prevent pollution in the environment.

Marble powder –

A by-product of the quarrying process, marble dust powder (MDP) is made from the parent marble rock and has a high calcium oxide content of more than 50%.

Ferrochrome slag –

The waste product known as ferrochrome (FeCr) slag is produced when FeCr ore is reduced carbothermically to produce high- or low-carbon ferrochrome alloy. The yearly production of ferrochrome alloy is thought to be between 12 and 16 metric tons worldwide.

Imperial smelting furnace slag –

The by-product known as Imperial Smelting Furnace (ISF) slag is produced when zinc ore is first melted in a blast furnace. There is 1.6 waste-to-product ratio. ISFS is a granular substance with a black colour. About 720,000 tpa are produced in India each year from ISFS.

Table 1: Physical properties of different replacement materials

Materials	Specific gravity	Surface texture/Colour	Size	Bulk density (Kg/m^3)	Fineness modulus
Bottom ash	2.24	Grey	0.18 to 1mm	2500	2.82
Copper slag	3.6	Black	0.5 to 2.5mm	1970	4.06

Crumb rubber		Black	50% chips waste tires (13-100mm) , and 50% grounded waste tires of (0.14-13mm)	745	2.95
Crushed glass waste	2.4	Glassy	Around 3mm	1850	3.32
Precious slag balls	3.58	Shiny/Dark grey	0.1 to 4.5mm	2400	3.14
Quarry sand	2.5	Rough	<4.75mm	1520 - 1680	2.9
Foundry sand	2.49	Black	0.6 to 0.075mm	1690	1.78
GGBS	2.98	Greyish white	125 – 250 microns	1200	
Fly ash	2.503	Grey	Around 100 microns	798.2	5.73
Saw dust	2.43	Brownish yellow	>10 microns	210	1.9
Crushed palm oil Clinker	2	Greenish grey	Around 0.6mm	1122	2.88
Marble powder	2.57	Glassy/White	10 - 35µ	1118	1.5
Ferro chrome slag	2.38	Grey	0 to 5mm	1870	4.8
Imperial smelting furnace slag	3.62	Light grey	Around > 10 microns	3900	3.3

II. LITERATURE REVIEW

Concrete's mechanical characteristics have a direct impact on the functionality, robustness, and safety of concrete structures, making them crucial to comprehend and manage. These characteristics aid engineers and building specialists in creating structures that are resilient to a range of loads and environmental factors.

Bottom ash –

A.V. Chitharth Kannappan (2017) For the different percentages (ranging from 0 to 50%) of bottom ash replacement in concrete, the following strengths are obtained: compressive strength, split tensile strength, and flexural strength.In 7 and 28 days, the average maximum compressive strength of 29.58 N/mm2 and 34.30 N/mm2, respectively, was achieved; this is 17.06% and 9.7% higher than that of conventional concrete. In 7 and 28 days, the average maximum split tensile strength was 2.66 N/mm2 and 3.83 N/mm2, respectively, which is 10% and 6.38% higher than that of conventional concrete. It is discovered that the average maximum flexural strength achieved in 7 and 28 days is 2.42 N/mm2 and 3.78 N/mm2, respectively, which is 8% and 7.3% more than the conventional concrete.

Copper slag –

Ambrish, Dhavamani Doss, ShanmugaNathan, Ganapathi Raj (March, 2017) In order to prepare the concrete for M25 grade concrete, copper slag was used in various percentages 0%, 10%, 15%, and 20% to partially replace the fine aggregate. The samples were tested after being cast for seven, fourteen, and twenty-eight days. The average maximum compressive strength of 28.44N/mm2, obtained after 28 days with 20% replacement, is 12.6% higher than that of conventional concrete. The average maximum split tensile strength of 3.3395N/mm2 obtained after 28 days of 20% replacement is 25% higher than that of conventional concrete. 19.5% more flexural strength than conventional concrete, with an average maximum strength of 10.25N/mm2 attained after 28 days of 15% replacement.

Crumb rubber –

Falak O. Abas, Enass A. Abdul Ghafoor, Mohammed U.Abass, Talib Kamil Abd (March, 2015) The concrete mixtures containing 20% waste tire rubber have the lowest compressive strength at 56 days of curing age. This mixture's decreasing ratio below the reference concrete mixture at the same curing age is 35.25 percent. At 56 days of curing age, the concrete mixture with 20% waste tire rubber has the lowest flexural strength. At the same curing age, its flexural strength is 17.6% less than that of the reference concrete mixture. As this waste ratio increases, the slump values of the rubber concrete mixtures made from waste tires tend to fall below the referent concrete mixture's slump. Despite this reduction in those mixtures' slump.

