COMPARATIVE ASSESSMENT OF THE QUALITIES OF TOP AND CLAY SOILS AS AN ALTERNATIVE PLASTER MORTARS IN CONSTRUCTION

Abstract:

The economic situation in Nigeria has escalated the cost of construction materials in common use, hence, the cost of building a house has almost gone out of reach of the average person. People must have shelter, which means they must build houses to live in. The river plaster sand is one of such materials, which may not be available in some places or very expensive if seen. The solution to this is to exploit alternative materials such as clay and soil. This research work thus, studied the compressive strength, water absorption, and weight loss due to dehydration of plaster mortars made with cement- clay soil and cement- topsoil and compared with the control mix of cement-river plaster sand to draw conclusion. The results of the compressive strengths, percentage water absorption, and percentage weight loss due to dehydration of these mortars are as presented in tables 5, 6, and 7 respectively at the various curing and testing ages. The results obtained at various curing days for the cement mix with the various materials for the compressive strength at 7days, 21days, and 28days are 7.36N/mm^2, 8.52N/mm^2, and 10.44N/mm^2; 9.16N/mm^2, 10.64N/mm^2, and 11.76N/mm^2; and 9.72N/mm^2, 11.56N/mm^2, and 12.2N/mm^2, respectively for river plaster sand RS, clay soil CS, and topsoil TS. In conclusion, results based on the objectives of this research work, which are the compressive strength, water absorption and weight loss due to dehydration of mortar made with these materials has convincingly, proved that the materials can be used as alternative materials in plaster mortar.

Keywords: *Suitability, Replacement, River plaster sand, Clay, Top soil, mortar plaster material.*

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1.0 Introduction

This research has become necessary after several observations at construction sites that excavated soils at some depths are often mixed with coarse river sand and cement to form plaster mortar, and in some cases used alone with cement to form plaster mortar where there is no plaster sand. The scarcity of river plaster sand in some areas or its high cost if available has lead engineers and other professionals in the construction industries, to think of alternative materials of which, top soils and clays are considered as better options. The economic situation in Nigeria has escalated the cost of construction materials in common use, hence, the cost of building a house has almost gone out of reach of the average person. People must have shelter, which means they must build houses to live in. This thus has given rise to the patronage of alternative available materials such as sand and clay soils. Many people have ever thought that plaster mortar, can only be made from cement river plaster sand. The revelation from this research work will create awareness in them that there are many available materials which can be used as alternative to the traditional river plaster sand.

Chuddley (1996) and Braja (2007) has classified soil according to their particle size distribution based on BS1377 and AASHTO as table 1.

Table 1: **Soil classification**

Type of soil	Particle size (mm)
Gravel particle	> 2
Sand particle	Btw 2 & 0.06
Silt particle	,, 0.06 & 0.002
Clay particle	< 0.002

Lambe and Whitman (2000), has stated that soil is the most plentiful construction material in the world and in many regions it is essentially the only locally available construction material. Chuddley (1996) has categorized clay soil based on unconfined compression test using 75mm long and 38mm diameter soil sample as obtained in table 2

Table 2: Compressive strength of clay soil

Compressive strength (KN/m^2)	Category of clay soil
< 25	Very soft clay
25 – 50	Soft clay
50 – 100	Medium clay

100 – 200	Stiff clay
200 – 400	Very stiff clay
> 400	Hard clay

According to Taylor (1991), quality mortar should resist water penetration through the units, and should resist frost or other forms of environmental attack (i.e., should be durable). The factor controlling the strength of any particular mortar mix are the ratio of binder to aggregate plus water to cement ratio and the strength any particular mix can be ascertained by taking the arithmetic mean of a series of test cubes (BE EN 196). Mortar is an adhesive mixture, which holds bricks and concrete blocks together. Mortar usually consist of water activated binding mediums of cement and lime, and a fine aggregate filler such as sand, in the proportion of one part binder to three parts of aggregate; though lime aid workability in mortar but cement maybe preferred as it has integral plasticizer (Osbourn and Greeno, 2007). The major types of mortar are lime mortar, cement mortar, combination mortar or gauge mortar, and mud mortar; and the main requirements of mortar and plaster are strength, workability, durability, and compatibility with the process of painting work. Another important requirement of mortar and plaster is resistance to rainwater, and water retentivity. For a mortar mix of 1:3, the amount of water required is 70% of the weight of cement (Varghese, 2010). Mortar is mixture of cementitious mineral aggregate, water, which can be classified as cement-lime mortar, cement mortar or masonry cement mortar. Mortar is manufacture in four types depending on the functional requirement. Plaster is a fluid mixture of cement, lime, sand and water; which is used for finishing masonry and either used for exterior or interior walls. The average compressive strength of plaster at 28 days according to ASTM C-109 is about 13.8N/mm^2 (Mamlouk & Zaniewski, 2011). According to these authors, ASTM C270 has specified the minimum average compressive strength of various types of mortar M, S, N, and O at 28 days as 17.2N/mm^2, 12.4N/mm^2, 5.2N/mm2, and 2.4N/mm^2 respectively.

