A Study on Utilization of Sludge in Brick Manufacturing

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Abstract-*In the recent times, it is seen that there is steep increase in the sludge production due to the rapid growth of urban areas and consequent generation of waste.; as a result of which the safe disposal of the same has become a challenge in terms of cost and availability of landfills and dump yards.*

In an attempt of finding possible solutions to this problem, this paper focuses on utilizing sludge in a productive way ,which may facilitate resolving the problem of disposal of industrial sludge as well as giving an effective outcome to use it as a cost effective construction material .The air dried sludge from the city municipal sewage treatment plant was collected and tested for its geotechnical properties along with that of clay and fly ash which are the main components of conventional brick .Different proportions of dried sludge was used as a substitute for clay along with fly ash. To find out the performance of the brick along with its strength, the sludge proportions were varied out from 5% to 20%. Two major tests for the bricks viz. compressive strength test and water absorption test were conducted on the bricks having varying sludge proportions to obtain the optimum proportion at which highest strength is obtained as compared with those of conventional bricks. From the test results it could be inferred that, a sludge percentage varying between 5-10%, yields the best results in terms of compressive strength and other parameters as per Indian Standards. This paper thus brings out the importance of management of industrial sludge as well as its suitability in using as a brick additive material; thereby offering a possible way of safe disposal of the sludge.

Index terms- ***brick manufacture, cost effective construction material, dried sludge, sludge brick, waste management, waste water treatment.***

I. INTRODUCTION

The population of Hubli-Dharwad twin city, Karnataka, being 9 lakh and counting, it is obvious with the increase in waste generation every year, which in turns results in large volume sewage waste. The sewage water entering the treatment plant which is to be treated has also increased with time. The Madihal sewage water treatment plant of Municipal corporation treats about 10 MLD of municipal waste water on an average basis (with capacity of 20MLD) for the twin city. As a result of this treatment process, the plant produces as large up to 2000kg of sludge on weekly basis. This sludge obtained from the centrifugal area is air dried. A very little part of the same is used for agriculture where farmers use it as a compost, and majority of the sludge is left unused which is to be disposed off in the landfills. While sanitary landfills and dump yards are commonly used for disposal of sludge, rapid urbanization has made it increasingly difficult to find suitable landfill sites (keeping in account cost and availability). Due to all these inconveniences faced, there is an urgent need to find an alternative way of disposal for left out sludge or to use it in a productive way.

Utilization of sludge as an addition to construction and building material including building bricks or any other construction material is an effective strategy because it not only converts the wastes into useful materials but it also reduces the disposal problems. Keeping all these points in view, this work is an attempt to utilize sludge as a substitute of clay and fly ash for making of bricks and check whether it can be manufactured as per Indian national standards. Also, the effect of usage of sludge on raw materials is also studied.

II. METHODS AND COMPONENTS

The process of manufacturing of bricks is carried out in a number of stages. These are listed below. Each stage has its own specific importance.

Stage 1. Selection of the suitable type of brick earth.

Stage 2. Preparation and Tempering of Mud.

Stage 3. Shaping or Molding of brick units.

Stage 4. Drying of molded bricks.

Stage 5. Cooling and Burning of bricks.

A. Methodology

On the weekly basis air dried sludge was collected from the municipal sewage treatment plant as and when required. Manually few impurities like hay straws, plastic shreds and stones were removed. As the dried sludge had huge lumps, it had to be crushed and sieved through 600micron sieve to get uniform sized particles. This crushed sludge was carried to the brick manufacturing unit for the further processes.

A good quality brick earth should have the following constituents, Alumina (20-30%), Silica (50-60%). Lime (4%).A mixture of brick earth and fly ash is dryly mixed thoroughly in the ratio 1:20 (1 part of ash to 20 parts of earth).At this stage, sludge was added in different proportions to the mixture in the batches of 10 kilograms each for every proportion (5%.10%,15%,20%).The equal percent of mixture of fly ash and earth was removed and substituted with sludge. This mixture is uniformly dry mixed. Because water content is an important factor affecting the quality of the brick, tests including heavy compaction, and Atterberg limits were conducted first to obtain the plastic nature of the sludge clay ash and to determine the optimum moisture content (OMC) in the brick manufacturing process. Water is added as prescribed by the INS. This mixture of earth, fly ash, sludge and water is rinsed for 24 hours for better binding and adherence.

