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THE POTENTIAL USE OF WASTE FROM SEWAGE TREATMENT PLANT AS A SUSTAINABLE MATERIAL IN THE CONSTRUCTION INDUSTRY

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Abstract: The construction industry in India is increasingly embracing sustainable practices to reduce environmental degradation and manage industrial by-products more efficiently. This study explores the feasibility of utilizing sludge from Sewage Treatment Plants (STP) a by-product of municipal wastewater treatment as a sustainable material in the production of fly ash and burnt clay bricks. Experimental trials were conducted by systematically replacing fly ash and clay with STP sludge in varying proportions, ranging from 10% to 60%. Comprehensive tests, including Compressive Strength, Water Absorption, Block Density and efflorescence were carried out in accordance with Indian Standard codes IS 3495:1992 and IS 2185 (part1):2005. The primary objective was to determine the optimal sludge replacement percentage while ensuring that the resulting bricks meet the structural and functional standards required for construction applications. Based on the experimental study, it was found that a sludge replacement up to 20% is optimal, as it does not adversely affect the strength and performance of the bricks and complies with the relevant IS requirements

I. INTRODUCTION

The construction industry in India has witnessed rapid growth in recent decades due to urbanization, population increase, and economic development. However, this growth has led to serious environmental issues such as resource depletion, waste generation, and high carbon emissions. To address these concerns, the industry is increasingly adopting sustainable practices aimed at reducing environmental impact while remaining economically viable.

One such sustainable approach is the use of industrial by- products and waste materials in construction. Among these, Sewage Treatment Plant (STP) sludge presents a significant opportunity for reuse. As India improves its sewage treatment infrastructure, the volume of STP sludge generated annually is increasing. This creates a pressing need for environmentally sound disposal or reuse methods. Burnt clay bricks and fly ash bricks are fundamental construction component in India, with billions produced each year to meet infrastructure demands. However, their production contributes to environmental degradation through clay mining, high energy consumption, and greenhouse gas emissions. By partially replacing clay or fly ash with STP sludge, it is possible to reduce the environmental impact of brick production while addressing waste management challenges.

This research focuses on evaluating the technical feasibility of incorporating STP sludge into brick manufacturing. It examines various replacement levels, ranging from 10% to 60%, to identify optimal mixes that meet the structural and functional standards outlined in Indian Standard codes IS 1077:1992 (for burnt clay bricks) and IS 16720:2018 (for fly ash bricks). These standards ensure that the modified bricks maintain quality and safety requirements.

Table 1.1: Recent research contributions on STP sludge utilization in construction materials (2020-2024)

Author(s)	Year	Key Contribution	Findings
Reddy & Desai	2024	Conducted life cycle assessment of WWTP sludge incorporation in brick manufacturing	30% reduction in global warming potential compared to conventional bricks when incorporating 20% sludge
Gupta & Sharma	2023	Assessed thermal properties and energy efficiency of WWTP sludge-incorporated bricks	15% sludge incorporation reduced thermal conductivity by 22%, improving insulation properties
Shah & Patel	2022	Evaluated mechanical properties of bricks containing up to 30% WWTP sludge	Compressive strength decreased but remained within acceptable limits for non-load bearing applications at 20% replacement
Kumar etal.	2021	Investigated leaching behavior and environmental safety of WWTP sludge in construction materials	Proper firing temperatures (>850°C) effectively immobilized heavy metals, reducing leaching potential below regulatory thresholds
Verma & Singh	2020	Developed optimal mix designs for fly ash bricks with WWTP sludge	25% sludge replacement achieved optimal balance between mechanical properties and environmental benefits

Previous studies have shown promising results for the use of STP sludge in construction materials. However, since the composition of STP sludge can vary based on wastewater sources and treatment methods, region-specific studies are essential for effective implementation.

India generates about 1.2 million tons of dry STP sludge annually, a figure expected to rise. At the same time, the country produces around 250 billion bricks each year, consuming nearly 400 million tons of clay. Even a small-scale adoption of STP sludge in brick production could lead to substantial environmental benefits. This research bridges the gap between laboratory studies and practical applications by providing data on the performance of sludge-based bricks. The findings can influence policies, promote sustainable industry practices, and support circular economy principles in construction.

