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A Study On Utilizing of Brine Sludge And Silica Fume In M35 Grade Paver Blocks

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Abstract - This *paper systematically reviews the utilization of brine sludge and silica fume into the production of M35 grade paver blocks. Brine sludge a byproduct of desalination processes and silica fume an industrial waste contribute to waste reduction, improved mechanical performances and reduce environmental effects. This review includes the examining their effects on properties such as compressive strength, water absorption, abrasion, durability and toxicity characteristics leaching process. Brine sludge was used 30 Percent and different proportions of silica fume from 0-30 percent was used. Compressive strength at 10 percent of silica fume is higher than the other compositions. The paving blocks were meeting the standards of IS 15658-2006 and toxicity characteristics.*

Key Words: Paver block, Brine sludge, fly ash, Aggregate, Toxicity Characteristics Leaching Process.

1.INTRODUCTION

In India there are about 40 units of caustic soda manufacturing. In modern chlor-alkali industry, the basis of the process is mainly in electrolysis, which may be separated in three different kinds of ways, including mercury cell, membrane ll and bipolar diaphragm cell.The brine sludge is produced from the byproduct of the chlorine and caustic soda. These huge amounts of industrial waste will pollute the environment and increase the cost for transportation. Consequently, the utilization of the brine sludge is quite desirable for the waste management and ecosystem protection. Recently, many studies have focused on this problem and experimented different methods to recycle the brine sludge.

Fly ash is a fine, powdery residue generated from the combustion of pulverized coal in thermal power plants. This byproduct is collected from the flue gases using electrostatic precipitators or other particle filtration methods. Composed mainly of silica, alumina, iron, and calcium, fly ash possesses pozzolanic properties, making it a valuable supplementary cementitious material There are two main types of fly ash: Class F, derived from burning anthracite and bituminous coal, and Class C, produced from sub-bituminous and lignite coal. Class F fly ash is generally low in calcium, while Class C fly ash contains higher amounts of calcium oxide. In construction, fly ash is often used as a partial replacement for Portland cement in concrete production.. The conversion of brine sludge into building materials includes bricks as Non-Structural used the brine sludge to manufacture the non-structured material for architecture engineering. Verma et al. applied the byproduct material, brine sludge, to develop the flexible and moldable radiation shielding material. Besides, they also improved the geopolymerized brine sludge by promoting the reaction taken place in the sludge incorporated advance matrix. Masilea et al. preliminarily studied that utilization of the industrial brine sludge waste. (IBSW) as a sorbent in wet flue gas desulfurization (FGD) can solve the problem in waste management of chlor- alkali factories. Over the past decade, controlled low-strength materials (CLSM) have begun to apply in a lot of countries.

The most important reason was that CLSM could distribute randomly in complex sites. Researches about the adopting granular material in CLSM have been significantly published in recent processing of brine, which is a highly concentrated solution of salt in water. The formation of brine sludge typically occurs during various industrial processes, such as desalination, water purification, or have been separated or precipitated during the treatment. Brine sludge is a challenging waste material that requires proper handling an disposal due to its concentrated and potentially hazardous nature, especially if it contains contaminants from the original brine solution. Vireen Limbachiya has discussed that a study successfully reduced the cement content of concrete paving block by 40%. Sustainable urban drainage system (SUDs) is used for growing application of concrete paver block). K. Shyam Prakash had said, the mechanical properties and elastic modulus are improved by replacement of quarry dust. 100% replacement of sand with quarry dust gives better results in terms of compressive strength studies .The environmental effects and waste can be significantly reduced. M.Nishanth premhar The Effect of silica fume (SF) various strength properties of replacement of cement, coarse aggregate. 10% of cement weight replaced by silica fume. Result shows that 30% of silica fume in paver block attain its maximum compressive strength.

1.1 Brine Sludge and Silica Fume Paver Blocks

In the quest for sustainable construction practices, the utilization of alternative materials has emerged as a key strategy to reduce environmental impact and promote resource efficiency. Brine sludge, a by-product of desalination processes, and silica fume, a waste material from silicon and ferrosilicon alloy production, offer untapped potential as sustainable construction ingredients. This introduction serves as a gateway to explore the innovative application of brine sludge and silica fume in the development of eco-friendly paver blocks, offering a sustainable solution to both waste management and construction material demands.

