CHAPTER 1
INTRODUCTION

1.1GENERAL

The construction industry has long sought ways to improve the performance of building materials while addressing environmental challenges. One key area of research is the use of industrial by-products and wastes in concrete production. This approach not only offers enhanced material properties but also contributes to waste management and environmental sustainability. Over the years, several industrial by-products, such as fly ash, silica fume, Ground granulated blast furnace slag (GGBS), and glass cullet, have been explored for their potential to augment the performance of concrete. These materials can be used either as partial replacements for cement or aggregate, depending on their chemical composition and particle size. Their inclusion in concrete has gained importance due to the need for safer disposal methods and the drive to reduce environmental footprints in the construction industry.

India, as the sixth-largest coal producer, plays a significant role in this field. The country produces nearly 100 million tonnes of coal annually, with its reserves predominantly consisting of lower-ranking coals like lignite, which are less suitable for high-performance applications. On the other hand, the demand for high-rank coals, such as anthracite and coking coals, is growing, especially for metallurgical and fuel purposes. Coal, as it is mined, contains various impurities like magnesium sulphate , fire clay, and pyrites, which increase the specific gravity of impure coal. These impurities necessitate coal washing techniques, such as jigging and heavy-media separation, to clean the coal before it is used. Pure coal has a specific gravity ranging from 1.2 to 1.7, while impure coal can range from 1.7 to 4.9, requiring careful screening and cleansing. The coal industry is increasingly facing the challenge of balancing growing energy demands with environmental sustainability. There is rising pressure to reduce pollution and greenhouse gas emissions, especially as society emphasizes cleaner energy sources. To remain relevant in a sustainable energy future, the coal industry must adapt to stricter environmental standards. Part of this challenge involves the effective utilization of coal by-products, such as coal bottom ash, which is generated during coal combustion. There is rising pressure to reduce pollution and greenhouse gas emissions, especially as society emphasizes cleaner energy sources. Coal bottom ash, a residue formed from the combustion of coal, is primarily composed of non-combustible materials. During combustion, the rock detritus and other impurities in coal are separated, and carbon and other combustible elements burn away, leaving ash behind. The ash particles are carried away by swirling air from the hot zone, where they cool down. Boiler flue gases transport finer and lighter particles of ash, while electrostatic precipitators capture these particles for safe disposal. This by-product of coal combustion has shown potential for use in concrete, further contributing to sustainability efforts within the construction industry by providing an alternative material for cement or aggregate replacement.

In addition to the environmental benefits and improved performance, the use of industrial by-products in concrete can lead to significant cost reductions in construction projects. Fly ash, silica fume, and other by-products are typically more affordable than traditional concrete materials like Portland cement. Their inclusion can reduce overall production costs, making infrastructure development more economical, especially in developing countries where resources are limited. Furthermore, these materials often improve the workability and durability of concrete, enhancing its long-term performance and reducing the need for maintenance, which results in further cost savings over the life cycle of a structure. The incorporation of by-products in concrete contributes to reducing the carbon footprint of the construction industry. Cement production is a major source of carbon dioxide emissions globally, accounting for a significant portion of industrial greenhouse gases. By partially replacing cement with materials like fly ash or GGBFS, the construction sector can significantly reduce its reliance on energy-intensive processes. This shift towards greener construction practices aligns with global efforts to combat climate change, promoting sustainable urban development and eco-friendly infrastructure.

1.2 GEO-POLYMER PAVER BRICKS IN INDIA

A large number of industrial by-products such as fly ash, slag, and other pozzolanic materials have been collected from various industrial sectors and are used in the manufacturing of geopolymer paver bricks as a replacement for traditional cement. These materials are available in large quantities, thus reducing the cost of production. When we have industrial waste, we can focus on reuse, recycle, and reduce principles. It is important to be mindful of our actions, carefully select sustainable building materials, and check whether we can opt for alternatives that come with less environmental impact. The global market for geopolymer materials in brick manufacturing is witnessing substantial growth, and this trend is expected to accelerate in the coming years. Geopolymers, which rely on aluminosilicate materials like fly ash, are widely recognized for their potential in replacing conventional cement, significantly reducing carbon emissions associated with construction. According to global environmental reports, industrial waste from power plants and metallurgical processes is available in abundance, making it a cost-effective alternative for the construction sector. Geopolymers use fly ash and other by-products, which account for a significant portion of industrial waste annually. However, the recycling and reuse of industrial by-products is complicated due to variations in the composition of the materials.

Despite these challenges, only a portion of the industrial waste generated is reused effectively. For instance, in the case of fly ash, around 35% is reused in construction, while the rest accumulates in landfills, leading to environmental concerns. Geopolymer bricks, used extensively for partition walls, structural walls, boundary walls, and even in road construction, provide an eco-friendly alternative. Global research over the last decade has proven that geopolymer technology can be effectively used in manufacturing bricks and paver blocks, and this innovation is one of the key drivers for the growth of the market for geopolymer materials in the manufacturing of bricks during the forecast period.

1.3 WHY INTERLOCKING CONCRETE BLOCKS ARE MADE USING COAL WASHERY REJECT AND INDUSTRIAL WASTE

Bricks are traditionally made from clay or cement, both of which are finite natural resources. The overuse of these materials contributes to the depletion of resources and increases carbon emissions. On the other hand, coal washery waste a by-product of coal processing is often disposed of in landfills, causing soil and water pollution. The use of this waste in the form of geopolymer materials can significantly reduce the need for cement and clay, while also addressing the environmental challenges posed by coal waste disposal Utilizing coal washery waste to develop environmentally friendly geopolymer interlocking blocks presents a sustainable solution. This approach not only minimizes the carbon footprint associated with cement production but also reduces the quantity of waste going to landfills. Geopolymer technology leverages aluminosilicate-rich by-products like coal washery waste, transforming them into durable, eco-friendly construction materials. The use of coal waste also lowers the cost of manufacturing geopolymer blocks, making it a more economical alternative to conventional bricks. This encourages the sustainable reuse of industrial waste while contributing to green construction practices. As the global construction industry moves toward environmentally friendly alternatives, geopolymer interlocking blocks offer a solution for reducing both resource consumption and environmental pollution. It can be concluded that coal washery waste-based geopolymer blocks provide a promising solution for the safe and efficient use of industrial by-products. However, more extensive research and experimental studies are necessary to fully explore the potential of using coal washery waste as a raw material for large-scale geopolymer block production. By optimizing these processes, the construction industry can contribute significantly to waste reduction and sustainable development.

