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Reusing of IOT in building materials

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ABSTRACT: This study investigated the effects of incorporating industrial waste (IOT) in construction materials with various constituents. The results revealed that the wet compressive strength of blocks increased with ageing, especially when prepared with 40% MSW. The combination of lime and cement in block stabilization showed a delayed but significant impact on compression strength, becoming more pronounced after 30 days of ageing. Alkali-activated bricks with 40% IOT exhibited the highest compressive strength, indicating improved microstructure and durability properties. Additionally, the utilization of IOT waste in concrete led to enhanced compressive strength, especially at 40% addition rate. Addition of IOT is very cost effective method However, specific standards and long-term durability testing for IOT-based materials require further research for wider industrial adoption. Despite limitations, the use of IOT offers economic benefits, environmental mitigation, and resource conservation in construction materials.

I. INTRODUCTION

The Indian government's ambitious 'Housing for all' vision aims to provide housing for the urbanpoor by 2022, with a total demand of 90 million units in both urban and rural areas. However, the current use of fired clay bricks and cement blocks contributes to CO₂ emissions, making them environmentally unfriendly. As a result, researchers are focusing on alternative binders like geopolymers and alkali-activated binders for eco-friendly construction products. Iron Ore Tailings (IOT), a solid waste from iron ore beneficiation, is generated in large quantities worldwide and poses environmental challenges if not properly managed.[1][3]

In India, the mining sector significantly contributes to the country's economic development, generating substantial amounts of IOT waste. Prolonged disposal of IOT can lead to environmental issues, including soil and water contamination, deforestation, and land degradation. To address this problem and reduce the carbon footprint in construction, researchers are exploring the use of IOT to produce bricks and other construction materials.[1][3]

Various studies have investigated the application of IOT in concrete, tiles, and brick production. By utilizing IOT in the development of eco-friendly bricks, it offers a potential solution to both the waste management challenges in the mining industry and the need for sustainable building materials in the construction sector.[1][3]

The hilly terrain of the Sandur-Hospet region in Bellary district, Karnataka, India, is rich in iron ore reserves. However, during the mining, crushing, and screening processes, a significant amount of fines are generated, making up nearly 50-60% of the total burden removed. These fines are usually discarded as waste and dumped at mine sites.

Unfortunately, during the rainy season, the runoff water carries these fines, leading to silting and deposition of suspended matter in nearby tanks and reservoirs, including the Ankamanahal dam. The accumulation of mine spoil waste in the upstream portion of the Ankamanahal dam caused a reduction in its storage capacity over the years. In August 2011, a flash flood led to the dam's breach, highlighting the urgent need to remove the silted mine spoil waste for desilting and restoring the dam's capacity. As part of geotechnical consultancy work, the possibility of utilizing this huge quantity of mine spoil waste was explored to prepare Compressed Stabilized Earth Blocks (CSEBs). Through detailed sub-soil exploration, it was confirmed that a uniform deposit of mine spoil waste extended to a considerable depth along the proposed length of the dam. This presented an opportunity to explore the use of this iron mine spoil waste in the production of CSEBs, offering a feasible solution to both remove the waste and utilize it beneficially in the construction process.[1]



In this paper we are going to review effect of adding IOT as a product in bricks and cement to have desired results. Different constituents react with IOT in different manner to enhance the strength upto some extent.

overview from [1]

An investigation was conducted to explore the feasibility of using Iron Mine Spoil Waste (MSW) to create Compressed Stabilized Earth Blocks (CSEBs). Samples of MSW with a particle size distribution passing through a 75 µm I.S. sieve were collected from the Ankamanahal dam site. To achieve the required strength and durability for CSEBs, a blend of MSW and quarry dust was used as a cost-effective replacement for river sand, along with admixtures such as Ordinary Portland Cement (OPC) of 53 grades and lime. The study aimed to promote sustainable and economical construction practices.

Table 1. Physical properties of Iron mine spoil waste and quarry dust used in the preparation of CSEBs

Sl. No.	Material	GS #	wL (%)	wP (%)	wS (%)	Grains size distribution (%)			
						Gravel	Sand	Silt (size)	Clay (size)
1	Iron mine spoil waste	2.80	53	40	39	0	0	79	21
2	Quarry dust	2.75	-	-	-	0	89	11	0

Three variations of MSW (30%, 40%, and 50%) were combined with quarry dust and two admixture combinations (8% and 10% - cement and lime). Six series of blocks were prepared to investigate the impact of time on compressive strength and water absorption. Testing was conducted at intervals of 7, 15, 30, 60 days, and 6 months to assess aging effects on CSEBs. Additionally, a flexure test was performed after one month to evaluate block properties.