The mortar mix proportion and average compressive strength at 28 days as specified by BS 998-2 according to Chuddley and Greeno (2006) is depicted in table 3.

Table 3: Mix proportion and compressive strength

S/No.	Mix proportion	Strength (N/mm^2)	Application
1	1:3	12	Exposed External
2	1:3-4	6	General External
3	1:5-6	4	Shelter External
4	1:7-8	2	General Internal
5	1:10-12	-	Internal grouting

2.0 Materials and methods

2.1 Materials for the experiments

The materials for this research experiments were locally sourced from the immediate environment in Kaura- Namoda, Zamfara state, which includes the following.

Dangote brand of ordinary Portland cement (OPC) of grade 42.5R conforming to BS and ASTM standards commonly used in concrete, free from hard lumps and of uniform colour with medium rate of hardening used as the binder was bought from local cement market in kaura Namoda. The river plaster sand used in this research was obtained from river gabaki situated along kaura Namoda /shinkafi road. The clay soil used in the research work was obtained from an excavation near the new bridge, along sabon gari road in kaura Namoda local government area. The top soil used was a disturbed sample free of decayed organic matters, obtained at a depth of between 250mm to 300mm, after removing the vegetable top at the Lagos campus of the main campus of the federal polytechnic, Kaura Namoda, Zamfara state. The Water used for the mixture and curing of mortar in the experiment is potable water from drinking water tap confirmed to be free from impurities/injurious amount of deleterious materials has its source from a borehole in the campus.

2.2 Batching

Considering the case of general external application for the mortar, a mix ratio of one part of cement to five parts of river sand (1: 5), was used in this experiment. This mix proportion was equally applied in the mixture for cement, clay and top soil samples. A predetermine water to cement ratio of 0.5 was used to carefully mix the cement and all other samples in the research tests. Each set of mixture, were given reference marks for identification as;

RS = cement and river sand mixture as reference mixture

CS = cement and Clay soil mixture

TS = cement and top soil mixture

2.3 Experimental Methods

2.3.1 Fineness and setting time test for the OPC. fineness and setting time of the dangote brand of ordinary Portland cement used in the experiment, was determined through laboratory experiments using the appropriate tools and procedures such as, the vicat apparatus as for setting time in accordance with ASTM and BS as specified in Neville and Brooks (2010), and Shetty (2005) and the results presented in table 4

Table 4: Fineness and setting time of cement

Fineness test results			Setting time test results	
% retained	Specific surface(m^2/kg)	Code Requirement	Initial setting time (mins)	Final setting time (mins)
2.00	425	Not more than 10% of material retained	190	238

2.3.2 The specific gravity: the specific gravity of the disturbed clay and top soil samples were, evaluated through normal testing procedures in the laboratory and the results obtained are 2.57 and 2.53 respectively.

2.3.3 Compressive Strength Test: A compressive strength test was conducted on sample mortar specimen 50mm x 50mm x 50mm cubes to determine the strength at 7, 21, and 28 days of curing in accordance with BS 516-1959 specification. After curing at each specified days, three mortar cubes of each sample RS, CS, and TS, were tested for strength at failure using standard concrete crushing machine. The load was applied gently and progressively until failure, and the loads at failure recorded. The compressive strength is determined from the failure load/ cross-section area of mortar cube ratio (i.e, $\frac{Failure\ Load\ \ (N)}{Cross-sectional\ Area(\ mm^2)}$) in N/mm^2.

At each curing age, the average of the compressive strengths is determined and recorded as presented in table 5.

2.3.4 Water absorption test: The total water absorption test which was conducted in accordance with BS 2586 specifications, was only for 7 days of mortar curing. The cured mortar cubes specimen were placed in an oven set 110^{oc} at a room temperature of ±2^{oc} for 24 hours, after which the specimens were removed and allowed some seconds to cool under the same normal room temperature and weighed, and the weights recorded as dry weight (wd). The specimens were then, totally immersed in water in a tank and at time intervals of 15mins, 30mins, 1hr, 3hrs, 24hrs, and 72hrs; the specimens were removed from the water, and cleaned to remove excess surface water and weighed. These weights are recorded as the wet weights (Ww). The total water absorption in percentage is determined from $\frac{wet\ weight\ (Ww)-\ dey\ weight\ (Wd)}{dry\ weight\ (Wd)}$ x 100. For each sample, three cubes of 50mm x 50mm x 50mm were tested and the average determined as presented in table 6.