1.4 ADVANTAGES OF CWR PAVER BLOCK

1.4.1 Waste Utilization and Environmental Sustainability

Utilizing coal washery waste in geopolymer interlocking blocks addresses critical waste management challenges by repurposing industrial by-products in a sustainable manner. Coal washery waste, a by-product of coal cleaning, traditionally poses significant environmental hazards, including risks to land and water quality due to improper disposal. By incorporating this waste into construction materials, the need for extensive landfill space is minimized, effectively reducing pollution and mitigating environmental damage.

This approach aligns with circular economy principles, transforming what would otherwise be a disposal burden into a valuable asset for construction. The production of geopolymer blocks from coal washery waste not only lessens reliance on traditional cement but also demonstrates a responsible, low-carbon alternative that benefits both industry and the environment. Through this innovative recycling, the construction industry can contribute positively to sustainability, advancing both ecological preservation and resource efficiency.

1.4.2 Reduction in Greenhouse Gas Emissions

Traditional cement production is a major contributor to carbon dioxide emissions due to the energy-intensive process of clinker production. Geopolymer technology, however, offers a low-carbon alternative by using industrial waste materials as a binder instead of Portland cement. The use of coal washery waste in geopolymer blocks drastically reduces the reliance on cement and cuts down CO_2 emissions, contributing to global efforts to mitigate climate change.

1.4.3 Cost-Effective and Sustainable Construction

Geopolymer interlocking blocks are often more cost-effective to produce because they rely on readily available industrial wastes like coal washery residues, which are cheaper than conventional building materials. Furthermore, the interlocking design of these blocks reduces the need for mortar and skilled labour during construction, leading to quicker and more economical building processes. This makes them particularly beneficial for low-cost housing and infrastructure projects, especially in regions with limited access to expensive raw materials.

1.4.4 Improved Durability and Strength

Geo-polymer blocks exhibit excellent mechanical properties, including high compressive strength, fire resistance, and durability. Coal washery waste, when used as part of the geopolymer mixture, enhances the block's performance by providing a strong and stable matrix. These blocks are resistant to harsh environmental conditions, making them suitable for long-lasting structures in various climates.

1.4.5 Energy Efficiency

Unlike traditional fired clay bricks or cement blocks that require high-energy processes, geopolymer blocks can be cured at room temperature. This significantly reduces the energy required for production, further contributing to their environmental friendliness. Additionally, the blocks' insulating properties can lead to more energy-efficient buildings, reducing the need for heating or cooling and contributing to lower energy consumption over time.

1.4.6 Modular and Versatile Design

The interlocking feature of these blocks allows for easier construction and modular designs, making them ideal for quick assembly and disassembly. This flexibility is beneficial for temporary structures, disaster relief housing, and projects requiring rapid development. Their precision in design also reduces construction waste and ensures better alignment, leading to more stable and durable buildings.

1.5 FUTURE WORK

Research can focus on refining the mix design by incorporating different ratios of coal washery waste with other industrial by-products (e.g., fly ash, GGBS) to maximize strength, durability, and environmental benefits. Investigate advanced curing methods like steam or microwave curing to reduce the time required for blocks to reach full strength, making them more practical for large-scale construction.

- Perform comprehensive life cycle assessments and carbon footprint studies to quantify the environmental impact and demonstrate the sustainability benefits of geopolymer blocks.

- Conduct long-term studies to assess the blocks' real-world performance under different environmental conditions, such as weathering, chemical exposure, and freeze-thaw cycles.
- Focus on scaling up the production process, including developing automated manufacturing systems and cost-effective methods for processing coal washery waste, to make the blocks commercially viable.

1.6 OBJECTIVES

- To develop geopolymer interlocking blocks using coal washery waste as binder material
- To study the mechanical properties (compressive strength) and durability properties (Water absorption and Fire resistance) of geopolymer interlocking block containing CWR as a partial substitute of binder material at different proportions (0% - 30%)
- To explore the feasibility of using industrial waste in construction and compare the performance of these interlocking blocks with traditional blocks

1.7 SCOPE

- This research investigates the feasibility and benefits of using coal washery rejects as a partial replacement for geopolymer concrete. It focuses on analyzing material properties as well as evaluating mechanical properties
- The goal is to provide a comprehensive assessment of the performance and durability of concrete with coal washery rejects, promoting sustainable construction practices.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Literature review describes about the previous journal papers and research papers who did some research and projects related to geopolymer technology Interlocking Blocks used on Coal Washery Waste and Industrial waste

2.2 LITERATURE REVIEW

Bhogayata and Arora et.al (2020), The workability of concrete decreased with the increase in bottom ash content due to the increase in water demand. The compressive, splitting tensile and flexural strength properties of concrete using bottom ash as fine aggregate were lower than control concrete at all ages. But, after 28 days the strength difference between bottom ash concrete and control concrete specimens was less distinct

Shyam and Prakash Koganti et al. (2017), explored the The early age compressive strength of concrete using granulated blast furnace slag (GBFS)as fine aggregate was lower than concrete made with river sand, but at later ages the strength was higher

Balasubramanian et al. (2020) It have done tests in this study to compare the compressive strength of a typical block to the results of completely replacing fine aggregate with demolition trash. Concrete paver blocks with the M40 mix design were used in the test. Results show that the concrete paver blocks compressive strength has decreased slightly compared to the conventional concrete mix. Therefore, low load-bearing pavements can employ the concrete blocks created from demolition trash. The study has suggested using such paver blocks for low volume traffic roads

Jerome Song Yeo et al. (2021) It have used various types of waste materials in making the paver blocks. Some of such waste materials were soda-lime glass, recycled concrete wastes, marble waste, crumb rubber wastes, etc. The study investigated the impact of waste materials on the mechanical properties of paving blocks. The study has shown that soda-lime glass, recycled aggregates, marble wastes, and crumb rubber wastes could be mixed at appropriateproportions to make high-performance paver blocks**.**