The blocks were manufactured using a Mardini press, resulting in dimensions of 230 x 110 x 75 mm. The wet mix was placed in a mould on the press, compacted using a toggle lever mechanism, and ejected to create consistent and reliable soil blocks.

The study shows that the wet compressive strength of blocks increases with ageing, especially when 40% municipal solid waste (MSW) is used. The combination of lime and cement for stabilization exhibits a delayed but significant impact on strength, becoming more pronounced after 30 days of ageing. There is an optimal content of MSW that can be utilized in block preparation. [1]

overview from [2]

The study explored the use of Iron Ore Tailings (IOT), fly ash, and Ground Granulated Blast Furnace Slag (GGBS) as precursors for alkali-activated binders to promote sustainable construction practices. XRF, XRD, SEM, and PSA techniques were used to characterize the raw materials. Different compositions of bricks were evaluated, varying IOT content from 40% to 90% in 10% increments (e.g., AABI40, AABI50). The liquid alkaline activator remained constant at 8%, and water content was adjusted for each brick composition. Mixing was done manually, and the bricks were cured under ambient conditions after compaction using a brick-making machine.



Table 2: Chemical Composition of Raw Materials (wt%)

Material	Content (wt%)									
	SiO2	Al2O3	Fe2O3	CaO	MgO	K2O	TiO2	Na2O	SO3	LOI
IOT	30.37	12.43	46.33	3.88	1.68	0.25	3.96	-	-	1.10
Fly ash	59.18	21.48	3.70	6.42	2.22	1.90	-	1.72	0.90	2.48
GGBS	32.50	17.54	1.36	37.10	7.34	0.31	0.85	0.57	0.63	1.80

Table 3: Physical Properties of Raw Materials

Material	Specific gravity	Density (kg/m ³)	Specific surface area (m ² /g)	Finer than 45 μm (%)
IOT	3.20	2410	0.513	39
Fly ash	2.28	1030	0.576	85
GGBS	2.65	1240	0.67	95

Table 4 : Mix Proportions and Molar Ratios for Different Brick Types

Brick type	Mix proportions					Molar ratios				
	IOT	Fly ash	GGBS	Na2sio3sol	water	Sio2	Na2o	cao	cao	Na2o
AABI40	964	216	260	128	100	4.37	0.20	1.26	0.28	0.16
AABI50	1205	175	210	128	80	4.38	0.19	1.10	0.25	0.17
AABI60	1446	134	161	128	60	4.38	0.17	0.95	0.22	0.18
AABI70	1687	93	111	128	40	4.38	0.16	0.82	0.19	0.19
AABI80	1928	52	62	128	20	4.39	0.14	0.70	0.16	0.20
AABI90	2169	-	-	128	20	4.40	0.13	0.56	0.13	0.23

The compressive strength of alkali-activated bricks is a critical characteristic as it reflects their ability to withstand compressive forces, indicating the efficacy of the reaction between the alkali source and solid aluminosilicates. A higher resistance to compressive forces is indicative of a superior microstructure and enhanced durability properties for the bricks. It can be observed that among all the brick types, AABI40 exhibited the highest average compressive strength, measuring 18.45 MPa. This result suggests that AABI40 outperformed the other brick types in terms of their ability to resist compressive forces and showcased improved overall strength and durability properties.

overview from [3]

Kuranchie et al. introduced an innovative method for producing eco-friendly geopolymer bricks using Iron Ore Tailings (IOT) from Western Australia and sodium silicate as an activator. The bricks achieved an impressive compressive strength of 50.35 MPa after 7 days of curing, meeting industry standards. Additionally, geopolymer bricks showed superior economic and environmental benefits compared to traditional fired clay bricks. [3]



Table 5: Average Cost of Making Cement Bricks using Natural Material

Materials	Cost (USD/t)	Average Proportion (%)
Sand	20	30
Stone	15	55
Cement	80	15
Total	26.25	100