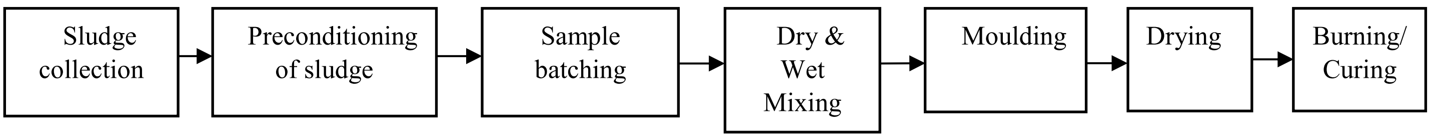
II. OBJECTIVES OF STUDY

A. To examine the effects of STP sludge use on the structural and functional properties of brick, including compressive strength, water absorption, block density and efflorescence.
B. To determine the optimal replacement percentage of STP sludge with clay to achieve desired properties of burnt clay brick.
C. To determine the optimal replacement percentage of STP sludge with fly ash to achieve desired properties of fly ash brick.
D. To ensure compliance with relevant Indian Standard codes for quality and performance, particularly IS 1077:1992 and IS 16720:2018.
E. To evaluate the environmental benefits of using STP sludge in brick production, including waste reduction, resource conservation, and carbon emission mitigation.

III. METHODOLOGY

The research methodology employs a systematic experimental approach to evaluate STP sludge as a partial replacement in brick manufacturing. Initially, STP sludge samples will be characterized for chemical composition and physical properties. Subsequently, multiple brick formulations will be prepared by replacing clay and fly ash with sludge in varying proportions (10%, 20%, 30%, 40%, 50% and 60%). Brick specimens will be manufactured following standard procedures and subjected to comprehensive testing for compressive strength, water absorption, block density, and efflorescence according to IS 3495:1992 and IS 2185 (part1):2005 specifications. statistically analyzed to determine optimal replacement percentages that maintain compliance with standards while maximizing environmental benefits.

Flow chart: -



IV. SAMPLE COLLECTION AND PREPARATION

STP sludge samples were collected from a municipal sewage treatment plant located in Shirpur city. The collected sludge underwent preliminary treatment through air-drying for 3-5 days to reduce moisture content and facilitate further processing. This systematic preparation approach established standardized input material for subsequent experimental trials, thereby enhancing the reliability and reproducibility of results.

Table 4.1: Sieve Analysis Results for Processed STP Sludge

Sieve Size(mm)	Weight Retained (g)	% Retained	Cumulative % Retained	% Passing
4.75	45.2	9.04	9.04	90.96
2.36	98.7	19.74	28.78	71.22
1.18	116.5	23.3	52.08	47.92
0.6	103.2	20.64	72.72	27.28
0.3	75.8	15.16	87.88	12.12
0.15	42.3	8.46	96.34	3.66
Pan	18.3	3.66	100	0
Total	500	100	-	-

Fineness Modulus = 3.47

Table 4.2: Raw sewage chemical characteristics

Parameter	Range
pH Value	6.5 - 8.5
Total Suspended Solids (TSS)	350 - 450 mg/L
Total BOD_5 (at 20°C)	250 - 350 mg/L
Total COD	450 - 550 mg/L
Oil and Grease	20 - 30 mg/L
Total Phosphorus (as P)	5 - 7 mg/L
Total Kjeldahl Nitrogen (TKN)	40 - 50 mg/L

Table 4.3: Treated Sewage chemical characteristics

Parameter	Standard
Total BOD @ 20°C	Less than or equal to 10 mg/l
Total Suspended Solids	Less than or equal to 10 mg/l
Chemical Oxygen Demand (COD)	Not to exceed 100 mg/l
pH	5.5 to 9.0
Oil & Grease	Not more than 10 mg/l
Ammonical Nitrogen (NH_4-N)	Less than or equal to 1 mg/l
Nitrate Nitrogen (NO_3-N)	Less than or equal to 10 mg/l
Total Phosphorus (TP)	Less than or equal to 2 mg/l
Colour & Odour	Remove colour and unpleasant odour as far as practicable
Bio-assay Test	90% survival of fish after 96 hours in 100% effluent
Residual Chlorine	Not more than 1 mg/l
Temperature	Shall not exceed 5°C above the receiving water temperature

V. TEST RESULTS ON FLY ASH BRICKS

- **Block Density Test**
  The block density test is conducted by dividing the dry mass of the block by its volume. A higher density typically indicates a more compact and stronger block. This test helps assess the uniformity and consistency of the block mix and the influence of various additives or materials such as STP sludge. The block density test is essential for evaluating the structural properties of fly ash bricks, including their strength, durability, and suitability for various construction applications. This test is conducted as per the guidelines provided in ANNEX-C of IS 2185(part1):2005.