Suchithra et.al (2022) It has been investigated whether building and demolition trash, as well as recycled plastic waste, may be used to make paver blocks. They suggested that C&D waste be mixed with melted polyethylene terephthalate wastes. The study was done to find the durability, water absorption, compressive strength, and flexural strength of the blocks and have seen acceptable results for their use

Yazi Meng et al. (2018) It highlight the typical qualities of concrete blocks made using waste materials. The study shows that the fire resistance properties of the blocks were improved by using recycled crumb rubber, plastic wastes, and crushed bricks. Moreover, the proportion of waste materials used in concrete blocks can be increased significantly to substitute the natural aggregate to meet the specifications for concrete blocks

Uygunoğlu, T., Topcu, I. B., Gencel, O., & Brostow, W. (2012) The effect of fly ash content and types of aggregates on the properties of pre-fabricated concrete interlocking blocks (PCIBs). Construction and Building Materials, 30, 180-187.

Eshmaiel et al (2014) It have explored ways to reduce cement content in paving blocks by incorporating waste and by-product materials such as ground granulated blast-furnace slag (GGBS), plasterboard gypsum (PG), and cement bypass dust (BPD). Different mixtures, including binary and ternary blend combinations, were considered. Tests on tensile strength, skid/slip resistance, and freeze/thaw durability of paving blocks show that a cementitious mix containing up to 5% GGBS, BPD, and plasterboard gypsum (by weight) can effectively replace Portland cement without significantly impacting strength or durability. Results from XRD and XRF tests for selected mixtures have been presented and analyzed. Compared to typical factory cement use, concrete blocks incorporating GGBS and BPD can reduce cement content by up to 30%

Olofinnade et al. (2021) discussed solid waste management in developing countries and the reusing of steel slag aggregate in eco-friendly interlocking concrete paving blocks production. Although the research addressed the utilization of waste materials in concrete production, it did not specifically mention the integration of e-waste and industrial waste in the manufacturing process.

Bhogayata and Arora et.al Introduced 0.5%, 1.0%, 1.5%, and 2.0% metalized plastic waste. It is observed that compressive strength decreases with an increase in plastic content while a decrement in density is recorded. Tensile strength was observed to increase up to 1%, and after that, a decrement was seen for both flexural and splitting tensile strength. The reference value is taken as 41 MPa for compressive strength; 3.55 MPa and 3.10 MPa for flexural tensile strength and splitting tensile strength, respectively; and 2,460 kg/m3 for density. It is observed that the plastic content brick shows less compressive strength, greater tensile strength, and less density com- pared to the reference brick.

Siddique R et.al It was suggested that copper slag can be used as a replacement for fine aggregate to obtain a concrete with good strength and durability requirements

De Brito J et.al The incorporation of plastic aggregate (PA) decreased the slump of the fresh concrete. The strength properties and modulus of elasticity of concrete using PA as coarse aggregate are always lower than the control concrete

Energy Statistics et.al, The generation of rejects from washeries in Coal India Limited (CIL) in 2004-05 was 2.44 Mt. Accumulated stock of washery rejects up to March'05 was 18.15Mt. The coal washery rejects (CWR) are the major environmental hazard during the process of coal washing. Disposal of this huge quantity of rejects in an environment friendly manner creates a real problem. For solving the disposal of large amount of coal washery rejects, reuse of CWR in concrete industry can also be considered as the most feasible application

Huggins FE et.al , During the coal washing process, cleaned coal carried out by the water flow over a weir and the refuse sinks at the bottom. Refuse is removed time to time from the washer and stored in bunker storage. This refuse which is stored in bunker storage is called coal washery rejects (CWR)

2.3 SUMMARY OF THE LITERATURE

- Coal washery waste typically contains fine coal particles, clay, shale, and other impurities, which can be used as an aluminosilicate source in geopolymer synthesis.
- The production of geopolymer blocks from coal washery waste emits up to 80% less CO_2 compared to conventional Portland cement-based blocks.
- Research indicates that a coal washery waste-to-activator ratio of approximately 3:1 provides the best balance between workability and strength in geopolymer blocks.
- The dense microstructure of geopolymer blocks results in water absorption rates as low as 5–10%, compared to conventional blocks, which can absorb up to 20% water.
- While initial costs may be higher due to alkaline activator use, the long-term durability, lower maintenance, and reduced environmental impact make geopolymer blocks a cost-effective choice over their lifecycle.

CHAPTER 3

METHODOLOGY AND EXPERIMENTATION

3.1 GENERAL

The physical and chemical properties of materials, methodology and mixture proportions of concrete to be used in this work are discussed in this chapter.

