Investigative Study to Assess the Potential of Paper Industrial Sludge as a Material for Construction

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Abstract— **The disposal of waste is a global problem. Presently all over the world the industrial waste is disposed of by dumping it in landfill sites. However, in order to provide value addition in terms of application the efforts are focused towards partial replacement in the process of preparing building materials. In the present work we have focused our attention towards brick manufacture and associated strength evaluation. Our present invention utilizes industrial waste and relates to a synergistic composition for producing building bricks for assessment of their potential for consideration as a material for construction.**

***Index Terms*— Sludge, Characterization, Bricks, Composite, Crushing strength, Water Absorption ratio.**

I. INTRODUCTION

Bricks are generally manufactured with clay, coal and ash mixtures. There is need for new kind of bricks to replace the bricks manufactured by conventional methods. Manufacture of brick using Paper making wastes as raw material has been carried out by Xu, Quianli. [1]The studies revealed that fly ash can be used to replace clay; and the content of Paper making wastes is 10 –30 %. The Product brick was found to have light weight and thermal insulation property. Laboratory tests were carried out by Ducman et al [2] on specimen bricks made of clay and up to 30% saw dust and / or paper making sludge as pore forming agents. The tests revealed that these agents reinforce that structure of the ceramic body during drying and counteract cracking and formed a highly porous ceramic structure. Strength tests have been conducted on prisms made out of country burnt bricks laid in mud mortar by Subbarao revealed that the compressive strength of these bricks are lower than 35 Kg/cm^2 [3]. The Paper industry located in East Godavari region, Andhra Pradesh, India has been generating solid waste (sludge) at an order of 540 tons/day and the quantity is quite considerable. Keeping it in view, efforts are made in characterizing the sludge to assess its potentials to suggest its usage as filler in the manufacturing of bricks which are considered to be a significant material for construction purposes.

II. MATERIALS AND METHODS

Sampling Site: The sludge generated at Effluent Treatment Plant after treatment was collected from the paper mill. The sludge sample has been taken and dried at 105^0 C and analyzed as per the standard analytical procedures [4, 5, 6]. The sludge sample is represented in figure-1

Fig-1: Sludge sample from Paper Industry

The parameter pH is measured by pH meter, Electrical Conductivity by conductivity meter. The moisture content is measured by using Moisture bottle balance and desiccators. The total volatile solids are measured by evaporating the sample in an oven at 110±2^{0}C until complete dryness. After complete evaporating the dish is kept in decicator for cooling and its final weight is noted. The total volatile solids is calculated by using the relation (A-B) x (1000/W), where A= Wt of the dish + residue in gm, B=Wt of the empty dish and W= Wt of the solid sample taken. Total Fixed solids are estimated by heating sludge at 600^{0}C in a Silica crucible placed in a muffle furnace and ignited at 600^{0}C and the difference between the initial and final rate gives the weight loss on ignition which otherwise known as fixed solids. The total organic carbon is measured with walkley and black method and the calorific value of the sludge is measured with a bomb calorimeter.

Crushing Strength: The bricks with the compositions 15:85, 20:80, 25:75 and 30:70% of sludge and clay are tested for the Crushing strength with universal testing machine (UTM) of range 200 tons and the crushing strength has been measured

Water Absorption Ratio: It is called 24hrs Immersion cold water test. The bricks prepared by the novel composition of the present invention were immersed in distilled water for 24 hours. The strength of brick also depends on its water absorption capacity. Bricks with more water absorption capacity will lose strength earlier and should not exceed 20%

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by weight for first class variety bricks. The Water absorption capacity can be calculated by the relation

$$\text{Water Absorption Ratio} = \frac{(W_2 - W_1) \times 100}{W_1}$$

Where W_1 = Weight of dry Brick, W_2 = Weight of Brick after soaking in water. The characteristics of the sludge are presented in table-1.

Table –1: Characteristics of the sludge

S. No.	Parameter	Observed Value
1.	pH	8.0
2.	Moisture (%w/w)	25
3.	Volatile solids (% w/s)	37.58
4.	Fixed solids (Ash) (% w/w)	62.40
5.	Total organic carbon (TOC) (% w/w)	70.42
6.	Calorific Value (cal/gm)	1674

The present invention employs the technique of preparing a synergistic composition by mixing clay and industrial waste. Bricks were manufactured with the combination of Clay and Sludge from paper industry. Bricks with various compositions such as 15%, 20%, 25% and 30% of sludge with clay are manufactured.