2.3.5 Weight loss with time (shrinkage): This is to check the water loss capability of each sample specimen when exposed to open atmospheric condition (sundry). Three mortar cubes of each sample specimen were tested at the curing ages of 3 and 7 days. After each curing age, the specimens to be tested were weighed and the average weight recorded as W_1. These specimens, were then exposed to the open atmospheric condition (sundried) for 3 and 7 days and weighed and the average weight at each day recorded as W_2. The percentage average weight loss was calculated as; $\frac{W1-W2}{W2}\ x100;$ and results presented as in table 7. This can be considered as the shrinkage condition of samples specimen.

3.0 Results and Discussions

3.1 Results

i. Compressive strength test results: the results of the compressive strength tests for each sample mix with cement at various curing ages are represented in the table 5 and figure 1.

Table 5: compressive strength Results

Mix reference marks	Curing age (days)	Weight (gm)	Compressive strength (N/mm^2)
RS	7	265	7.36
	21	264.7	9.16
	28	272	9.72
CS	7	268	8.52
	21	268	10.64
	28	272.3	11.56
TS	7	259.7	10.44
	21	275	11.76
	28	282	12.2

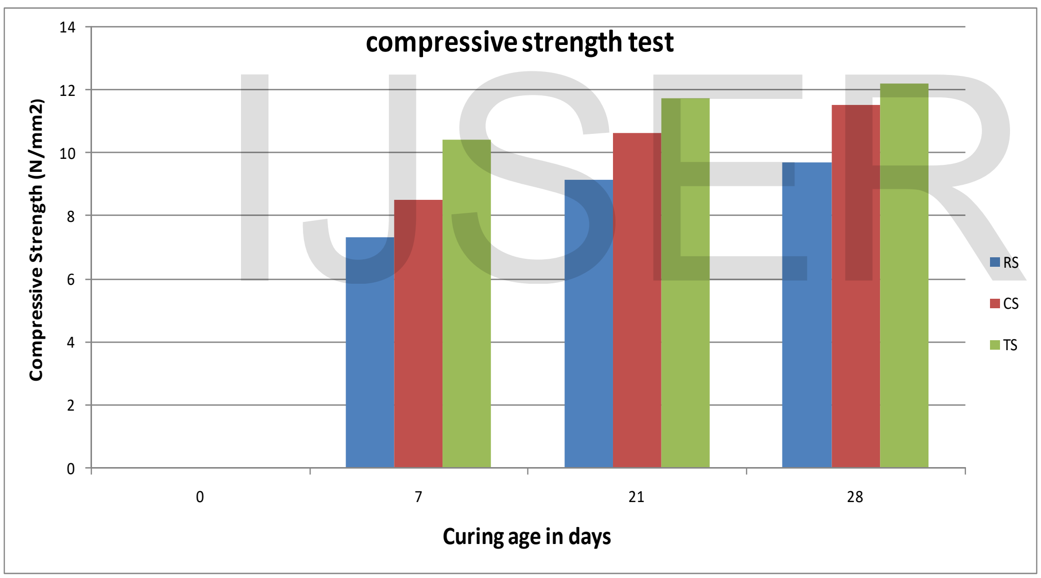

Figure 1: compressive strength VS curing ages in days

ii. Water Absorption test results: results of water absorption of each sample mix tested, is

Presented in the table 6 and figure 2

Table 6: Water Absorption Results

Ref. marks	Time / water absorption (%)

	15mins	30mins	1hr	3hr	24hr	72hr
RS	14.32%	17.62%	18.06%	20.74%	24.67%	44.05%
CS	6.45%	16.53%	18.95%	25.00%	28.83%	38.10%
TS	4.17%	5.24%	6.34%	6.84%	24.47%	27.14%