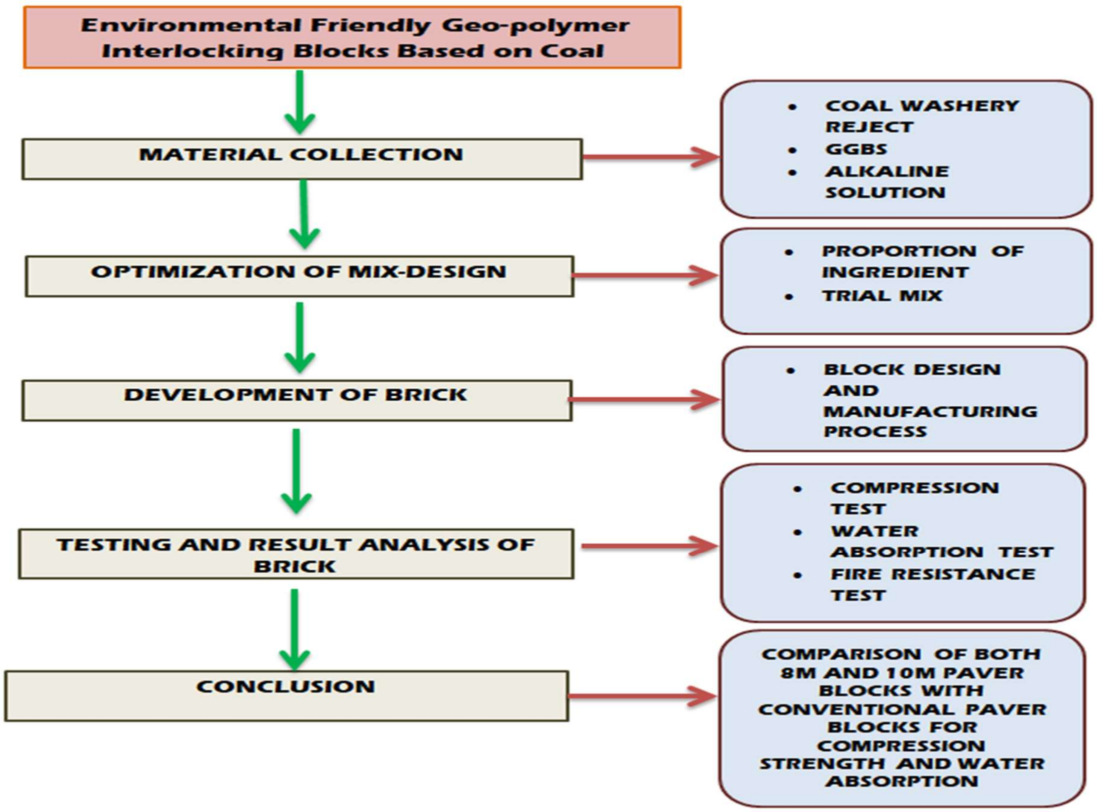


Figure 3.1 Methodology

3.2 PROPERTIES OF RAW MATERIALS

In the manufacturing process, several raw waste materials are used as follows.

1. Manufactured-sand (M-sand)
2. Sodium silicate
3. Sodium hydroxide
4. Coal washery reject
5. Ground granulated blast furnace slag (GGBS)
6. Gravel
7. Mould (I-shaped)

3.2.1 Manufactured sand(m-sand)

M-sand or manufactured sand, is a type of sand produced by crushing rocks, typically granite or basalt, to create sand-sized particles. Unlike natural sand, which is usually obtained from riverbeds or beaches, M sand is engineered to be a high-quality alternative with consistent properties. Here are some key characteristics and descriptions of M sand:

- Production: M sand is made by crushing rocks into sand-sized aggregates. The process involves feeding the rocks into a crusher, which breaks them into smaller pieces, and then further grinding them to achieve the desired sand texture.
- Quality: M sand is designed to have consistent grain size and shape, making it suitable for construction. It often has a cubical or angular shape, which can provide better bonding with cement compared to natural sand. Refer figure 3.2

Figure 3.2 Manufactured Sand Or M-Sand

Table 3.1 Physical properties of manufactured sand (M-sand)

S.No	Property	Typical value/range
1	Particle size	150 microns to 4.75 mm
2	Shape and texture	Angular and rough
3	Fineness modulus	2.6 to 3.5
4	Water absorption	2% to 4%
5	Specific gravity	2.5 to 2.9
6	Moisture content	Low (depends on storage conditions)
7	Consistency	Consistent due to manufacturing

3.2.2 Sodium Silicate

Sodium silicate, also known as water glass or liquid glass, is an essential component in the production of geopolymer concrete, an eco-friendly alternative to traditional Portland cement concrete. In geopolymer concrete, aluminosilicate materials such as fly ash, slag, or metakaolin are used as the primary binder instead of cement. These materials are activated using alkaline solutions, typically a combination of sodium silicate and sodium hydroxide. Sodium silicate plays a critical role by enhancing the dissolution of aluminosilicate precursors, allowing for the formation of a three-dimensional geopolymer network. This process is key to developing the strength and durability of geopolymer concrete. Refer figure 3.3

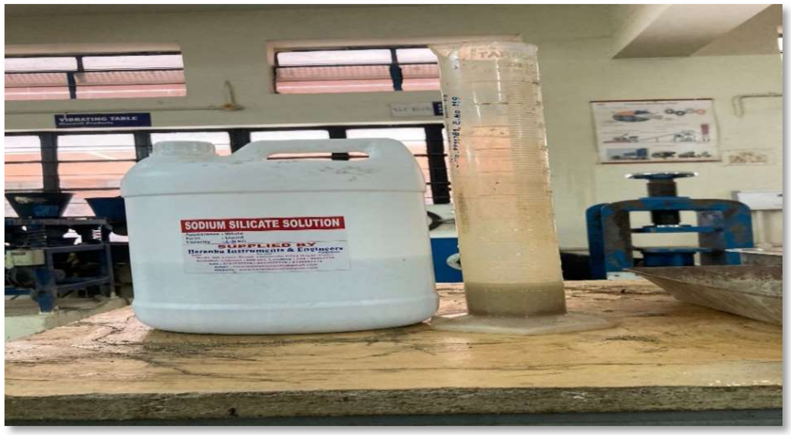


Figure 3.3 Sodium Silicate

Table 3.2 Physical properties of sodium silicate:

S.No	property	Typical Value/Ranges
1	Appearance	Colorless to light yellow
2	Molecular Weight	Varies based on composition
3	Solubility in Water	Highly soluble
4	Viscosity	Viscous liquid
5	pH Value	Typically 11 to 13
6	Refractive Index	Approximately 1.46 to 1.48
7	Conductivity	Varies based on concentration

3.2.3 Sodium Hydroxide

Sodium hydroxide (NaOH) is a critical alkaline activator used in the geo-polymerization process, which transforms aluminosilicate materials (such as fly ash, slag, or metakaolin) into a durable binder. When mixed with water, NaOH dissociates into sodium ions (Na^+) and hydroxide ions (OH^-), creating a highly alkaline solution that facilitates the activation of the aluminosilicate materials. Refer figure 3.4

Figure 3.4 Sodium Hydroxide

Table3.3 Physical properties of sodium hydroxide (NaOH):

S.No	property	Typical Value/Ranges
1	Melting Point	318 °C (604 °F)
2	Boiling Point	1380 °C (2516 °F)
3	Density	2.13 g/cm³ (solid)
4	Solubility in Water	111 g/100 mL at 20 °C
5	pH	pH > 14 in solution
6	Viscosity	~1.0 mPa·s (at 20 °C)
7	Conductivity	High (depends on concentration)

3.2.4 Coal Washery Reject

Coal washery rejects, commonly referred to as coal rejects or coal tailings, are by-products produced during the washing and cleaning of coal. These rejects consist of non-valuable materials that are separated from clean coal in the beneficiation process, including a mix of fine coal particles, ash, and various impurities. The composition of coal washery rejects can vary significantly based on the quality of the raw coal and the specific washing techniques employed.

