Sodium Chloride Influence on Cement Stabilised Bricks Compressive Strength

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Abstract

This research reports the suitability of lateritic soil contaminated by sodium chloride for brick production. Five different percentages (0%, 1%, 3%, 5% and 10%) by weight of sodium chloride were mixed with 10% cement stabilised lateritic soil. The mixtures were used to produce bricks of size 230mm by 110mm by 90mm, and air cured for 56 days. During the curing period, the bricks compressive strength was monitored with the aid of a universal testing machine. Results showed that the compressive strength of the cement stabilised bricks decreased with increasing levels of sodium chloride salt content, and increased as the curing age also increased. In addition, 28-day compressive strength values of stabilised bricks contaminated with up to 3% sodium chloride were higher than 2.5 N/mm^2 minimum strength, stipulated by Nigerian Standard Organisation. Hence stabilised bricks with up to 3% sodium chloride can be used in building construction.

Keywords: Bricks, Sodium chloride, compressive strength, lateritic soil, cement.

1. Introduction

Laterite is a material with many significant different material compounds, containing a large proportion of iron and aluminium hydroxides (Steve [1]). Moreover, silica, calcium, magnesium, potassium, and sodium are present in very low amounts. In some instances, the iron content of laterite can exceed the aluminium content, but even a small amount of iron will tint the laterite rust red (Roger [2]). Osula [3] defined laterite as a highly weathered tropical soil, rich in secondary oxides of any or a combination of iron, aluminium, and manganese. According to Maignien [4], three stages of production of laterites identified are decomposition, leaching, and accumulation.

Laterite deposits ranging in thickness from a few centimetres to tens of metres are roughly horizontal and can cover thousands of square kilometres. Laterite can be found in areas that are no longer subject to laterite formation because of the changes in climate, hydrological conditions, or topography. Where climates have become wetter, caves can form as a result of ground water solution and snap beneath an old laterite crust (McFarlene [5]). In tropical parts of the World, lateritic soils are used as a road making material and they form the subgrade of most tropical roads. They are used as subbase and base courses for low cost roads, carrying low to medium traffic. Furthermore, in the rural and urban areas of developing countries like Nigeria, laterite is used as building material for moulding brick production.

Salt is currently mass produced by evaporation of seawater or brine from other sources such as brine wells and salt lakes, and by mining rock salt called halite. According to Feldman [6], the World production was estimated at 210 million metric tonnes, the top five producers being the United States of America (40.3 million tonnes), China (32.9 million tonnes), Germany (17.7 million tonnes), India (14.5 million tonnes) and Canada (12.3 million tonnes) as of year 2002. The most common use of salt is for cooking but salt can be used for a number of applications; from manufacturing pulp and paper to setting dyes in textiles and fabric, to production of soaps and detergents. In most part of Canada and the USA, large quantities of rock salt are used to help clear highways of ice during winter.

Soil, initially from three phases, namely, soil solid, water, and air, has been contaminated due to indiscriminate dumping of wastes. The wastes are organic, inorganic, or both in origin or nature. Research has shown that salt partially modifies the mineralogy of the bricks, acting as a melting agent, especially at high firing temperatures and gives rise to more resistant products which are suitable for restoration work (Cultrone *et a*l [7]). Sunil *et al* [8] observed that the geotechnical and chemical properties of lateritic soil are altered in three pH conditions (5.0, 7.0 and 8.0). The compressive strength of lateritic blocks reduced under all the pH conditions and considerable reduction in strength was observed when the pH was 5.0. Park *et al* [9] investigated comprehensive effects of surfactants and electrolyte solutions on kaoline clay soil for index properties, compaction, strength characteristic, hydraulic conductivities and adsorption characteristic. The shear strength of the kaolinite clay increases while its hydraulic conductivity was not significantly affected.

Khamehchiyan *et al* [10] investigated the geotechnical properties of oil contaminated coastal soils and sediments for engineering and environmental purposes. The contaminated samples were prepared by mixing the soils with crude oil in the amount of 2, 4, 8, 12 and 16% by dry weight. The results indicated a decrease in strength, permeability, maximum dry density, optimum moisture content and Atterberg limits.

The literature or research on the effect of salts on the lateritic bricks properties is still scanty. The possibility of disposing of common salt sodium chloride on any available land is very high. The study, therefore, set out to know the effect of the mentioned salt on lateritic clay bricks.