Brine sludge, often regarded as a challenging waste stream due to its high salt content and alkalinity, poses significant environmental concerns if improperly managed. On the other hand, silica fume, characterized by its high silicon dioxide content and pozzolanic properties, has traditionally been underutilized despite its potential to enhance the mechanical properties of concrete and related products. By combining these two by-products, we aim to not only mitigate the environmental impact associated with their disposal but also create value-added construction materials that contribute to sustainable development goals.

The integration of brine sludge and silica fume into paver blocks presents a compelling opportunity to address both environmental and construction challenges simultaneously. By harnessing the unique properties of these by-products, such as the binding capabilities of silica fume and the potential for salt stabilization in brine sludge, we endeavor to produce paver blocks that meet or exceed industry standards for strength, durability, and environmental sustainability.

This paper explores the synthesis process, mechanical properties, environmental implications, and potential applications of brine sludge and silica fume-based paver blocks. Through comprehensive analysis and evaluation, we aim to elucidate the feasibility and viability of this innovative construction material in real-world applications. By demonstrating the technical feasibility and environmental benefits of these paver blocks, we seek to inspire broader adoption within the construction industry, driving a paradigm shift towards more sustainable practices.

The development of paver blocks utilizing brine sludge and silica fume represents a significant step towards achieving a circular economy where waste is minimized, and resources are maximized through innovative reuse and recycling strategies. By embracing such sustainable innovations, we can pave the way for a greener, more resilient built environment, where construction materials are not only functional and durable but also environmentally responsible and socially beneficial.

2. MATERIALS AND METHODOLOGY

2.1 Brine Sludge

Brine sludge refers to the solid residue or sediment that results from the treatment or processing of brine, which is a highly concentrated solution of salt in water. The formation of brine sludge typically occurs during various industrial processes, such as desalination, water purification, or chemical production, where brine is a byproduct. The composition of brine sludge can vary depending on the specific treatment process and the impurities present in the original brine solution. It often contains salts, minerals, and other solid particles that have been separated or precipitated during the treatment. Brine sludge is a challenging waste material that requires proper handling and disposal due to its concentrated and potentially hazardous nature, especially if it contains contaminants from the original brine solution. Effective management of brine sludge may involve further treatment processes, disposal in compliance with environmental regulations, or, in some cases, efforts to recover valuable materials from the sludge.

Table -1: Physical and Chemical Properties of Brine Sludge

SL.NO	PARAMETER	RESULTS	UNIT
1	$BaSO_4$	24.12	%
2	$CaCO_3$	12.80	%
3	$Mg(OH)_2$	5.8	%
4	Total Chloride as NaCl	1.80	%
5	Moisture	30.7	%
6	Acid insoluble (Sand & Silica)	16.3	%
TCLP Extract Test			
1	pH (1:25 Extract)	8.02	--
2	Lead	<0.05	mg/l
3	Cadmium	<0.05	mg/l
4	Copper	<0.05	mg/l
5	Zinc	1.18	mg/l
6	Nickel	1.62	mg/l
7	Arsenic	<0.05	mg/l
8	Hexavalent Chromium	<0.05	mg/l
9	Trivalent Chromium	<0.05	mg/l

10	Mercury	BDL	mg/l
11	Free Barium as Ba except Barium Sulphate	3.60	mg/l
12	Cobalt	<0.05	mg/l
13	Fluoride as F	1.23	mg/l
14	Manganese	<0.20	mg/l
15	Selenium	<0.05	mg/l

2.2 Silica Fume

Silica fume, also known as micro silica, is a byproduct of producing silicon metal or ferrosilicon alloys. Composed mainly of fine, amorphous particles of silicon dioxide (SiO2), it's collected from furnace flue gases during the production of silicon or ferrosilicon. These particles are extremely small, with an average diameter less than 1 micron, resulting in an exceptionally high surface area per unit mass. Silica fume exhibits significant pozzolanic properties, reacting with calcium hydroxide in the presence of water to form cementitious compounds, thereby enhancing the strength and durability of concrete. It's primarily used as a supplementary cementitious material in concrete mixes to improve compressive strength, durability, and resistance to various environmental factors such as chloride ion penetration, sulfate attack, and alkali-silica reaction. Despite its benefits, handling silica fume can be challenging due to its fine particle size and tendency to form agglomerates, requiring special precautions. However, its use offers environmental benefits by utilizing industrial byproducts and contributing to the reduction of carbon dioxide emissions associated with cement production. Overall, silica fume plays a crucial role in improving the performance, durability, and sustainability of concrete structures in the construction industry.