The disposal of these rejects raises significant environmental concerns, as they can contribute to land degradation, water pollution, and air quality issues if not managed appropriately. However, recent research has highlighted their potential for utilization in construction materials, such as geopolymer blocks and bricks, which can help mitigate waste and promote sustainable practices. By reusing coal washery rejects, the construction industry can reduce reliance on traditional raw materials, leading to economic benefits through cost savings and minimizing disposal fees**.** The physical properties of coal washery rejects, such as particle size and moisture content, play a crucial role in determining their suitability for various applications. As the demand for environmentally friendly construction solutions increases, coal washery rejects present a valuable opportunity for promoting circular economy principles in the coal industry while addressing environmental challenges.Refer figure 3.5

Figure 3.5 Coal Washery Reject

Table 3.4 Physical Properties of Coal Washery Reject:

S.No	property	Typical Value/Ranges
1	Particle Size	0.1 mm to 2 mm (can vary)
2	Moisture Content	5% to 20%
3	Bulk Density	1.0 to 1.5 g/cm³
4	Ash Content	30% to 50%
5	Calorific Value	2,000 to 4,500 kcal/kg
6	pH Value	6 to 8 (slightly acidic to neutral)

3.2.5 Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast Furnace Slag (GGBS or GGBFS) is a by-product of steel manufacturing, formed when molten iron slag is rapidly cooled and granulated. Refer figure 3.6 ,Its pozzolanic properties allow it to react with calcium hydroxide in the presence of water, forming additional cementitious compounds that contribute to the overall strength of the concrete mix. In geopolymer concrete, GGBS plays a crucial role by providing an aluminosilicate source, enhancing the binder's characteristics while reducing the carbon footprint associated with traditional Portland cement. The incorporation of GGBS not only improves workability and reduces heat generation during hydration but also contributes to the long-term sustainability of concrete structures, making it a valuable material in eco-friendly construction

Figure 3.6 Ground Granulated Blast Furnace Slag (GGBS)

Table 3.5 Physical Properties of Ground Granulated Blast Furnace Slag

S.No	Property	Typical Value/Ranges
1	Specific Gravity	2.8 - 3.0 g/cm³
2	Bulk Density	0.9 - 1.2 g/cm³
3	Fineness (Blaine Surface Area)	300 - 600 m²/kg
4	Chemical Composition (SiO_2)	30 - 40%
5	Chemical Composition (Al_2O_3)	8 - 15%
6	Chemical Composition (CaO)	30 - 50%
7	Loss on Ignition	0.5 - 2.0%

3.2.6 Gravel

Gravel is a naturally occurring or crushed rock aggregate commonly used in construction. It comes in various sizes, with fine gravel or small coarse aggregate being a smaller variant. Typically, the size of the gravel used is around 6mm, falling between the categories of fine and coarse aggregate. This type of aggregate is valued for its strength and stability in concrete mixes, offering improved workability, while maintaining structural integrity. Gravel's natural composition, coupled with its size, makes it an ideal component in applications requiring a balance of strength and smooth finish. Refer figure 3.7

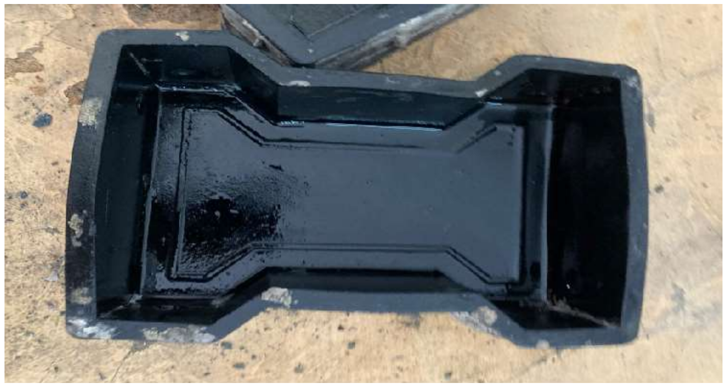
Figure 3.7 Gravel

Table 3.6 Physical Properties of Gravel:

S.No	Property	Typical Value/Range
1	Particle Size	2 mm to 64 mm
2	Specific Gravity	2.65 – 2.75
3	Density	1,520 – 1,680 kg/m³
4	Porosity	25% – 40%
5	Water Absorption	0.5% – 1.5%
6	Shape	Angular, sub-angular, or rounded
7	Bulk Density	1,500 – 1,700 kg/m³

3.2.7 Mould

"I" shaped paver bricks are widely recognized for their distinctive interlocking design, which enhances both stability and visual appeal in various paving applications. The "I" shape allows for an efficient and robust interlocking pattern that distributes loads evenly across the surface, reducing the risk of shifting or displacement under pressure. This makes them especially suitable for areas exposed to heavy traffic, such as roads, parking lots, and industrial spaces. Additionally, the interlocking feature improves the structural integrity of paved surfaces by providing better resistance to lateral forces. These paver bricks are easy to install and maintain, making them a practical and cost-effective choice for both residential and commercial projects. Their design also contributes to better water drainage, minimizing surface water accumulation and enhancing safety in wet conditions. Refer figure 3.8



Dimension: 250*100*70 mm

Figure 3.8 Mould (I-Shaped)

3.3 OPTIMIZATION OF BINDER MATERIAL AND UTILIZATION OF GEOPOLYMER INTERLOCKING BLOCKS USING COAL WASHERY REJECT AS FILLER MATERIAL

The optimization of binder composition in geopolymer interlocking blocks, incorporating coal washery waste (CWW) as a filler, focuses on creating a sustainable and efficient alternative to traditional construction materials. Geopolymer binders, made from aluminosilicate materials like fly ash and activated by solutions such as sodium hydroxide and sodium silicate, offer benefits like reduced carbon emissions, high strength, and long-term durability. In this method, coal washery waste serves as a filler material, tested in various proportions of 8M and 10M. The goal is to enhance the sustainability of the interlocking blocks without compromising their strength and durability.