2. Methodology

The lateritic soil sample for the study was taken from a burrow pit located along Lagos Ibadan Expressway at Oluyole Local Government Area in Ibadan, South-Western Nigeria. The soil sample was air-dried, pulverised, sieved with the aid of BS sieve no. 4 of aperture 4.75mm and stockpiled for later usage. The cement used for stabilising the laterite was ordinary Portland cement and the water used for the bricks production was potable water taken from the University of Ibadan, Water Treatment Plant.

Prior to the production of lateritic bricks, the soil sample liquid limit, plastic limit, optimum moisture content (OMC), and maximum dry density (MMD) were determined. The liquid limit was measured using a standard liquid limit device while laterite plastic limit was determined by rolling the moist soil into a thread of about one-eighth inch on flat thick glassed plate. The moisture content at which the thread began to break was taken. The soil optimum moisture content (OMC) and maximum dry density (MDD) were determined using a standard Proctor test. Details of the tests are covered in BS 1337 [11]. Furthermore, the laterite oxide contents were determined with the aid of an Absorption/Emission Spectrometer.

About 0.2 g of the soil sample was pulverised into powder and poured into a round bottom conical flask. Exactly 5 ml of hydrochloric acid (HCl) was added to the soil, shaken, placed in a water bath, and steamed for one hour. In addition, 5 ml of both boric acid and lanthemium chloride were added to the mixture in order to prevent the silica from evaporating into the air. The mixture in flask was again steamed for another 30 minutes. Thereafter, it was poured into a 100 ml volumetric flask and made up to the mark by the addition of distilled water. An Atomic Absorption Spectrometer (AAS) was used to determine the percentages of different oxides present in the lateritic soil.

Enough quantity of sodium chloride was procured. The stockpiled laterite was divided into five equal parts by weight. Each part received 10% by weight of ordinary Portland cement for its stabilisation. The soil and cement were mixed on a flat and clean platform. Different percentages by weight of salt were added to five parts of the soil cement mixture with each part receiving single percentage. The five percentages of salt investigated were 0%, 1%, 3%, 5%, and 10%.

Each laterite/cement/salt part was placed on a flat and hard surface and the quantity of water corresponding to the soil optimum moisture content (OMC) by weight was added to the mixture. The mixture was mixed together manually using a hand trowel to produce a homogeneous mixture. The mould size used for bricks casting was 230 mm x 110 mm x 90 mm. The moulds were lubricated with oil to enhance easy removal of the moulded bricks. After mould lubrication, the moist mixture was placed in each mould in 3 layers, with each layer receiving 35 blows to eliminate entrapped air voids, with the aid of a 2.5kg rammer. The excess mixture was scraped off and the surface levelled using a straight edge iron. Twenty eight bricks were made from each part of laterite/cement/salt mixture, making a total of a hundred and forty bricks. The moulded bricks were air cured for a period of 56 days, covering the compressive strength monitoring time.

During the air curing of the bricks, their compressive strengths were determined on the 7^{th}, 14^{th}, 28^{th}, and 56^{th} day of curing. For each percentage mixture, a total of 16 bricks were tested with four bricks crushed on each testing day. The mean values of the maximum loads at which each group of four bricks failed were found and the compressive strength determined.

In accordance with BS 3921 [12], a brick water absorption test was carried out. Prior to the performance of the test, the bricks were dried in an oven at 60 ^{o}C until a constant weight was recorded. The samples were removed from the oven and allowed to cool, reweighed, and immersed completely in water for 10 minutes. After 10 minutes immersion, the bricks were removed and the free surface water wiped off as fast as possible with a cloth. The bricks were reweighed again in order to calculate the amount of water absorbed. The above procedure was repeated to determine brick water absorption at 60 minutes and 1440 minutes immersion. The average values of measured absorption rate for forty five bricks were recorded (nine bricks selected for each mixture).

3. Results and Discussion

The Atterberg limit results for the lateritic soil showed that the liquid limit was 49%, and the plastic limit was 22%. Linear shrinkage was 13% and the plasticity index was 27%. Using Casagrande's system of soil classification, the soil was inorganic silty clay with intermediate plasticity because its liquid limit fell between 35% and 50%. The soil chemical analysis for oxides contents revealed that the major oxide present was silica (58.91%) as shown in Table 1. The compaction test results showed that the mixture with 10% salt has the highest OMC value of 19.95% as shown in Table 2. The maximum dry density (MDD) increased with an increase in the salt content. The salt needs more water for ionization and the additional water brought about an increase in compacted soil density to a certain extent, as shown in Table 2.