Table 5.1: Findings of Block Density Test

Sr. No.	Sample No.	Replacement (%)	Volume (cm3)	Weight(kg)	Block Density(kg/m3)	Average block density (kg/m3)
1	A	0%	1842.24	3.704	2010.60	2001.36
	B		1904.86	3.774	1981.25	
	C		1842.24	3.707	2012.22	
2	A	10%	1838.20	3.473	1889.35	1844.61
	B		1899.81	3.475	1829.13	
	C		1876.78	3.407	1815.34	
3	A	20%	1905.97	3.414	1791.22	1778.10
	B		1905.97	3.366	1766.03	
	C		1886.83	3.353	1777.05	
4	A	30%	1841.61	3.270	1775.62	1767.87
	B		1876.80	3.322	1770.03	
	C		1836.24	3.228	1757.94	
5	A	40%	1901.28	3.297	1734.09	1695.20
	B		1923.72	3.199	1662.92	
	C		1970.31	3.327	1688.57	
6	A	50%	1964.11	3.297	1678.62	1694.42
	B		1971.42	3.336	1692.18	
	C		1971.42	3.376	1712.47	

The dimensions of each block shall be measured in centimeters (to the nearest millimeter) and the overall volume computed in cubic centimeters.

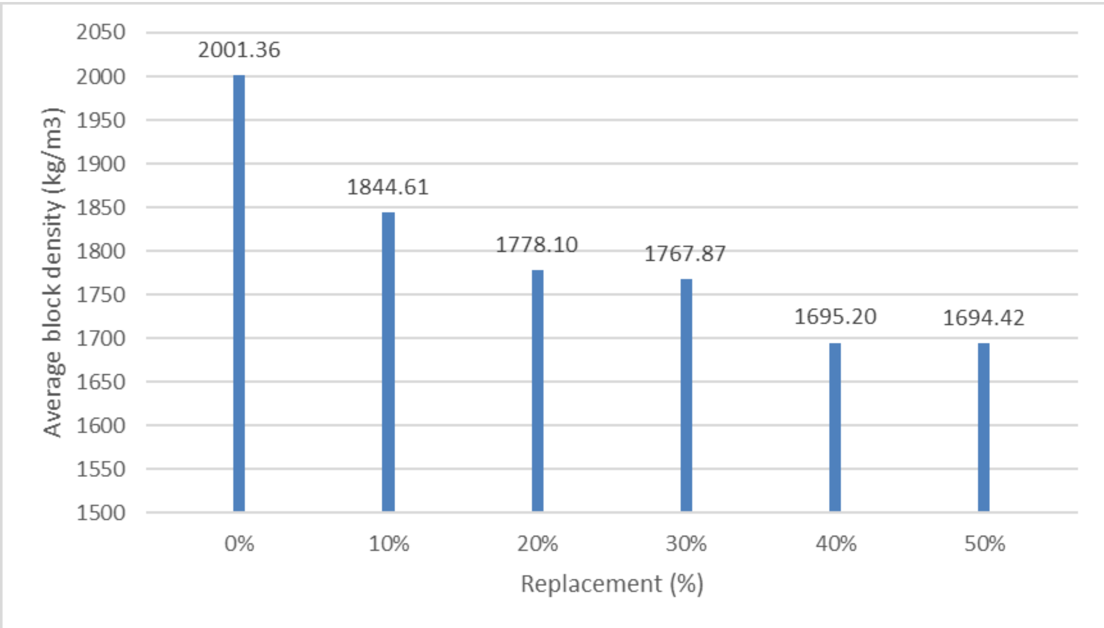


Fig.5.1: Graphical Representation of Block Density Test

- **Water Absorption Test**

The water absorption test determines the porosity and moisture resistance of the fly ash bricks. The specimen is first dried in an oven at temperature of (105 °C to 115 °C) for 24 hours and then immersed in water for a 24 hours duration. The increase in weight indicates the amount of water absorbed. Lower water absorption typically indicates higher durability and better performance under wet conditions. This test helps assess the suitability of fly ash bricks for use in areas exposed to moisture. The test is conducted in accordance with IS 3495 (Part 2):1992.