Table 6: Average Cost of Making Bricks using Iron Ore Tailings

Materials	Cost (USD/t)	Average Proportion (%)
Iron ore tailings	0	40
Sand	20	15
Stone	15	35
Cement	80	10
Total	16.25	100

Using Iron Ore Tailings (IOT) as a substitute for natural materials in brick manufacturing results in significant cost savings. With 40% IOT utilization, raw material costs per ton decrease by 91.2% compared to clay bricks and 38.1% compared to cement bricks. This approach not only saves on IOT disposal costs but also lowers the overall production cost of bricks. Economically, manufacturing bricks with IOT proves to be highly advantageous over traditional clay and cement bricks.

Table 7: Component and Proportion (% by weight)

Component	Proportion (% by weight)
Coal Gangue	20%
Iron Ore Tailings (IOT)	40%
Lime	25%
Cement	10%
Gypsum	5%
Properties	Value
Compressive Strength	3.68 MPa
Bulk Density	609 kg/m ³

The study investigated the impact of Iron Ore Tailings (IOT) content and fineness on Autoclaved Aerated Concrete (AAC) blocks. Increasing IOT reduced compressive strength, with an optimal limit of 40% dosage. Grinding IOT for 20 minutes improved strength. AAC blocks with 40-60% IOT, cement, quicklime, and gypsum met requirements and were environmentally safe. The optimal AAC mixture included 20% coal gangue, 40% IOT, and other raw materials, achieving high compressive strength (3.68 MPa) and bulk density (609 kg/m³). Overall, incorporating IOT into AAC block production is feasible, meeting required strength standards without adverse environmental impacts.

The study explored the use of Iron Ore Tailings (IOT) as a replacement for natural sand in Ultra-High Performance Concrete (UHPC). Complete replacement negatively affected workability and strength, but limiting the replacement to 40% resulted in UHPC with impressive 90-day compressive and flexural strengths (150 MPa and 30 MPa, respectively). Partial replacement of natural sand with IOT is feasible for producing UHPC. Additionally, IOT has shown promise in aerated concrete applications, offering advantages in lightweight construction and thermal insulation. Autoclave curing is essential for achieving desired strength properties in aerated concrete.

overview from [4]

This study investigated the use of Iron Ore Tailings (IOTs) as a partial replacement for river sand (RS) in concrete. Cement, fly ash, limestone gravel, and RS were used as other components. The physical properties of IOTs were



suitable for the study, with smaller particle size than RS. Six groups of specimens were prepared with varying IOTs replacement ratios (0%, 20%, 40%, 60%, 80%, and 100%) at a water-to-cement ratio of 0.4. The specimens were cured for 28 days and tested for compressive strength (fcu) and splitting tensile strength (fst) using a 1000 kN MTS microcomputer-controlled electro-hydraulic servo universal testing machine.

Table 9: Material and chemical composition

Component	SiO2	Al2O3	Fe2O3	MgO	CaO	SO3	Na2O	K2O	Others
RS	98.21	1.02	0.11	0.14	0.32	0.02	0.16	0.01	0.001
IOTs	70.26	6.42	13.75	2.85	4.21	0.24	1.22	1.0	0.002

Table 10: Mixing Proportions (kg/m³)

No.	C	FA	RS	IOTs	NCA	W	W/C	SP
NC	440	110	656	0	1103	220	0.4	2.2
T20	440	110	524.8	131.2	1103	220	0.4	2.2
T40	440	110	393.6	262.4	1103	220	0.4	2.2
T60	440	110	262.4	393.6	1103	220	0.4	2.2
T80	440	110	131.2	524.8	1103	220	0.4	2.2
T100	440	110	656	0	1103	220	0.4	2.2

Incorporating 20-40% IOTs in concrete significantly enhanced fcu, with increases of 3.56% and 5.34% for mixes T20 and T40 compared to the reference mix without IOTs. This enhancement was attributed to the fine particles and rough surface of IOTs, which optimized the concrete pores. Other studies have also reported similar increases in compressive strength when incorporating 25-50% IOTs. The testing procedures ensured accurate assessment, and the MTS machine provided precise control and measurement during the tests. Overall, this research suggests that partial replacement of RS with IOTs is a promising approach for enhancing the strength properties of concrete.

overview from [5]