Table 1 Results of the chemical analysis of the lateritic soil

Oxide	Composition (%)
Silica SiO_2	58.91
Aluminium oxide Al_2O_3	18.05
Ferrous oxide Fe_2O_3	7.96
Sodium oxide Na_2O	0.35
Magnesium oxide MgO	1.27
Potassium oxide K_2O	1.47
Tin oxide TiO_2	1.13

Table 2 Results of compaction test of the stabilised bricks

% of NaCl	OMC (%)	MDD (g/cm^3)
0	17.23	1.81
1	18.38	1.83
3	19.50	1.84
5	19.90	1.85
10	19.95	1.85

The standard test ages used for the study were 7, 14, 28 and 56 days in order to obtain the compressive strength of the bricks at different ages. It was observed in Table 3 that the compressive strength of the bricks decreased with an increase in percentage of sodium chloride added to the stabilised lateritic soil. In addition, the compressive strength of both controlled and NaCl contaminated bricks appreciated with age as revealed in Figure 1. The presence of sodium chloride in lateritic bricks hindered compressive strength development. The replacement of strong cations in the soil (clay) minerals with Na^+ or attraction of Na^+ to clay minerals can weaken the bonds among clay minerals and also between the clay minerals and cements. Invariably, reduction in the brick compressive strength is observed.

Table 3 Results of compressive strength test of the stabilised bricks

NaCl (%)	Average compressive strength (N/mm^2)			
	7-days	14-days	28-days	56-days
0	2.03	2.52	3.01	3.11
1	1.83	2.42	2.80	3.01
3	1.45	2.27	2.60	2.82
5	1.24	2.15	2.42	2.57
10	1.09	1.80	2.17	2.32

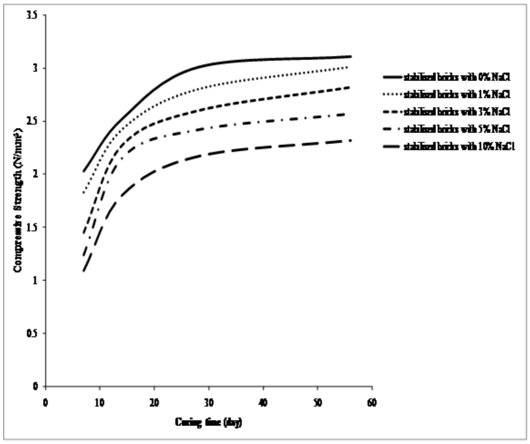

Figure 1 Compressive strength of cement stabilised bricks contaminated with NaCl

Using 28-day compressive strength as a benchmark for design and with reference to Table 3, the compressive strengths of stabilised bricks contaminated with up to 3% NaCl were above 2.5 N/mm^2. This is the minimum value of compressive strength for clay bricks for building construction given by the Nigerian Standard Organisation (Okoli [13]). Therefore, bricks contaminated with more than 3% NaCl should be avoided in practice.

The durability of the stabilised lateritic bricks was examined in terms of permeability using the water absorption test.

Table 4 displayed the water absorption results after 10 minutes, 60 minutes, and 1440 minutes of immersion of the stabilised bricks in water. The stabilised bricks did not dissolve when immersed in water due to presence of cement added to stabilise them. Hence the bricks were hard to disintegrate in water. The results further revealed that the average rate of water absorption increased slightly and then decreased as the percentage of sodium chloride in the mix increased.

Table 4 Results of rate of water absorption test of the stabilised bricks

NaCl (%)	Average rate of absorption (%)		
	10 minutes	60 minutes	1440 minutes
0	10.5	16.1	17.6
1	13.0	17.9	17.9
3	4.5	6.2	7.1
5	5.6	4.9	4.8
10	2.3	3.1	3.1

4. Conclusion

The influence of sodium chloride on cement stabilised lateritic bricks was investigated in the study and the following assertions were drawn from the results obtained. The compressive strength of cement stabilised bricks increased with age irrespective of the quantity of sodium chloride present, but the magnitude decreased with an increase in salt content. Therefore, the presence of the salt hindered brick strength development. Furthermore, the compressive strength values of stabilised bricks contaminated with up to 3% NaCl were greater than 2.5 N/mm^2 minimum value given given by Nigerian Standard Organisation. This revealed that stabilised bricks with up to 3% NaCl can be used in building construction. Absorption of water due to complete immersion of stabilised bricks decreased as the percentage of sodium chloride increased. There was however an increase in the percentage of water absorbed by the stabilised bricks as the period of immersion increased.

5. References

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