Table 5.2: Findings of Water Absorption Test

Sr. No.	Sample No.	Replacement (%)	Weight of brick (OD) in gm (W1)	Weight of brick (SSD) in gm (W2)	Weight of water in gm(W3)	Water absorption (%) = (W3/W1) *100	Average water absorption (%)
1	A	0%	3704	4187	483	13.04	10.61
	B		3774	4067	293	7.76	
	C		3707	4116	409	11.03	
2	A	10%	3473	3857	384	11.06	11.26
	B		3475	3863	388	11.17	
	C		3407	3800.5	394	11.55	
3	A	20%	3414	3843	429	12.57	13.23
	B		3366	3836	470	13.96	
	C		3353	3794.5	442	13.17	
4	A	30%	3270	3810.5	541	16.53	15.05
	B		3322	3763.5	442	13.29	
	C		3228	3722.5	495	15.32	
5	A	40%	3297	3738	441	13.38	16.46
	B		3199	3861	662	20.69	
	C		3327	3836	509	15.30	
6	A	50%	3297	3828	531	16.11	17.52
	B		3336	3771.5	436	13.05	
	C		3376	3778	402	23.40	

SSD- Surface Saturated Dry Weight
OD- Oven Dry

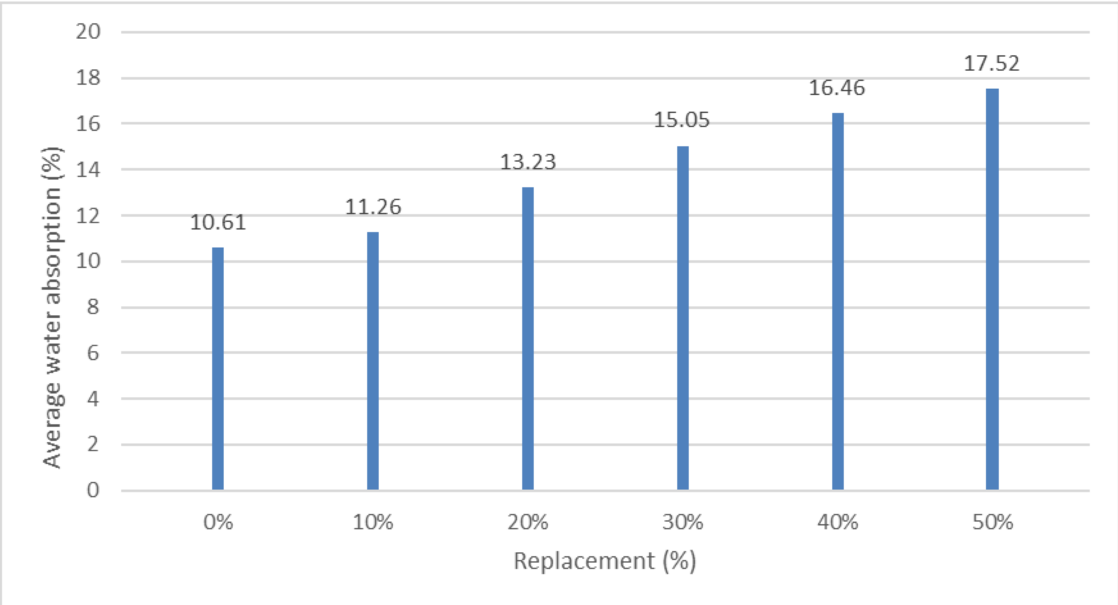


Fig.5.2: Graphical Representation of Water Absorption Test

- **Compressive Strength Test**
  The compressive strength test measures the ability of fly ash bricks to withstand load without failure. Specimens are placed under a compression testing machine and subjected to gradually increasing load until failure occurs. The maximum load applied divided by the bed face area gives the compressive strength. This test helps evaluate the load- bearing capacity and structural performance of fly ash bricks. It is carried out as per IS 3495 (Part 1):1992.