Geopolymer cement was produced using metakaolin (MK) activated with sodium silicate (Na2SiO3) and sodium hydroxide (NaOH). Three different iron ore tailings (IOT) from Brazilian mines were used as fillers. XRF analysis determined chemical composition, laser granulometry assessed particle size distribution, and XRD and FTIR spectroscopy analyzed MK and geopolymers. One-part geopolymer cements were produced using a planetary mixer. Reactive powder materials were dry mixed, water added, and continuous mixing produced a uniform paste. IOT was then added and mixed. Cylindrical samples were cast for evaluation. T2-60 exhibited favorable results, with compressive strength almost doubling from 23.6 to 43.6 MPa between days 1 to 3, showing a 20% increase when IOT2 tailings were varied from 50% to 60%. Enhanced particle packing and water content may contribute to the higher compressive strength. Further investigation is needed for better understanding.

Table 11: Designed Mix Proportions

Mix ID	MK (%)	SS (%)	SH (%)	IOT (%)
T1-50	35	12	3	50
T2-50	35	12	3	50
T3-50	35	12	3	50
T2-60	28	9.6	2.4	60



Table 12: Chemical Composition of Precursors, Activators, and Tailings (%)

Material	SiO2	Al2O3	Fe2O3	CaO	Na2O	K2O	MgO	H2O	LOIa
MK	56.25	36.87	0.58	0.05	0.21	3.21	0.32	-	2.19
SS	53.35	-	-	-	25.28	-	-	21.37	-
SH	-	-	-	-	25.28	-	-	21.37	-
IOT1	84.66	0.77	13.75	0.03	<0.1	0.06	<0.1	-	0.28
IOT2	82.97	0.30	15.88	0.01	<0.1	<0.01	<0.1	-	0.57

Major chemical composition of IOT in different countries.[3]

Table 8: Major Chemical Composition of IOT in Different Countries (wt.%)

Country	Location	Major composition (wt.%)							
		SiO2	Fe2O3	Al2O3	CaO	MgO	K2O	Na2O	
China	Maanshan	50.88	25.18	13.62	3.26	0.59	-	-	
China	Miyun,Beijing	67.29	8.95	8.49	3.63	4.80	-	2.90	
China	Yeshan,Nanjing	47.39	24.82	7.42	8.85	0.10	0.70	0.32	
Malaysia	Johor	56.00	8.30	10.00	4.30	-	1.50	-	
Brazil	Belo Horizonte	45.72	34.26	2.06	-	-	-	-	
Brazil	Belo	67.97	21.99	0.15	-	-	-	-	
India	-	51.12	44.36	1.22	0.22	-	-	-	
India	-	83.36	15.98	0.44	-	-	-	-	
India	Joda-Badbil	16.58	55.78	15.46	1.44	0.13	-	-	
India	Tata Steel Ltd	6.63	83.04	6.37	0.39	0.52	1.62	0.82	

Conclusion

The utilization of IOT as a replacement material in concrete products has shown promising results, especially with a 40% addition rate, and in certain cases, it can be increased to 60% depending on the composition of IOT. This application not only allows for the reuse of IOT waste but also leads to cost savings, with potential cost reductions of approximately 10-20%.

One significant advantage of using IOT in construction materials is its potential to address disposal-related issues, such as water, soil, and air contamination. By consuming a significant quantity of IOT waste that would otherwise be disposed of in tailings dams, this approach helps mitigate environmental hazards and reduces disposal costs. Additionally, incorporating low-cost or free solid waste materials instead of expensive natural resources results in cost-effective materials production, while also conserving natural resources that are otherwise heavily extracted each year for similar purposes. The chemical and mineral composition of IOT supports its suitability for preparing construction and building materials.

Despite these benefits, there are some limitations to consider when applying IOT in industrial settings. Currently, specific standards and testing methods for the utilization of IOT in construction and building materials are lacking, which may hinder its widespread adoption. Moreover, the existing literature primarily focuses on mechanical properties at short curing ages, and there is a need for further research on the long-term durability, dimensional stability, and environmental performance of IOT-based materials.

In conclusion, the use of IOT as a substitute material in construction products shows great promise, yielding economic benefits, addressing environmental concerns, and conserving natural resources. However, further research and the establishment of specific standards are essential to fully explore its potential in various industrial applications, particularly with respect to long-term performance and sustainability.



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