The characteristics of the bricks are presented in table-2.

Table-2: Characteristics of the bricks with sludge and clay composites

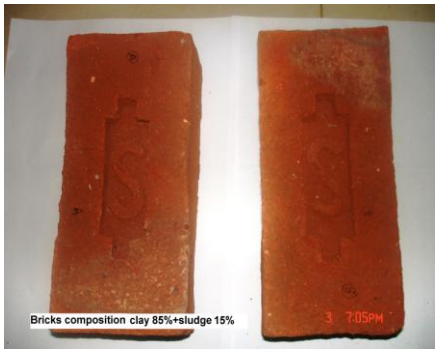
S.No	Characteristics	Observation
1.	Appearance	Rectangular faces with sharp edges free from cracks and are present with red colour.
2.	Hardness	Hard.
3.	Soundness	When struck with another brick metallic sound is heard.
4.	Porosity	The absorption of water by the bricks is up to 20%.

The dimension of the bricks and their weight are measured and the details are summarized in table-3.

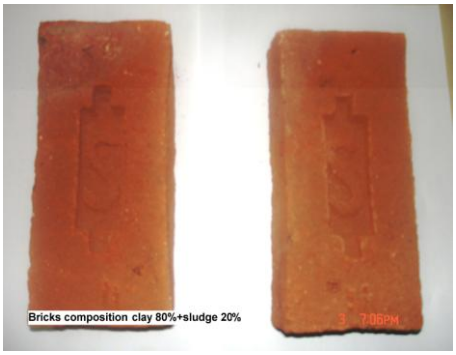
Table-3: Composition, dimensions and weight of bricks

S.No	Brick & sample code	Length (cm)	Width (cm)	Height (cm)	Weight (gms)
1.	Burnt clay bricks (control)				
	S-1	21.90	10.25	6.75	1790
	S-2	21.80	10.10	6.70	1770
	S-3	21.55	10.05	6.70	1790
2.	Brick with 85% clay + 15% sludge				
	S-4	20.50	9.27	6.17	1690
	S-5	20.63	9.27	6.20	1675
	S-6	20.55	9.25	6.18	1680
3.	Brick with 80% clay+ 20% sludge				
	S-7	20.57	9.20	5.90	1390
	S-8	20.67	9.17	5.77	1400
	S-9	20.62	9.18	5.75	1410
4.	Brick with 75% clay+ 25% sludge				
	S-10	20.20	8.70	5.40	1180
	S-11	19.97	8.93	5.53	1170
	S-12	20.00	8.80	5.50	1185
5.	Brick with 70% clay+ 30% sludge				
	S-13	19.65	8.45	5.30	1090
	S-14	19.50	8.50	5.35	1130
	S-15	19.45	8.30	5.25	1075

Figure- 2: Brick prepared from (Paper sludge + clay) composites and Clay as control

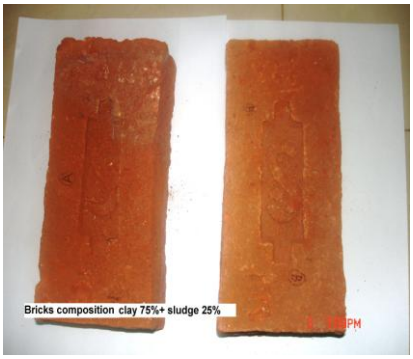


Clay 85% + Sludge 15%



Clay 80% + Sludge 20%

Control



Clay 75% + Sludge 25%

Clay 70% + Sludge 30%

Figure- 3: Water Absorption Ratio (24hr immersion cold water test)

As per IS: 3102-1965, the minimum compressive strength prescribed for brick is 50 kg/cm^2.The Crushing strength has been measured and the details are presented in the table-4.