Key factors influencing the composition include the ratio of binder additives, the concentration of activating solutions, and the curing conditions. To ensure the blocks meet construction standards, tests are conducted to evaluate compressive strength, water absorption, and thermal properties. These tests help determine the optimal blend that provides robust, durable, and efficient blocks for construction use. Beyond the technical aspects, utilizing CWW in this way contributes to environmental sustainability by reducing the carbon footprint and addressing waste management issues. This process also offers economic benefits by using low-cost industrial by-products. However, further research is necessary to ensure long-term durability and consistency, especially in large-scale production

3.3.1 Mix Ratio

Table 3.7 Mix ratio of CWR paver blocks

S/no	COARSE AGGREGATE	FINE AGGREGATE	GGBS	COAL WASHERY REJECT	NaoH	Na2SiO3
1	8.1 kg	1.72 kg	1.47 kg	745 gm	405ml	990ml

Table 3.8 Mix ratio of alkaline solution

S/no	DESCRIPTION	SODIUM HYDROXIDE(NaOH)	WATER (H2O)
1	8 Molarity	320 g	1000 ml
2	10 Molarity	360 g	1000 ml
3	12 Molarity	400 g	1000 ml

Table 3.9 Percentage of mix ratio

Aggregates			Binder + Activator			
70%			30%			
			Binder		Activator	
C&D waste	Gravel	M sand	GGBS	Coal washery reject	NaOH	Na_2SiO_3
28%	12%	30%	12%	7%	3.2%	7.8%

3.4 STEPS INVOLVED IN THE MANUFACTURING PROCESS

3.4.1 Collection of Material

Coal washery rejects can be collected from coal washery plants and also there is a need of sodium silicate and sodium hydroxide for the geopolymer concrete which is bought from local suppliers. GGBS, M sand, and gravel stones can be purchased from the local supplier.

3.4.2. Batching of Material

Measurement of material is called Batching. After collection of the material weighed and batched accordingly and moisture content is checked if presented, then dried

3.4.3 Mixing

The batched materials are one by one added in which sodium hydroxide is mixed with water and kept for 24 for the formation of alkaline solution with respective quantity, after it is continuously stirred so that materials get mixed properly and bonded

3.4.4 Moulding

Apply the oil on the inner surface of mould so that bricks can be removed easily. If oil is not applied, after solidification of brick will not come out easily. So proper oiling is needed before filling the mixture in the mould. Prepared mixture is filled into the wooden mould and tamping is done by rod to achieve proper compaction and the wooden mould is filled properly. And block can be removed from the mould after 24 hours.

Figure 3.9 steps involved in manufacturing process

3.4.5 processing

The processing of geo-polymer interlocking blocks begins with collecting materials such as coal washery rejects, sodium silicate, and sodium hydroxide from local suppliers. Additional materials like Ground Granulated Blast Furnace Slag (GGBS), manufactured sand (M sand), and gravel stones are sourced locally for quality assurance. In the batching phase, materials are accurately measured and weighed, with moisture content checked and adjusted as needed. Sodium hydroxide is then mixed with water to create an alkaline solution, and allowed to sit for 24 hours for activation. The mixture is poured into oiled moulds, tamped for compaction, and set for 24 hours before removal as filler material in addition to GGBS and acts as binding material. enhances the mechanical properties of the final product.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 GENERAL

In this chapter, the experimental results obtained are discussed and presented in the form of a table for clarity. A detailed analysis of the performance of geo-polymer interlocking blocks made from coal washery waste is provided. The test results are examined thoroughly, highlighting key performance trends and structural responses.

4.2 INVESTIGATION OF PROPERTIES OF GEOPOLYMER PAVER BLOCKS USING VARIOUS TESTS

4.2.1 Compressive Strength Test (IS 3495-1992 Part 1):

In this study, the impact of compressive strength on newly developed WPB has been tested by applying compressive force in the range of 14 N/mm^2. After the moulding process, the well-defined shape brick has been kept in a compression testing machine and then the compressive force has been applied slowly on the brick surface till the sample get brittle. From the analysis, the compressive strength of the brick has been evaluated by using the given below equation. Kindly refer to Figures 4.1 and 4.2. illustrate the comprehensive test of 5%, conventional paver bricks and Table 4.1 the result and values are provided in Table 4. Compressive Strength of Bricks = Maximum Load at Failure (N)/ Area of bed face (mm^2)

Table 4.1 Results of compression strength test

S/NO	DESCRIPTION	NO OF SPECIMEN	AREA (mm^2)	WEIGHT (Grams)	PEAK LOAD (kN)	AVG PEAK LOAD (kN)	COMPRESSION STRENGTH (MPa)
1	8 MOLARITY	SAMPLE 1		4000 Gm	819 kN		
		SAMPLE 2	0.0028	3870 Gm	955 kN	903.67 kN	32.27 MPa
		SAMPLE 3		3870 Gm	937 kN		
2	10 MOLARITY	SAMPLE 1		3890 Gm	735 kN		
		SAMPLE 2	0.0028	3810 Gm	715 kN	823.67 kN	29.94 MPa
		SAMPLE 3		3730 Gm	1021 kN		
3	STANDARD BRICK	SAMPLE 1	0.0028	3560 Gm	865 kN	865 kN	31.97 MPa

Figure 4.1 Compressive strength of 8 molarity paver blocks

Figure 4.2 Compressive strength of 10 molarity paver blocks

CALCULATIONS :

8 molarity paver block peak load : 903.67 kN ; Area : 0.028mm^2

Compressive strength of 8 molarity brick : $\dfrac{903.67 * 1000}{28000}$: 32.27 MPa

10 molarity paver block peak load : 823.67kN ; Area : 0.028mm^2

Compressive strength of 10 molarity brick : $\dfrac{823.67 * 1000}{28000}$: 29.42 MPa

Standard brick peak load :865KN Area: 0.028m^2

Compressive strength of no plastic brick $: \frac{865*1000}{2800}$: 31.97 N/mm^2

Note: Minimum average compressive strength of brick shall not be less than 7.5 N/mm^2 when tested as per IS-3495 (Part1):1992. The compressive strength of any individual brickshall not be falling below the minimum average compressive strength by more than 20%.