Table 5.3: Findings of Compressive Strength Test

Sr. No.	Sample No.	Replacement (%)	Compressive strength (N/mm2)	Average 15 days compressive strength (N/mm2)	Average 28 days compressive strength (N/mm2)
1	A	0%	8.7	6.1	7.1
	B		4.9		
	C		7.6		
2	A	10%	5.4	5.6	6.3
	B		5.6		
	C		5.7		
3	A	20%	4.8	4.8	5.5
	B		5.1		
	C		4.6		
4	A	30%	4.1	4.3	4.8
	B		4.3		
	C		4.4		
5	A	40%	2.7	3.1	3.6
	B		3.1		
	C		3.5		
6	A	50%	2.4	2.6	3
	B		2.7		
	C		2.8		

Bed face area (mm2) is 23000
Standard fly ash brick size is (23x10x8) cm

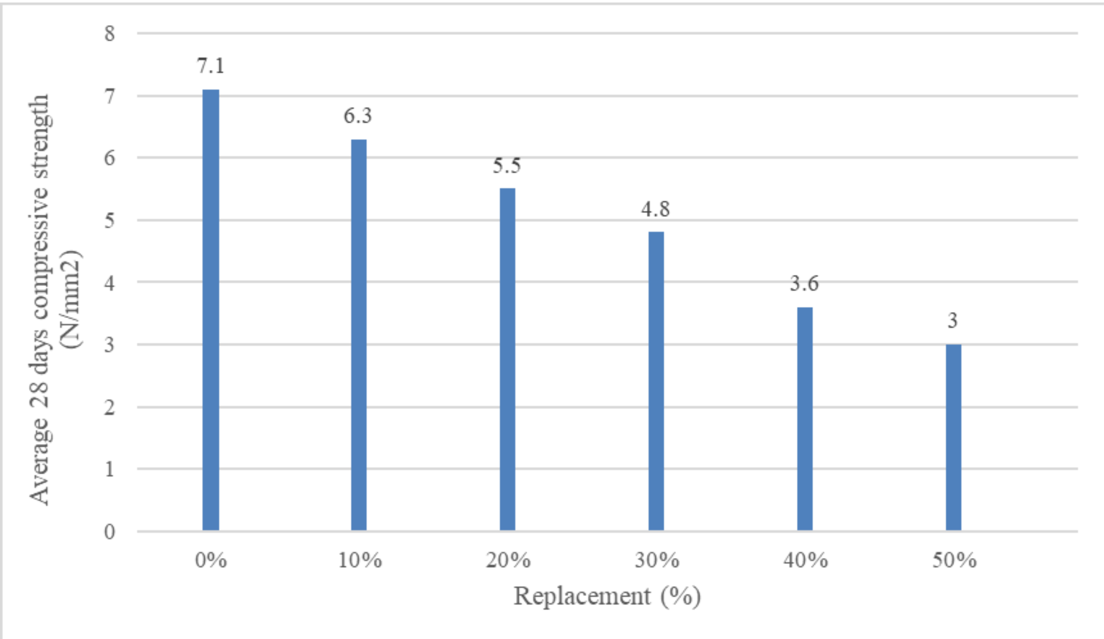


Fig.5.3: Graphical Representation of Compressive Strength Test

VI. Test Results on Burnt Clay Bricks

- **Efflorescence Test**
  The efflorescence test assesses the presence of soluble salts in bricks, which can appear as a white, powdery deposit on the surface. Bricks are partially immersed in water and left to dry in well-ventilated room. The extent of white deposits is visually assessed and categorized based on severity. Efflorescence affects both the aesthetics and long- term durability of bricks. This test is conducted as per IS 3495 (Part 3):1992.

Table 6.1: Findings of Efflorescence Test

Sr. No.	Observations	Report	Test observations						
			0%	10%	20%	30%	40%	50%	60%
1	When there is no precipitable deposit of efflorescence	NIL	YES	YES	YES	YES	YES		
2	When not more than 10% of the exposed area of the brick is covered with a thin deposit of salt	SLIGHT						YES	
3	Covering up to 50% of the brick surface but unaccompanied by Powdering	MODERATE							YES
4	When there is heavy deposit salt covering 50% or more of the exposed area of the brick surface	HEAVY							
5	When there is a heavy deposit of salts accompanied by powdering	SERIOUS							

- **Water Absorption Test**
The water absorption test determines the porosity and moisture resistance of the burnt clay bricks. The specimen is first dried in an oven temperature of (105 °C to 115 °C) for 24 hours and then immersed in water for a 24 hours duration. The increase in weight indicates the amount of water absorbed. Lower water absorption typically indicates higher durability and better performance under wet conditions. This test helps assess the suitability of burnt clay bricks for use in areas exposed to moisture. The test is conducted in accordance with IS 3495 (Part 2):1992.