The well-prepared mixtures were then introduced into a series of brick molds (190mm×90mm×90mm) and were molded as per Indian standards. After the unmolding of the bricks, the green bricks were sprinkled with red oxide and slightly patted. And then they were air and sun dried for seven days. After molding. The drying of green bricks is necessary for three reasons *Firstly*, to make them strong enough for rough handling during subsequent stages as for examples for stacking etc. Secondly, to allow a slow loss of moisture from the brick without disintegrating the unit. If a green brick is put to direct burning in a kiln, the rate of loss of moisture will be so fast that the brick will crack during the burning process. Thirdly, to save fuel during the burning stage, a brick containing 20 percent moisture will require more fuel to burn compared to a brick containing only 2-4 percent moisture.

These dried bricks were then put in the kiln for burning at the temperature maintained from 900^0c-1200^0c. The firing is carried out for 28 days. At this stage of manufacturing, the burnt bricks were placed in open air to be cooled before using it in the construction and then they are ready to be used. As required by the Indian National Standards for building bricks, the produced bricks will then undergo a series of post manufacture tests including firing, shrinkage, weight loss on ignition, water absorption, and compressive strength to determine the quality of bricks.

III. CHARACTERIZATION OF SLUDGE

A. Particle size distribution using sieve analysis

Particle size distribution, also known as gradation, refers to the proportions by dry mass of a soil distributed over specified particle-size ranges. Gradation is used to classify soils for engineering and agricultural purposes, since particle size influences how fast or slow water or other fluid moves through a soil.

Table.I.. Sieve analysis for dried sludge

Sieve Size	Sieve Size (Mm)	Mass Retained	% Mass Retained	Cumulative % Retained	Cum% Finer
4.75	4.75	112.5	11.25	11.25	88.75
2	2	622.5	62.25	73.5	26.5
1	1	186.5	18.65	92.15	7.85

600	0.60	25	2.5	94.65	5.35
425	0.425	11.3	1.13	95.78	4.22
300	0.3	10.5	1.05	96.83	3.17
212	0.21	7	0.7	97.53	2.47
150	0.15	7	0.7	98.23	1.77
75	0.075	7.5	0.75	98.98	1.02
PAN	--	10	0.1	99.08	0.92