4.2.2 Water absorption test (IS:3495Part-2)

In this work, to conduct a water absorption test of the waste plastic bricks first weighed in dry condition and they are immersed in water for 24 hours. After that, they are taken out from the water and they are wiped out with cloth. Then the difference between the dry and wet bricks percentage is calculated. brittle. From the analysis, the compressive strength of the brick habeen evaluated by using the given below equation

Figure 4.3 Weight Before water absorption of 8 And 10 Molarity

Figure 4.4 Weight Before water absorption of 8 And 10 Molarity

Table 4.1 Result of water absorption test

	DESCRIPTION	DRY WEIGHT OF SPECIMEN (W1)	WET WEIGHT OF SPECIMEN(W2)	RESULT (%)
1	8 Molarity	4.15 kg	4.25 kg	2.35%
2	10 Molarity	4.45kg	4.5 kg	1.12%

CALCULATION :

Water absorption of paver blocks : $\frac{(W2-W1)*100}{W2}$

8 molarity : $\frac{(4250 - 4150)*100}{4250}$

: 2.352

10 molariy : $\frac{(4500 – 4450)*100}{4500}$

: 1.12

Note: The bricks when tested in accordance with the procedure laid down in IS: 3495 (Part-2):1976 afterimmersion in cold water for 24 hours, shall have water absorption not more than

S.No	Test Conducted	8 MOLARITY	10 MOLARITY	Conventionl Specimen	Tested asper Standard	Limitsas per code
1	Fire ResistanceTest	One Hour	One Hour	One Hour	ASTM E119	OneHour

20%.

4.2.3 Fire resistance test (ASTM E119):

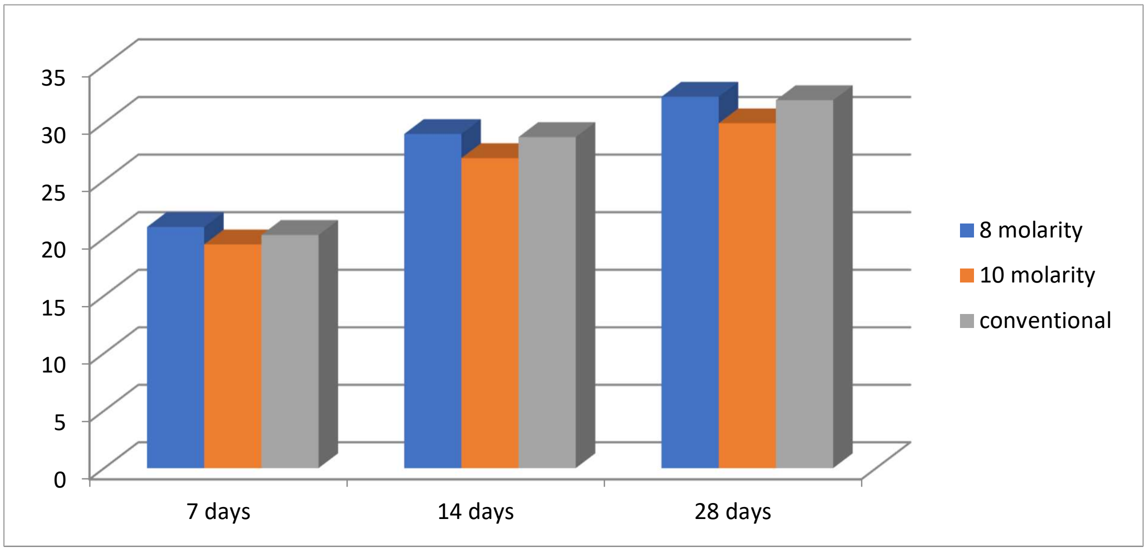
In this work, to find out no change in the structural properties of block of bricks up to 180ºC to check visible cracks are seen and to find deterioration with increase in temperature.

Table 4.3 Result for fire resistance test

4.3 DISCUSSION

The compression strength and water absorption of coal washery reject paver block of different 8 and 10 molarity are done. In which 8 molarity having higher compression strength as compared to 10 molarity paver block and conventional paver block, Refer chart 4.1

Chart 4.1 comparison of 8 molarity,10 molarity and conventional paver brick



In case of water absorption 10 molarity geo-polymer paver blocks is showing less absorption compared to 10 molarity and conventional paver blocks .even though 8 molarity paver block is having higher water absorption as compared to other 10 molarity it is lesser than the conventional or standard paver block tested . Grade of concrete for all the sample of paver block that is of conventional , 8 molarity and 10 molarity are m25. In which 8 molarity and 10 molarity having 30 % replacement of cementitious material which mainly include cement ,Using cement in concrete paver blocks has several drawbacks compared to using coal washery reject and GGBS

- **Environmental Impact**: Cement production is a significant source of CO_2 emissions, contributing to climate change. Using coal washery reject and GGBS reduces the carbon footprint of concrete paver blocks1.
- **Resource Depletion**: Cement production requires large amounts of natural resources, including limestone and clay. Utilizing coal washery reject and GGBS helps conserve these resources.

- **Energy Consumption**: The manufacturing process for cement is energy-intensive. Coal washery reject and GGBS can be used with less energy, making the production process more sustainable.
- **Waste Management**: Coal washery reject is a by-product of coal processing that would otherwise be disposed of in landfills. Using it in concrete paver blocks promotes waste recycling and reduces landfill waste.
- **Cost**: Cement can be more expensive than coal washery reject and GGBS, especially when considering the long-term environmental and social costs associated with its production.

By addressing these drawbacks, using coal washery reject and GGBS in concrete paver blocks offers a more sustainable and cost-effective alternative to traditional cement-based materials.

4.4 SOCIAL RELEVANCE AND USEFULNESS OF CWR PAVER BRICKS:

- **1. Reduction of Industrial Waste:** Coal washery waste, a by-product of coal processing often dumped in landfills, contributes to environmental pollution. Developing construction materials from this waste helps reduce environmental burden, promoting sustainable waste management.