Table-4: Crushing strength of Bricks

S.No	Brick sample code	Force (kg) F	Area (cm^2) A	Crushing strength P=F/A (kg/cm^2)	Average Crushing strength (Kg/cm^2)
1.	Burnt clay bricks (control)				
	S-1	10500	224.47	46.78	46.93
	S-2	10000	220.18	45.42	
	S-3	10500	216.07	48.60	
2.	Brick with 85% clay + 15% sludge				
	S-4	5500	190.03	28.94	28.00
	S-5	5000	191.24	26.14	
	S-6	5500	190.09	28.93	
3.	Brick with 80% clay+ 20% sludge				
	S-7	6500	189.24	34.35	32.57
	S-8	6000	189.54	31.65	
	S-9	6000	189.29	31.70	
4.	Brick with 75% clay+ 25% sludge				
	S-10	8500	175.74	48.37	45.28
	S-11	8000	178.33	44.86	
	S-12	7500	176.00	42.61	
5.	Brick with 70% clay+ 30% sludge				
	S-13	9500	166.04	57.21	56.76
	S-14	9500	165.75	57.31	
	S-15	9000	161.43	55.75	

Fig-3(a): Details of clay and sludge composition of bricks and their Average crushing strength

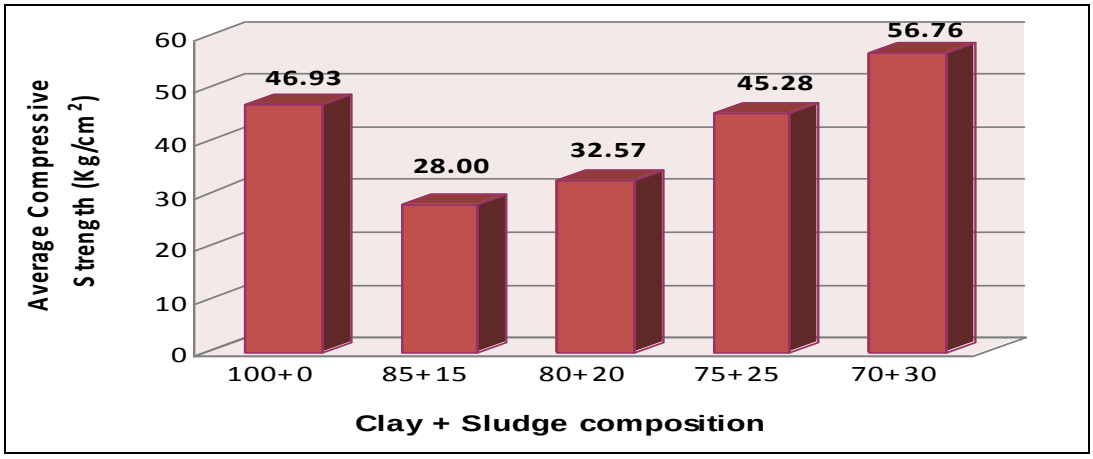
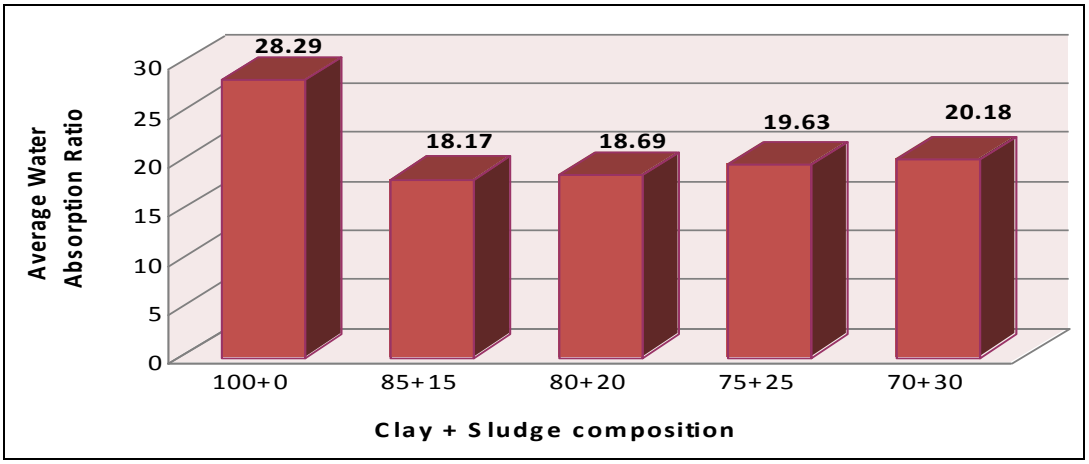


Fig-3(b): Details of clay and Sludge composition of bricks and their Average Water absorption ratio



The composition and water absorption ratio of bricks are represented in figures-3(a) and 3(b) respectively. are evaluated in comparison with the strength of the conventional brick
The details of the Water absorption ratio are presented in table-5.