Table -2: Physical and chemical Properties of Silica Fume

SL.NO	PROPERTIES	SILICA FUMES
Physical Composition		
1	Specific gravity	2.2
2	Mean grain size (μm)	0.15
3	Specific area cm^2/gm	15000-30000
4	Color	Light to Dark grey
Chemical composition		
1	Silicon dioxide (SiO_2)	85
2	Aluminum oxide (Al_2O_3)	1.12
3	Iron oxide (Fe_2O_3)	1.46
4	Calcium oxide (CaO)	0.2-0.8
5	Magnesium oxide (MgO)	
6	Sodium oxide (Na_2O)	0.5-1.2
7	Potassium oxide(K_2O)	
8	Loss on ignition	<6.0

2.3 Cement

Cement is a crucial building material with properties that make it integral to construction. It is a fine powder, primarily composed of limestone, clay, shells, and silica, which undergoes a high- temperature process called calcination in kilns. This process converts raw materials into clinker, a nodular substance. Grinding the clinker with a small amount of gypsum produces cement. The resulting cement is used as a binder in concrete, mortar, and other construction materials. It undergoes a hydration reaction with water, forming a solid, durable matrix that binds aggregates together. Portland cement is the most common type, but variations like blended cements exist, incorporating supplementary materials to enhance specific properties.

Cement plays a fundamental role in the construction industry, contributing to the structural integrity and durability of buildings and infrastructure worldwide. Its versatility and ability to adapt to various applications make it a cornerstone in modern construction practices.

Table -3: Physical and Chemical Properties of Cement

SL.NO	PROPERTIES	OPC
Physical Composition		
1	Specific gravity	3.1
2	Mean grain size (μm)	22.5
3	Specific area cm^2/gm	3250
4	Color	Dark grey
Chemical composition		
1	Silicon dioxide (SiO_2)	20.25
2	Aluminum oxide (Al_2O_3)	5.04
3	Iron oxide (Fe_2O_3)	3.16
4	Calcium oxide (CaO)	63.61
5	Magnesium oxide (MgO)	4.56
6	Sodium oxide (Na_2O)	0.08
7	Potassium oxide(K_2O)	0.51
8	Loss on ignition	3.12

2.4 Fine Aggregate

Fine aggregate is a granular material with particle sizes typically smaller than 5 millimeters, commonly used in construction to produce concrete and mortar. It is an essential component that, when combined with coarse aggregate, cement, and water, forms the matrix in various construction applications. The most common types of fine aggregate include sand, crushed stone dust, and gravel fines. Sand, often derived from natural sources like rivers or quarries, is the most widely used fine aggregate. Its gradation, particle shape, and texture significantly influence the properties of concrete. Fine aggregate serves several crucial purposes in construction: Water Demand, Filling voids, Strength and Durability, Economy, surface Texture.

Table -4: Physical and Chemical properties of Fine Aggregate

SL.NO	PROPERTIES	VALUE
1	Size range	0.075mm-5mm
2	Bulk density	1614.19kg/m3
3	Voids value	0.35
4	Specific gravity	2.332
5	Fineness modulus	2.44
6	Color	Brown
7	Particles shape	Angular

2.5 Coarse Aggregate

Coarse aggregate is an essential component of concrete, consisting of larger particles with sizes typically ranging from 5 to 20 millimeters. These particles, derived from various sources such as crushed stone, gravel, or recycled concrete, contribute to the structural integrity and mechanical properties of concrete when combined with fine aggregate, cement, and water. Significance of coarse aggregate in construction: structural support, particle size distribution, materials sources, particle shape and surface texture, strength and durability.

Table 4: Physical and Chemical properties of Coarse Aggregate

SL.NO	PROPERTIES	VALUE
1	Size range	4mm-10mm
2	Bulk density	1418.42kg/m^3
3	Voids value	0.48
4	Specific gravity	2.584
5	Color	Greyish black
6	Particles shape	Angular

2.6 Methodology

The research initiated with a thorough literature collection and study, delving into existing knowledge to establish a solid foundation for the subsequent phases. In terms of materials, the study incorporated a diverse range, including brine sludge, silica fume, cement, and both coarse and fine aggregate. The adherence to IS 15658 guidelines ensured a standardized approach to material selection and concrete mix design. The determination of the M35 mix ratio marked a crucial stage, establishing the specific proportions of components for optimal concrete performance. A meticulous trial mix was executed to assess the mix's workability, strength, and other pertinent properties. Subsequently, main tests were conducted, covering aspects such as compressive strength, durability, and consistency. The conclusion drawn from this comprehensive study encapsulates synthesized findings from the literature review, material analysis, mix ratio determination, and testing phases. It offers valuable insights into the overall performance and suitability of the M35 concrete mix, aligning with the study's objectives and contributing to the broader body of knowledge in the field.