Crushed waste glass –

SADOON MUSHRIF ABDALLAH (June, 2011) Compressive strength development over time for controlled mixes and mixes with 5, 15%, and 20% glass aggregate as sand replacement. It is evident that adding waste glass to concrete increases its compressive strength. According to the results, the concrete mix containing 20% waste glass fine aggregate had the highest 28-day compressive strength values of 34.22 MPa. This indicates a 5.28 percent increase in compressive strength when compared to the controlled mix. It can be observed that the percentage increases in compressive strength with age are generally increased with the increment of glass aggregate replacements. According to the test results ,the best 28-day splitting tensile strength value of 3.122 MPa was obtained from the concrete mix made of 20% waste glass fine aggregate, which represents an increase in the splitting tensile strength of up to 18.38% as compared to the controlled mix. The results of flexural strength illustrates the better behavior for mixes containing waste glass as compared with controlled mix. According to the test results, the 28-day flexural strength values were noticed to have a tendency to increase above the controlled mix by 3.54%, 5.03 %, and 8.92% as the waste glass content increased by 5%,15%, and 20%, respectively.

Precious slag balls –

S. Sharath, B.C. Gayana, Krishna R. Reddy and K. Ram Chandar (2019) Various percentages of precious slag balls are used in this study to find the optimum percentage. Percentage increase in 28 day compressive strength of the mix SP 20, SP 40, SP 60, SP 80 and SP 100 with respect to reference mix were 7.0%, 10.1%, 5.8%, 4.3% and 4.4% respectively. It was observed that, the concrete mix in which 40% of sand was replaced with PS balls showed the highest increase in compressive strength. With PS balls content more than 40% of fine aggregates, even though the density of the concrete increased with increase in substitution for sand with PS balls, the compressive strength decreased. The percentage variation of split tensile strength of SP 20, SP 40, SP 60, SP 80 and SP 100 with respect to control mix was 20%, 22.8%, 18%, 18% and 9%, respectively. The tensile strength improved 1.18 to 1.20 times when replacement ratio ranged from 20% to 80%. The percentage change of flexural strength of SP 20, SP 40, SP 60, SP 80 and SP 100 with respect to control mix was 2.2%, 8.7%, 6.2%, -7.2% and -9.2% respectively.

Quarry sand –

Sumit L. Chauhan, Raju A.Bondre (July, 2015) As the percentage of Quarry Dust gradually increases, the Compressive strength of concrete will also increase with condition that percentage of Quarry Dust should not exceed 50%. The value of strength for 28 days higher than the strength for 7 days. According to the value of compressive strength collected, the value is high and it show that quarry dust suitable to use as sand replacement. All the value of compressive strength surpasses the minimum value of compressive strength for normal concrete that is 7N/mm . So, quarry dust can apply as sand replacement in concrete mix for construction industry.

Foundry sand –

Amitkumar D. Raval, Dr. Indrajit N. Patel, Arti Pamnani, Alefiya I.Kachwala (January, 2015) Tests are conducted to determine the compressive strength after 7, 14 and 28 days for various replacement levels of foundry sand contents (0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80%). Comparing the concrete to the control mix, the compressive strength rose as foundry sand replacement reached up to 40%. However, the compressive strength of the concrete gradually declined as the amount of foundry sand increased relative to the amount of fine aggregate. When compared to control mix concrete, the progressive strength attainment rate of concrete containing foundry sand replacement is higher, reaching up to 50% replacement results. Concrete's compressive strength is negatively impacted by substituting foundry sand for whole fine aggregate, as evidenced by the lowest values.

Ground granulated blast furnace slag (GGBS) –

Baskaran.P, Karthickkumar.M, Krishnamoorthy.N, Saravanan.P, Hemath Naveen K.S, K.G.Vinothan (March 2017) The concrete was ready for the M25 grade by partially replacing the fine aggregate with GGBS in different proportions of 0%, 5%, 10%, and 15%. After being cast for seven, fourteen, and twenty-eight days, the specimens were tested**.** After 28 days, the compressive strength of the cubes varied in the following order: 31.61, 40.67, 43.47, and 45.59 for 0%, 5%, 10%, and 15% GGBS proportion replacements, respectively. This was due to the partial replacement of fine aggregate with GGBS. After 28 days, the value variation of the split tensile strength of the cylinder increased in the following order: 2.955, 3.29, 3.32, and 3.54 for 0%, 5%, 10%, and 15% GGBS proportion replacements, respectively. This was due to the partial replacement of fine aggregate with GGBS. The value variation of flexural strength of beam for the partial replacement of Fine aggregate with GGBS increased values in the order of after 28 days 5.86, 6.24, 6.53 and 7.03 for 0%, 5%, 10% and 15% GGBS proportions replacements respectively.