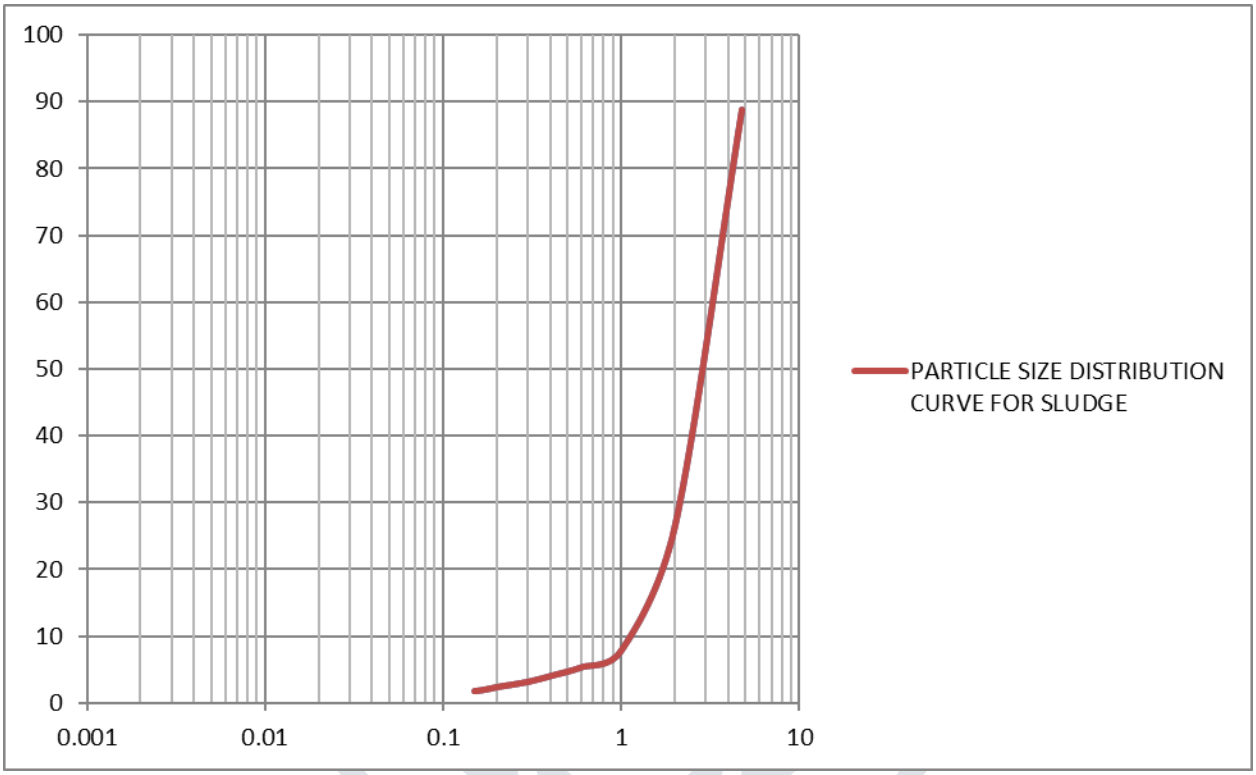

Fig 1. Particle size distribution curve for sludge

From the graph at Fig.1,

Coefficient of uniformity =3.8

Coefficient 0f curvature =1.15

4.75 - 2mm=73.5% (course gravel),
2mm-425mic=22.28% (course sand),
425mic-75mic=3% (fine sand)
Inference : More than 50% is retaining on 2mm.Hence it is a course grained soil of gravely nature. The soil does not fit into the well graded criteria hence it is poorly graded gravel.

Even though the analysis for original sludge showed it as a poorly grade gravel, for the manufacturing process ,uniformly graded sludge passing through 600 microns was used.

B. Liquid limit by Casagrande's apparatus and Plastic limit of powdered sludge

The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, its shrinkage limit, plastic limit, and liquid limit. As a dry, clayey soil takes on increasing amounts of water, it undergoes distinct changes in behavior and consistency. It brings out the nature of sludge and its water absorption characteristics can be known.

Soil taken-100gms

Percentage of water-45,55,65,75,85,95,105.

Inference: Even though 105% of water was added we were not able to get the liquid limit due to the non-plastic and non-cohesive nature of sludge

Hence the sludge is non plastic in nature.

C. Modified Proctors test

The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.

Table II. Modified compaction test results

Sl No	Particulars	1	2	3	4	5	6
1	Weight of mold + Compacted wet soil (gm)	4904.5	5062.5	5087	5102	5118.5	5117.5
2	Weight of compacted soil (gm)	1047.5	1205.5	1230	1245	1261.5	1260.5
3	Water content (%)	24	26	29	32	35	38
4	Bulk density (gm/cm^3)	1.05	1.208	1.232	1.248	1.264	1.263
5	Dry density (gm/cm^3)	0.856	0.958	0.955	0.945	0.936	0.915