3. RESULT AND DISCUSSION

3.1 Compressive Strength

The main objective of this study is to find the compressive strength of hardened concrete after subjecting of curing at room temperature for duration of 7 and 28days. The specimens were taken out of the curing tank after the completion of the curing period. They were allowed to dry at the room temperature for about 3hours. The actual dimensions of the specimens were accurately measured.

$$\text{Compressive Strength} = \frac{Load}{Cross\ Sectional\ area}$$

Table -5: Compressive strength of Paver Block

Paver Block Designation	Silica Fume (%)	Average 28 days compressive strength (N/mm^2)
M1	0	37.32
M2	10	40.11
M3	20	43.73
M4	30	47.98

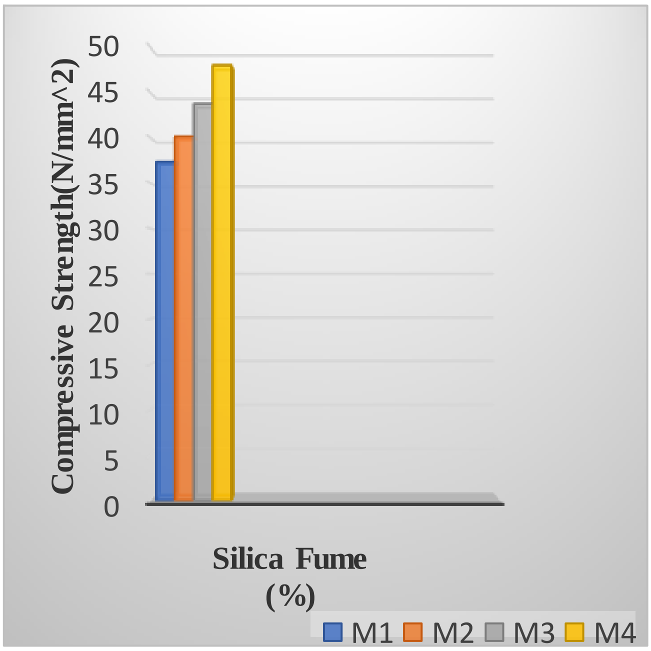

Fig -1: Compressive Strength

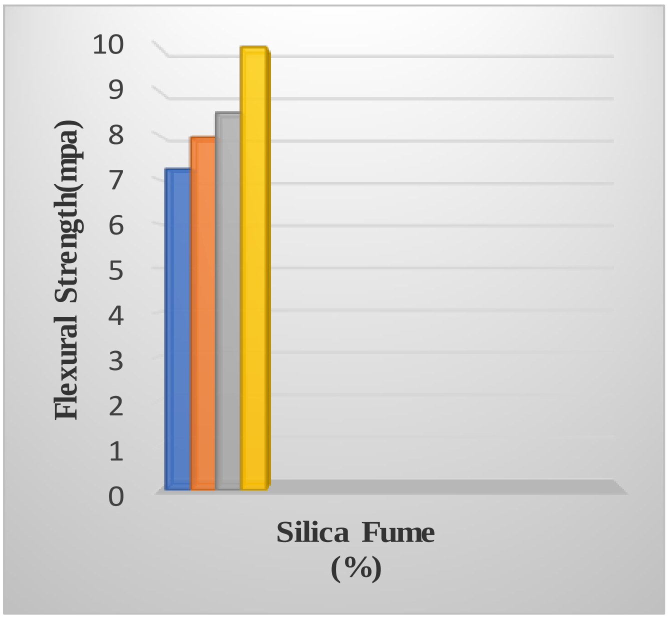

Fig -2: Graph for Flexural Strength

3.2 Flexural Strength

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an reinforced concrete beam or slab to resist failure in bending. Cracking is due to diagonal tension but mostly due to restrained shrinkage and temperature gradients. Direct application of pure tension is difficult. The theoretical maximum tensile stress reached in the bottom of the test beam is as modulus of rupture.

$$F=PL/(bd)2$$

Where,

F = Flexural strength of concrete (in MPa)

P= Failure load (in N)