Table 6.2: Findings of Water Absorption Test

Sr. No.	Sample No.	Replacement (%)	Weight of brick (OD) in gm (W1)	Weight of brick (SSD) in gm (W2)	Weight of water in gm(W3)	Water absorption (%) =(W3/W1)*100	Average water absorption (%)
1	A	0%	2070.5	2355.5	285.0	13.76	13.20
	B		2245.0	2362.0	117.0	5.21	
	C		2620.5	3161.0	540.5	20.63	
2	A	10%	1790.5	2072.5	282.0	15.75	14.32
	B		1904.0	2161.5	257.5	13.52	
	C		1833.0	2084.0	251.0	13.69	
3	A	20%	1728.0	1986.5	258.5	14.96	15.67
	B		1790.0	2023.5	233.5	13.04	
	C		1709.0	2034.0	325.0	19.02	
4	A	30%	1621.5	1885.5	264.0	16.28	16.19
	B		1540.5	1807.0	266.5	17.29	
	C		1525.5	1754.5	229.0	15.01	
5	A	40%	1459.0	1721.0	262.0	17.96	18.77
	B		1592.0	1858.0	266.0	16.71	
	C		1475.5	1795.0	319.5	21.65	
6	A	50%	1420.5	1704.5	284.0	19.99	19.49
	B		1563.5	1845.0	281.5	18.00	
	C		1406.0	1694.0	288.0	20.48	
7	A	60%	1053.0	1389.0	336.0	31.91	21.65
	B		1225.5	1365.0	139.5	11.38	
	C		-	-	-	-	

SSD- Surface Saturated Dry Weight
OD- Oven Dry

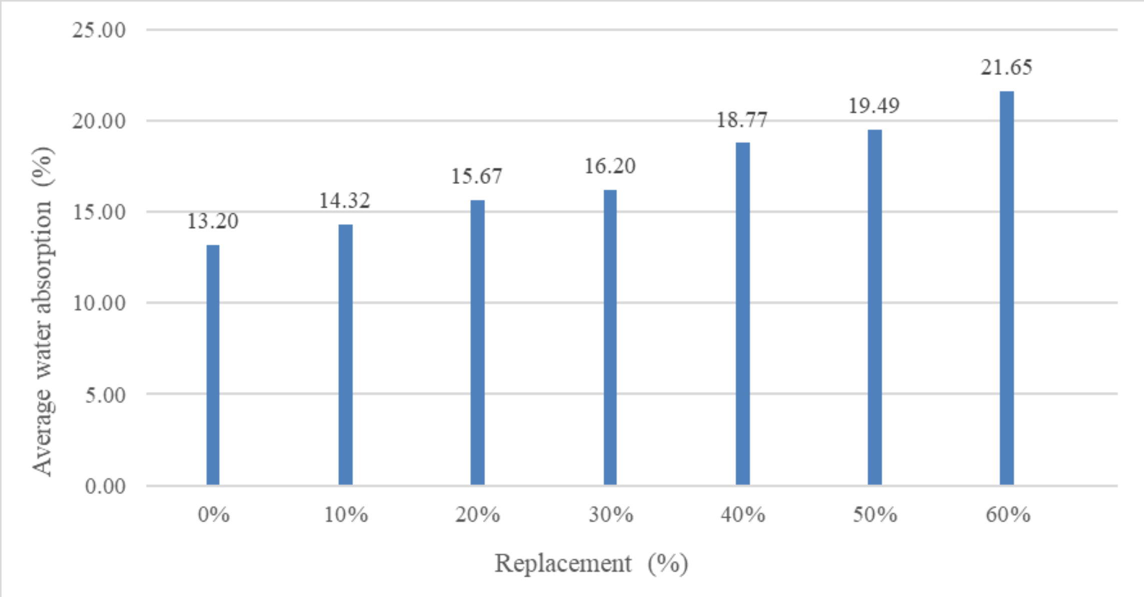


Fig.6.1: Graphical Representation of Water Absorption Test

- **Compressive Strength Test**

The compressive strength test measures the ability of burnt clay bricks to withstand load without failure. Specimens are placed under a compression testing machine and subjected to gradually increasing load until failure occurs. The maximums load applied divided by the bed face area gives the compressive strength. This test helps evaluate the load-bearing capacity and structural performance of bricks and blocks. It is carried out as per IS 3495 (Part 1):1992.