- **2. Reduction in Mining and Raw Material Extraction:** Traditional building materials like cement and clay bricks require significant natural resource extraction. Using coal washery waste to create interlocking blocks decreases demand for virgin raw materials, preserving natural resources and minimizing ecological degradation.
- **3. Geo-polymers as Sustainable Alternatives:** Geo-polymers have a lower carbon footprint compared to traditional Portland cement. By using geo-polymer technology, the project reduces CO_2 emissions, critical for mitigating climate change.
- **4. Cost-Effective:** Utilizing waste materials and reducing reliance on traditional cement-based products can lower production costs of geo-polymer interlocking blocks, making them an affordable alternative, especially for low-cost housing.
- **5. Resource Conservation:** Decreases demand for natural resources by substituting traditional materials like cement and clay bricks.
- **6. Lower Carbon Footprint:** Geo-polymer technology minimizes CO_2 emissions compared to traditional Portland cement, contributing to climate change mitigation.

- **7. Job Creation:** Stimulates local economies through job opportunities in the collection, processing, and manufacturing of geo-polymer blocks.
- **8. Community Engagement:** Involves local communities in production processes, raising awareness about sustainability and waste management.
- **9. Infrastructure Improvement:** Enhances the quality and resilience of infrastructure in urban and rural areas with durable building materials.
- **10. Energy Efficiency:** Provides better thermal insulation, leading to lower energy consumption for heating and cooling.
- **11. Innovative Waste Utilization:** Encourages other industries to adopt similar waste repurposing practices, promoting a circular economy.
- **12. Regulatory Compliance:** Aligns with sustainability regulations, helping builders meet local and international construction standards.
- **13. Educational Opportunities:** Serves as a learning platform for students and professionals in sustainable construction practices.

This project offers a socially relevant solution by addressing environmental waste, promoting sustainable construction, and providing cost-effective housing solutions. It contributes to reducing the carbon footprint of the construction industry, promotes waste recycling, and supports economic development in both urban and rural areas

CHAPTER 5
CONCLUSION

5.1 SALIENT CONCLUSION

The study investigated the feasibility of incorporating coal washery reject as a replacement for cementitious materials in the concrete modifies its mechanical properties, durability properties, temperature resistance, bond strength and structural behaviour (shear and flexure). These blocks exhibit longer lasting strength and durability than conventional concrete use has been demonstrated, and in some cases makes it suitable for use in buildings Instead, it reduces the carbon footprint associated with building materials because In the production of geo-polymer greenhouse gases less occurs when compared to conventional cement but the process is cost-effective and energy efficient, providing a viable solution for affordable housing and the implementation of projects The test results obtained from this study also provide significant understanding on the basic properties and the structural behaviour of environmentally geo-polymer concrete paver block made using coal washery reject and GGBS. This study gives suggestions for the proper use of coal washery reject which will hopefully lead to promotion of sustainable development in the construction industry. The following conclusion has been derived from the experimental work carried out:

- The composition of the interlocking block consists of a balanced mixture of aggregates, binders, and activators designed for strength and sustainability. Aggregates form 70% of the total mixture, 12% gravel, and 30% manufactured sand (M-sand). These materials provide the bulk and structural integrity of the block. The remaining 30% is made up of binders and activators. Ground Granulated Blast-furnace Slag (GGBS) makes up 12% of the binder component, while coal washery reject accounts for 7%, contributing to the block's cohesiveness. To activate the binding process, 3.2% sodium hydroxide (NaOH) and 7.8% sodium silicate (Na_2SiO_3) are used, initiating the chemical reactions needed to solidify the block. This formulation, with a significant use of recycled materials and industrial by-products, suggests that the interlocking block is designed to be both environmentally friendly and structurally robust, ideal for sustainable construction applications.

- Coal Washery Rejects (CWR) replace 30% of the binder content, which balances the amount of slag and CWR effectively. This proportion has likely contributed to an optimal geo-polymerization process, resulting in enhanced compressive strength compared to conventional Mix

- A good compressive strength of 32.27 N/mm^2 obtained for coal rejectory waste 30% , mixtures of industrial waste materials in ratios of 20:80 ratio which is suitable to be used as interlocking block.

- Conventional block has highest absorption rate at 3.5%. This rate drops markedly to 0.5% with a 20:80 ratio and further decreases to 0.43% and 0.40% for 30:70 and 40:60 ratios, respectively. Thus, increasing alternative material proportion enhances water resistance, making these blocks more suitable for low absorption applications.
- Efflorescence test reveals that while conventional block shows slight efflorescence, 20:80, 30:70 and 40:60 blocks exhibit good results. These results meet highest standard for first-class bricks, indicating that increasing alternative material proportion significantly improves block quality and durability.
- All block compositions, including conventional block, 20:80, 30:70 and 40:60 achieve a one-hour fire resistance duration, meeting ASTM E119 standard. This demonstrates that varying block composition does not affect fire resistance, ensuring compliance with first-class quality standards.

5.2 SUGGESTIONS FOR FUTURE WORK

The creation of new codes will be very expensive, so it requires the collaboration of governments, industries, and researchers. The main motivation for the adoption of such new materials is for sustainability and environmental issues. Only the basic engineering properties, bond properties, durability properties, flexural behaviour, shear behaviour, and temperature characteristics of geo-polymer specimen have been investigated in this study. Therefore, there are some uncharted areas which need to be researched. Some of the following future research areas are recommended.

- **Paving Blocks and Tiles**: Ideal for making durable paving blocks and tiles for sidewalks, driveways, and patios.

- **Precast Concrete Products**: Used to produce precast items like beams, slabs, columns, and wall panels, ensuring consistent quality and strength.

- **Road Construction**: Excellent for use in road sub-base and base layers, providing strong support and reducing the need for natural aggregates.

- **Building Foundations**: Suitable for constructing robust and sustainable building foundations, particularly in environmentally sensitive areas.

- **Retaining Walls**: Employed in constructing retaining walls, leveraging its high strength and durability.

- **Marine Structures**: Ideal for coastal and marine applications due to its resistance to chloride and sulfate attacks.

- **Industrial Flooring**: Perfect for industrial floors where high durability and resistance to wear and tear are essential.

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