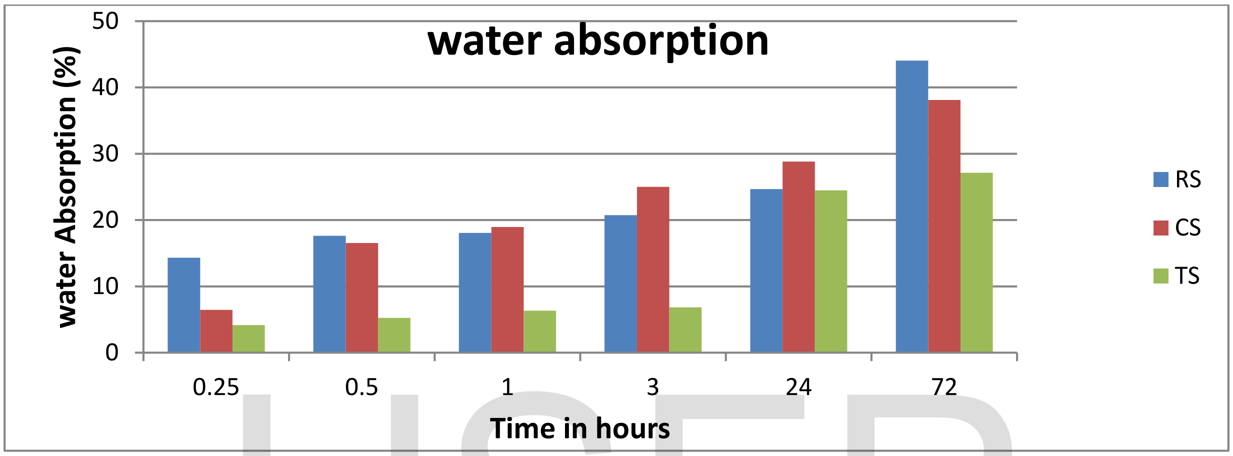

Figure 2: percentage water Absorption Vs Time in hours

iii. Weight loss with time (shrinkage): the weight lost in percentage after curing in water and sundried for 3 and 7 days, are represented in the table 7 and figure 3 and 4.

Table 7: weight loss in percentages

		Percentage weight loss (%) in days of sundry	
Ref. mix	Curing age (days)	3days	7 days
RS	3	9.6	11.4
	7	9.9	24.9
CS	3	1.9	4.3
	7	1.2	2.6
TS	3	13.8	20.8
	7	6.4	12.6