Flyash (Class F)–

Robert V. Thomas, Deepa G.Nair (August 2015) The results of tests carried out for the determination of compressive strength on 28 and 90 days of curing for both mixes 1:2:4 and 1:4:8 respectively. Compressive strength was found increasing as the percentage of fly ash up to 20% replacement and decreasing thereafter. An improvement in strength was reported for all replacement levels of fine aggregate with fly ash with respect to control mix up to 40%(1:2:4) and 30%(1:4:8). The reduction in compressive strength above 20% replacement can be due to the weak bonding between cement paste and fly ash particles. When the percentage of fly ash replacement rises, fly ash concrete blocks absorb more water. Similar to compressive strength, concrete block density increases by up to 20% replacement.

Saw dust –

Abishek Narayanan, Hemnath. G, Sampaul K & Anne Mary (April, 2017) In this experiment, the mix proportion is determined for M20 grade concrete for a w/c ratio of 0.50, respectively, using the IS:10262:2009 method of mix design, which keeps the w/c ratio for the control mix constant. Sawdust is replaced with 0, 1%, 2%, and 3% in the concrete. Compressive strength is increased by increasing the percentage of sawdust.

Crushed palm oil Clinker –

M A Sulaiman, M I Ali, M Y Al-Amri, K Muthusamy, A M Albshir Budiea, N Nordin, Y Duraisamy and R Othman (2019) The preparation of the control specimens (POC-0) involved using only river sand. Four more concrete mixes were made, with the percentage of palm oil clinker by weight of sand being0%,10%,20%, 30%, and 40%. Prior to being demoulded, every sample was covered with a wet gunnysack for a full day following the casting process. Every specimen underwent a 28-day water cure. The outcome shows that when more palm oil clinker is added, the concrete becomes less workable. This suggests that more water will be needed to make the mixtures more workable. As the curing age lengthens, the strength of every specimen rises because the continuous presence of water promotes an undisturbed hydration process. Consequently, a greater amount of CSH gel developed within the internal structure of the concrete, resulting in a more compact concrete with a higher load-sustaining capacity.

Marble powder –

Syed Furquan Ahmed, Asrar ul haq, Mohammed Mohiuddin Ejaz (December 2019) Marble powder in various percentages, such as 5%, 15%, 25%, 35%, 45%, 50%, and 100%, in place of fine aggregate (sand). After 28 days, 5% of the samples showed the highest compressive strength. After three-quarters of the way, the strength increased.

Ferro chrome slag –

N. A. G. K. Manikanta Kopuri , Dr. K. Ramesh (March 2019) the compressive strengths after seven and twenty-eight days of curing of different proportions of M30 grade concrete mix with different replacement levels of ferro chrome slag. As the percentage of ferrochrome slag replacement increased, so did the compressive strength values. After 28 days of curing, the maximum compression strength of the concrete is achieved at 40% replacement of ferro chrome slag, or 62.3, 59.2, and 56.6 N/mm2 in water, acid, and base curing, respectively. After 28 days of curing, the split tensile strength of concrete reaches its maximum at 20% replacement of Ferro chrome slag, or 3.3 N/mm2 in water curing. 3.6 and 3.5 N/mm2 for base and acid curing, in that order. After 28 days of curing, the maximum flexural strength of concrete is achieved at 40% replacement of Ferro chrome slag, or 5.9 N/mm2 in base, acid, and water curing, respectively.

Imperial smelting furnace slag –

S.Varadharajan, S.V.Kirthanashri, Kaushal Singh, Danish Irfan, Bishnu Kant Shukla and Ashish Kumar (September, 2019) Comparing mixes M1, M2, and M3 to M0, the average 28-day compression strength increases by 9.69%, 11.54%, and 14.43%, respectively. According to the compressive strength data, the addition of a bacterial solution increases the mix's compressive strength by 14.38 percent, 16.83 percent, and 17.21 percent, in that order.