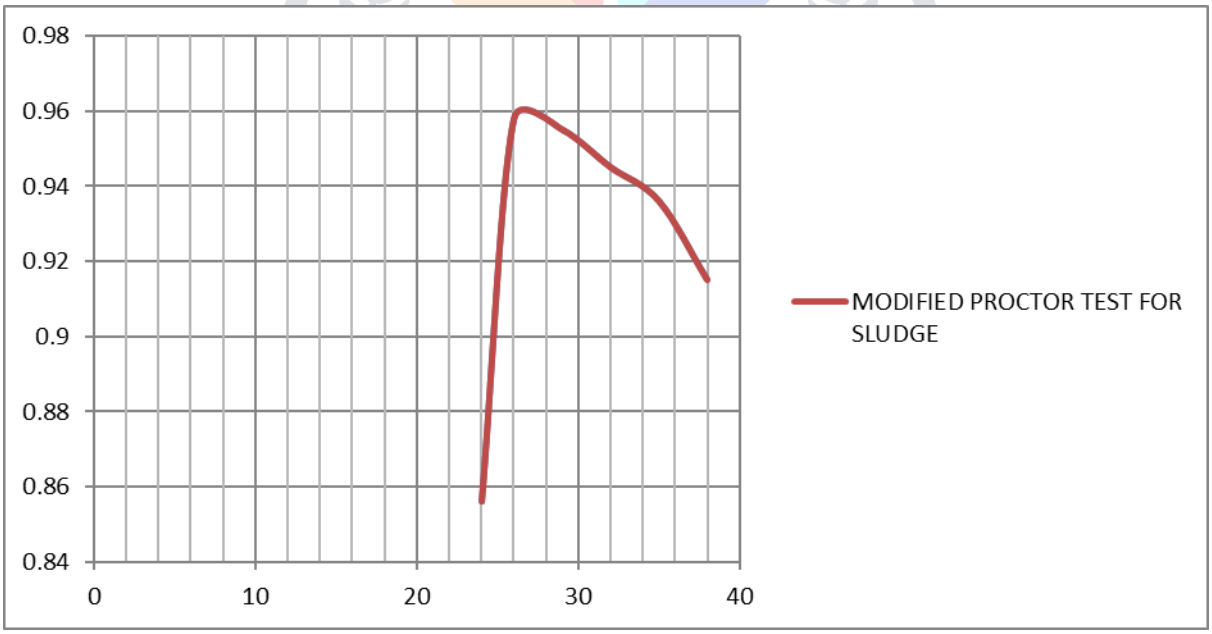

Fig 2. Proctors curve for sludge

Results:
Maximum dry density=0.958 g/cc
Optimum moisture content=26.3%

C. Compressive Strength (Crushing Strength)Test

The compressive strength test (BIS:1077-1957) conducted on the bricks yielded the following results

Table. III Compressive strength variation with % sludge

Compressive strength of normal brick =35 kg/cm^2				
Sludge % ➡	05	10	15	20
Compressive strength of brick treated with sludge (Kg/cm^2)	35.64	28.70	19.70	18.32

In addition to the above tests, simple usual tests like burning of bricks, observation of bricks for texture, scratch, ringing sound etc. were done on routine basis which showed that, the addition of sludge between 05% to 10% led to an improvement in all these test parameters. Study on the economical aspects implied that, the manufacturing cost of the sludge treated bricks is about 15% cheaper and 15% lighter (varies with proportion) than the normal bricks considering all the cost-benefit issues.

IV. RESULTS AND ANALYSIS

From the laboratory tests conducted on sludge for its geotechnical properties showed the swelling nature of sludge on addition of water. From Proctors test it can be concluded that for the sludge to reach its maximum dry density, its needs more moisture content as compared to that of clay (higher density at lesser moisture content). From the liquid limit, it can be concluded that sludge is a non-cohesive and non-liquid in nature which might cause a problem in binding with brick components.

During the manufacturing process, it was observed that, all the bricks which were made till the addition of 30% sludge were well bound well textured and no cracks were found. But further as the quantity of sludge addition was increased, the brick quality turned poor. Beyond 30% addition of sludge, the bricks were observed to be poorly bound and there was formation of cracks during sun drying even though they were well molded. These bricks are found more prone to cracking during the firing and burning process and may not necessarily possess the desirable characteristics and properties as per Indian Standards.

The compressive strength of the brick increased from 35 kg/cm^2 to 35.54 kg/cm^2 for the addition of sludge from 5% . This increase is due to the increase in the density of the brick earth and addition of sludge beyond 15%, observed to show no further considerable increase in the compressive strength. This may be due to the continued loss of plasticity and binding properties with the increased quantity of sludge.

CONCLUSIONS

This work has demonstrated the suitable conditions for using dried sludge from the sewage treatment plant as a clay substitute to produce an engineering quality of brick. Accordingly following conclusions could be drawn:

(1)The proportion of sludge in the mixture and the amount of water added while mixing are the key factors affecting the quality of brick in terms of binding and texture; which in fact facilitate proper burning and subsequent gain of strength.

(2)Addition of sludge to the clay increases the compressive strength but shows no effect beyond 30%. Maximum compressive strength obtained with the addition of sludge at 5%. Beyond 15% addition of sludge, no considerable effect is seen.

(3)When the sludge bricks are burnt, the organic matter in them gets oxidized resulting in lighter weight, which is desirable.

(4)The sludge treated bricks are economical as compared to the conventional bricks.

(5)The optimum percentage of sludge may be considered as 5% for the treatment of normal bricks.

It can be broadly concluded that using sludge as a substitute for brick earth at optimum percentage can be advantageous and points towards a possible way for the safe disposal of the treatment plant sludge.

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