Table-5: Water Absorption Ratio of bricks

S.No	Brick sample code	Weight of dry brick W_1 (gm)	Weight after soaking in water W_2 (gm)	$(W_2 - W_1)$ (gm)	Water Absorption Ratio	Average
1.	Burnt clay bricks (control)					
	S-1A	1780	2300	520	29.20	28.29
	S-2A	1785	2285	500	28.01	
	S-3A	1770	2260	490	27.68	
2.	Brick with 85% clay+ 15% sludge					
	S-4A	1690	1995	305	18.04	18.17
	S-5A	1680	1980	300	17.86	
	S-6A	1665	1975	310	18.62	
3.	Brick with 80% clay+ 20% sludge					
	S-7A	1395	1660	265	18.90	18.69
	S-8A	1390	1650	260	18.70	
	S-9A	1380	1635	255	18.48	
4.	Brick with 75% clay+ 25% sludge					
	S-10A	1180	1405	225	19.06	19.63
	S-11A	1190	1420	230	19.32	
	S-12A	1170	1410	240	20.50	
5.	Brick with 70% clay+ 30% sludge					
	S-13A	1090	1310	220	20.10	20.18
	S-14A	1080	1290	210	19.40	
	S-15A	1070	1295	225	21.02	

The values indicate that the bricks with the above combination can be considered as material for construction purposes as the Water Absorption Ratio of these bricks are with in the permissible limits.

III. Results and Discussion:

1. The average compressive strength of the conventional brick is found to be 46.93 kg/cm^2 and it is nearer to the standard value as per IS:3102-1965.
2. In case of the brick prepared with 30% sludge and 70% clay is found to have a compressive strength of 56.76 kg/cm^2 and it is above the minimum compressive strength 50 kg/cm^2 (IS: 3102-1965). Hence the bricks of 70% clay and 30% sludge composition can be considered as a material for construction purposes.
3. The bricks with the combination of 25% paper sludge and 75% clay are found to have a compressive strength of 45.28 kg/cm^2 which is nearly equal to the compressive strength of the conventional brick considered as standard. Hence these bricks can be considered as a material for construction purposes.
4. Bricks with 15% and 20% sludge respectively are observed to have a compressive strength of 28 kg/cm^2 and 32.57kg/cm^2 respectively. The values are low compared to the standard values (IS: 3102-1965). Hence these bricks are not suitable as material for construction purposes.
5. The water absorption ratio of the conventional brick manufactured from the brick industry is observed as 28.29 which is more than the standard value of of 20 (IS: 3102-1965).
6. The water absorption ratio of bricks with compositions of 15%, 20%, 25% and 30% of sludge with clay are observed as 18.17, 18.69, 19.63 and 20.18 respectively.

IV. Conclusions

The compressive strength 56.76 kg/cm^2 of the bricks with composition of 70% clay and 30% sludge indicate that the bricks can be considered as material for construction purposes. The compressive strength (45.28 kg/cm^2) is nearly equal to the compressive strength (46.93 kg/cm^2) of clay burning brick prepared by the brick industry. Hence these bricks can also be considered as material for construction purposes. The bricks with 15% and 20% with clay have a compressive strength of 28 kg/cm^2 and 32.57 kg/cm^2 respectively. These values are less (IS: 3102-1965) and hence these bricks are not suitable as material for construction purposes. The water absorption ratio of the bricks with sludge and clay in the ratio 30: 70 and 25: 75 are 20.18 and 19.63 respectively and are within the standard limits and hence the bricks can be considered as material for construction purposes. Though the water absorption ratio of bricks with 15% and 20% sludge with clay are within the standard values (18.17 and 18.69) cannot be considered as the material for construction due to the lower compressive strength of 28 kg/cm^2 and 32.57 kg/cm^2.

The bricks with combination of paper sludge and clay in the ratio of 30% and 25% can be considered as material for construction purposes. The bricks are non-load bearing type and hence can be employed in the construction of column bearing structures as curtain walls, garden walls, walls in

balconies, compound walls, bathroom walls and parapet walls with cement plastering.

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