III. CONCLUSION

- After replacing 30% of the bottom ash, the strength starts to decline. The higher the bottom ash content, the less workable it becomes. With increasing maturity age, compressed concrete's compressive strength increases.
- Compressive strength increases as the percentage of copper slag replacement increases, and split tensile strength decreases at first (10%) and then increases as the percentage of copper slag replacement increases. 15% is the ideal percentage for flexural strength; after that, it decreased.
- With an increase in the waste tires rubber ratio at all curing ages, the compressive strength values of all waste tire rubber concrete mixtures tend to fall short of the values for the reference concrete mixtures. The decrease in adhesive strength between the cement paste and waste tire rubber surface could be the cause of this. As the waste tires rubber ratio increases, the flexural strength values of the concrete mixtures made from waste tires tend to fall short of the values for the reference concrete mixtures. Mixtures are easy to work with based on the slump value because their workability ranges widely from very low to high workability for various construction applications.
- The slump of concrete that substituted waste glass for fine aggregate reduced as the amount of waste glass increased. Despite having lower slump values, mixes containing glass aggregate are still very workable. With some of the sand being replaced by finely crushed waste glass, the concrete's compressive strength increased as the waste glass increment ratio rose. Later-aged concrete that has been mixed with glass waste exhibits a higher compressive strength. The 20% replacement rate of finely ground waste glass by sand yields the highest values of tensile, flexural, and compressive strengths after 28 days.
- As the amount of PS balls increased, the slump values also increased, indicating that PS balls can be used to create more workable concrete at lower water contents. According to the experimental research, concrete with PS balls in it could withstand greater compressive loads than regular concrete. One crucial factor that makes concrete with PS balls ideal for use as pavement material is its increased flexural strength. Concrete with greater density and flexural strength is better for concrete pavements. Concrete becomes more durable when PS balls are added because their addition lowers the concrete's permeability and rate of conductivity. Overall, it was discovered that 40% replacement with PS balls yields the best outcomes.
- Based on the gathered compressive strength value, it is evident that quarry dust can be used as a suitable substitute for sand. One useful resource is quarry dust, an industrial waste or byproduct of crushing and construction companies. It is possible to lower construction costs by using quarry dust in place of some of the sand in concrete.
- Concrete specimens' compressive strength, split tensile strength, and flexural strength all increased as foundry sand replacement of fine aggregate increased. This provided maximum strength at 50% replacement; above that point, the strength parameters displayed a decline in their respective values. It is preferable to substitute up to 50% of natural sand with recycled foundry sand because it is more affordable, uses less virgin fine aggregate, solves land fill issues, and protects the environment.
- It is discovered that the maximum flexural strength achieved by partially replacing fine aggregate with GGBS by 15% is higher than that of conventional concrete. The maximum compressive strength was attained when 15% of the fine aggregate was replaced with GGBS. Therefore, 15% is the ideal replacement percentage of GGBS.

- The highest compressive strength was noted at a 20% fly ash replacement level in fine aggregate; blocks with a higher replacement level of 30% can be recommended for practical use since their density and strength are comparable to the optimal value. Blocks made with a 1:4:8 mix and 20% fly ash replacement can be recommended for load-bearing applications while meeting IS requirements and being economically viable.
- The analysis's findings indicate that, at a constant water-to-cement ratio, the workability of concrete with sawdust partially replacing sand decreases; up to 15% of sawdust's compressive strength is nearly identical to that of the control mix. In addition to being lighter than regular concrete, sawdust concrete was also more cost-effective.
- The use of crushed palm oil clinker content as a partial sand replacement affects the properties of concrete, according to the results of the experiment. Concrete's workability decreases when the amount of palm oil clinker content increases. The compressive and flexural strengths of concrete are decreased when palm oil clinker is used in part place of sand.
- The compressive strength of concrete can be increased by partially substituting marble powder for fine aggregate in a concrete mix. The results of the test also show that leftover marble powder can be used again to replace some of the fine aggregate in concrete. The utilization of marble powder lowers the cost of producing concrete because it is an inexpensive material.
- Ferro chrome slag is suitable for up to 40% replacement in an aggressive environment for both PCC and RCC works, according to the results of the entire experimental study. When fine aggregate is used in place of ferro chrome slag, it becomes resistant to base and acid attacks brought on by water.
- The mechanical properties have increased by 11.88%, according to the results of the experimental study of replacing fine aggregate using imperial smaelting furnace slag. The strength properties are enhanced by 3.33% when the bacterial solution is added. The evaluation of the environmental benefits indicates that replacing fine aggregate has a significant positive impact on the environment by reducing greenhouse gas emissions and particulate emissions by 36% and 43%, respectively, which can promote sustainable development.

This paper examined the alternatives to natural sand that can be used in concrete. There are numerous materials that are acknowledged as domestic or industrial waste products. However, the above conclusion indicates that a large number of researchers have identified these materials, devoted important time to their study, and shared their expertise to raise awareness of these materials for the construction sector.

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