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Table 6.3: Findings of Compressive Strength Test

Sr. No.	Sample No.	Replacement in (%)	Compressive strength (N/mm2)	Average compressive strength (N/mm2)
1	A	0%	5.7	5.63
	B		5.9	
	C		5.3	
2	A	10%	5.4	5.53
	B		5.8	
	C		5.4	
3	A	20%	5.3	5.23
	B		5.5	
	C		4.9	
4	A	30%	4.8	5.03
	B		5.5	
	C		4.8	
5	A	40%	4.7	4.40
	B		4.3	
	C		4.2	
6	A	50%	3.7	3.43
	B		3.1	
	C		3.5	
7	A	60%	3	2.70
	B		2.4	
	C		-	

Bed face area (mm2) is 18900
Standard burnt bricks size is (21x9x7) cm

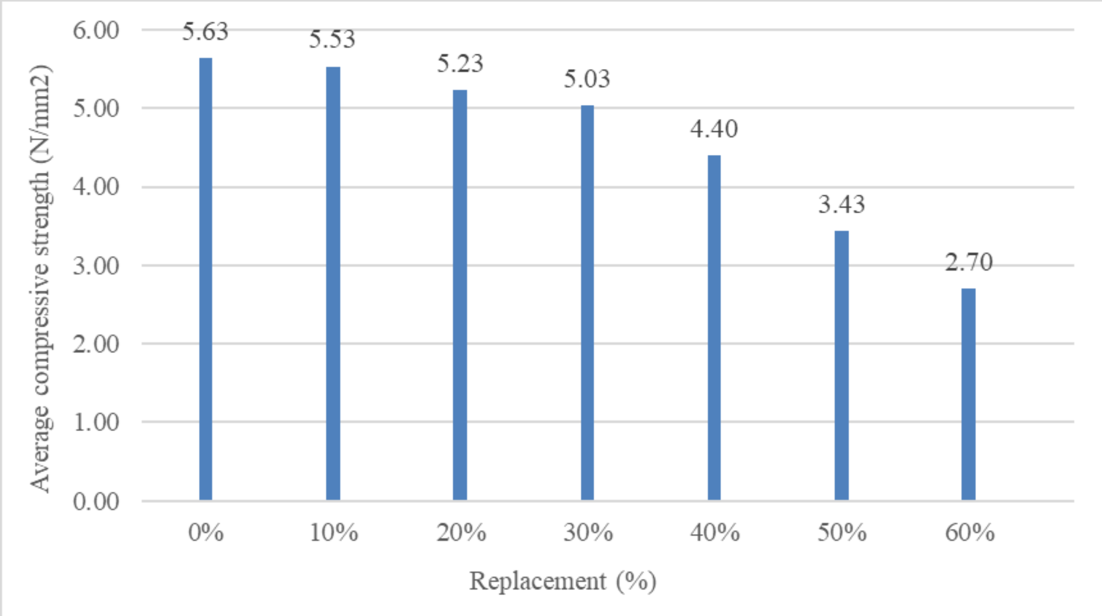

Fig.6.2: Graphical Representation of Compressive Strength Test

VII. CONCLUSION

Based on the study, it can be concluded that Sewage Treatment Plant (STP) sludge is suitable for use in brick manufacturing, as most of its properties meet the minimum requirements specified by Indian Standards, including compressive strength, water absorption, block density and efflorescence. Experimental results indicate that replacing clay or fly ash with up to 20% STP sludge provides optimal performance without compromising the structural integrity of the bricks. Furthermore, the use of STP sludge in brick production offers several environmental benefits, including waste reduction, resource conservation, and carbon emission mitigation, thereby contributing to sustainable development in the construction industry.

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