L-Effective spin of the block

B-Breadth of the block

Table -6: Flexural strength of Paver Block

Paver Block Designation	Silica Fume (%)	Average Flexural strength (mpa)
M1	**0**	**7.23**
M2	**10**	**7.94**
M3	**20**	**8.50**
M4	**30**	**9.98**

3.3 Water Absorption

This test method is used to determine the rate of absorption of water by hydraulic cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water. The specimen is conditioned in an environment at a standard relative humidity to induce a consistent moisture condition in the capillary pore system. The exposed surface of the specimen is immersed in water and water ingress of unsaturated concrete is dominated by capillary suction during initial contact with water. A brick is submerged in water for 24 hours. If its weight after 24hours exceeds its dry weight by 20%, the brick is not used for construction.

Table -7: Water Absorption of Paver Block

Paver Block Designation	Silica Fume (%)	Water Absorption (%)
M1	0	1.15
M2	10	2.50
M3	20	3.86
M4	30	5.78

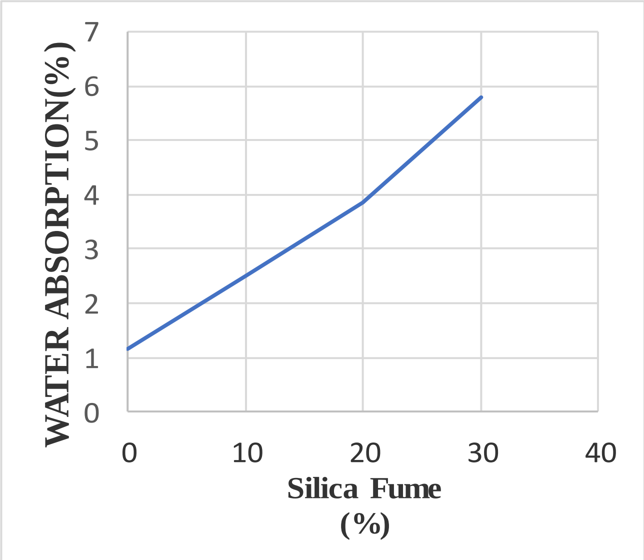

Fig -3: Graph for Water Absorption

3.4 Leachability Study

The toxic characteristic leaching procedure (TCLP) test is performed to evaluate the immobilization and stabilization of metal ions present in the hydrated product. The leaching test was conducted for 28-day cured paver block samples using the ASTM extraction D3987-85 method. The sample was ground to fine powder with a particle size passing through a number 6 sieve (0.333 cm) and retained on a number 16 sieve (0.119 cm). Thereafter, 10g of sample was added to 160mL of water and pH of solution was kept constant at 5.0 ± 0.2 by adding acetic acid (1 N). The samples were vigorously agitated (170 RPM) on a shaker for 24 hrs. Then, a 10mL sample was taken and filtered through a 0.45 μm membrane filter paper. The amount of metals leached was determined by measuring their concentration using inductively coupled plasma optical emission spectroscopy (ICP-OES, model: Prodigy XP). The results were compared with the limits for discharge of pollutants at inland surface water mentioned in Indian standard IS 10500.Theresults clearly revealed that the metal ions tested are tightly bound and retained into the material structure and do not readily leach from there. The concentration of leached metals is quite lower than the limits specified in Indian standard except for iron metal.

4.CONCLUSION

4.1 Properties of the Silica Fume-Brine Sludge Binders

The incorporation of fine silica fume particles into the binders proves to be favorable in many ways. The silica fume particles fill into the internal voids and capillary channel to decrease the number of large pores.

The measured 7-day, 14-day, and 28-day compressive strength and other properties of the cement-silica fume-brine sludge binders are summarized. From the test results, it can be observed that the properties of binders are affected by the cement/silica fume/sludge ratios.

The mix composition M1 has comparatively lower values of setting time and soundness than the mix compositions M2, M3 and M4. Data shows that the compressive strength increased with the increase in hydration period in all compositions and Maximum strength was achieved for the mix composition M4.

4.2 Water Absorption and Porosity of Silica Fume-Brine Sludge Binders

The water absorption and porosity are key factors for estimation of strength and durability of the binders.

Water absorption and porosity of all binders increased with an increase in the immersion period but became approximately linear after 7 days of immersion in water and ranked in the flowing order: M4>M3> M2 > M1 .

These results clearly shows the absence of leaching in all compositions which is ascribed to the filling up of pores in the binder matrix with the hydration products that make the binder particles integrate with each other.

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