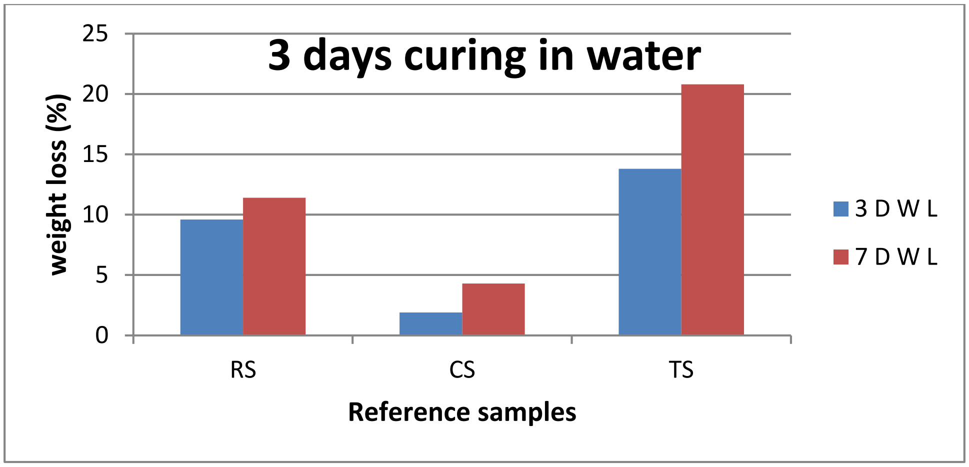

Figure 3: percentage weight loss in days

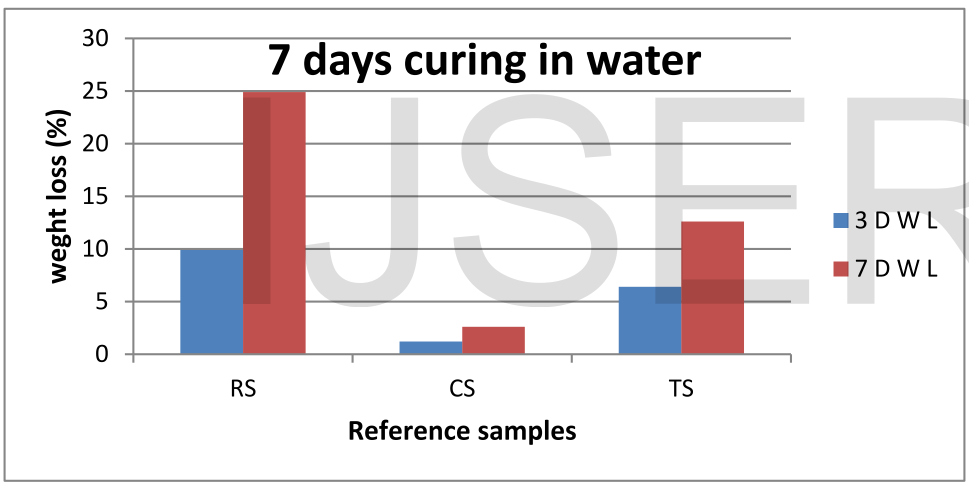

Figure 4: percentage weight loss in days

3.2 Discussion of Results

1. Compressive Strength: the compressive strength of plaster mortar for the materials used with cement increases with curing ages as presented in table 5 and figure 1 respectively. This phenomenon is not far from the simple saying that concrete strength increases with age. However, at each curing age, the strength of cement- topsoil plaster mortar appears to be the highest flowed by cement- clay plaster mortar. This may not be unconnected with the fact that these two materials have their particle sizes finer than the river plaster sand, which is coarser. The finer particle gives a higher compaction as well as higher density, which will provide higher resistance to the applied load. Table 1 presents the classification of soil that may assist in this.

The strength of the cement-clay plaster mortar is less than that of cement-topsoil plaster mortar, and the reason may be that clay retains water more than topsoil and the strength development may not be that faster. Based on the mix proportion and average minimum strength prescribed in table 2, the materials are suitable to be used as plaster mortar. The results confirms (Varghese 2010) claim that soft sand is the ideal material for making mortar or plaster for brickwork; and sharp mixed with soft sand can be also useful for plastering or as mortar.

2. Water absorption: the results of water absorption through total immersion are presented in table 6 and figure 2. These results shows that at early exposure to water condition, the cement-river sand plaster mortar can absorb water faster than all other materials followed by cement-clay as can be observed from the results at 15minutes, 30minutes; and 1hour, 3hours, and 24hours respectively. This may be because the river sand particles are coarser; hence, there may be more voids to facilitate the fast water intake. On the aspect of clay, naturally clay absorbs water faster until it is saturated. At the 72 hours, the cement- river sand plaster mortar again exhibits the highest percentage water absorption characteristic. This may be that at this later time, the other two materials, are already saturated with water and can take little or no more. At each period observed, the cement-topsoil plaster mortar exhibits the least percentage of water absorption characteristic. Comparing with the control (river plaster sand), these two materials can also serve as plaster materials.

3. Weight loss: Table 7, figures 3 and 4 represent the weight loss in percentage of plaster mortar made with cement and, river plaster sand, Clay, and topsoil at water curing ages of 3 and 7 days; and exposure to open atmospheric condition(sundry) at 3 and 7 days. For the values of percentage weight loss at each days of exposure for every curing age in days, it is observed that the weight loss in each material used, increases with days of exposure. This signifies that in as much as the plaster mortar is exposed to the open atmospheric conditions, the weight loss continues to increase just like the compressive strength that continues to increase with curing ages. A constant weight may be maintained when all the moisture is given up due to continuous exposure. Because clay has high water retention capacity due to its particle size and nature, it gives out little water with time compared with the other materials. In addition, because of the coarser nature and probably the high void potential of river plaster sand, the mortar gives out water faster than the other two materials. The rate of water loss is synonymous with shrinkage and potential cracks.

4.0 Conclusion and Recommendations

4.1 Conclusion

The results based on the objectives of this research work, which are the compressive strength, water absorption and weight loss due to dehydration of mortar made with these materials has convincingly, proved that the materials can be used as alternative materials in plaster mortar. These materials are much readily available in some areas compared with the river plaster sand hence, minimal cost.

4.2 Recommendations

- ✓ Integrate the materials for plaster mortar because of their abundant availability and quality as seen from the experimental results.
- ✓ These materials are recommended as alternative materials to reduce cost because of the scarcity of the river plaster sand in some areas in Nigeria leading to high cost of building in such areas,
- ✓ Adopt appropriate mix proportions using established standards in mixing these materials with cement or lime.
- ✓ Ensure adequate curing and maintenance in other to avoid possible excess shrinkage and consequently cracking.
- ✓ Researchers should conduct further study on these properties using different water/cement ratios in the mixture.

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ISSN 2229-5518

AN ASSESSMENT OF THE SUITABILITY OF REPLACING NORMAL RIVER PLASTER SAND WITH CLAY AND TOP SOIL AS ALTERNATIVE PLASTER MORTAR MATERIALS

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