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Durability of Laterized Concrete Exposed to Sulphate Attack Under Drying-Wetting Cycles.

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Abstract

The study investigated the performance of laterized concrete exposed to drying-wetting cycles of sulphate environments with a view to providing empirical data for laterized concrete specification. It adopted accelerated ageing method to investigate the effect of sulphate attack on laterized concrete exposed to wetting-drying cycle comprising of 4 days of full immersion and 3 days of drying at ambient temperature at two concentrations (3% and 5%) of magnesium sulphate solution for a total exposure period of 24 weeks. The test cubes were first cured by complete immersion in water for 28 days and afterward exposed to wetting-drying cycle of magnesium sulphate solution. The compressive strength was determined by using an ELE 2000kN compression testing machine. Data obtained from the experiments were analysed using percentages, mean, ANOVA and regression analysis. The results of the tests carried out showed that conventional concrete had a better resistance (in terms of compressive strength) to sulphate attack than laterized concrete. Conventional concrete exposed cyclically to sulphate solution of concentrations of 3% and 5% lost 18.91% - 30.34% of its compressive strength, after a period of 24 weeks of exposure. Whereas, laterized concrete similarly exposed for the same period; lost 26.54% - 31.79% (at 20% laterite content) and 36.67% - 51.33% (at 40% laterite content) of its compressive strength. It showed that the compressive strength of the tested laterized concrete specimen decreased significantly between 10% and 50%, each at $\alpha = 0.05$ with increasing sulphate concentration, laterite content and exposure period. The study concluded that conventional concrete performed better than laterized concrete in intermittently sulphate-laden environments.

Keywords: Laterized concrete, Sulphate, Durability, Compressive strength.

1. Introduction

The growing concern over the impact of buildings on environment has led to increasing demand for more environmentally friendly buildings constructed with cheap but durable building materials. In the context of concrete, which is the predominant building material, it is necessary to identify not only less expensive but more environmentally friendly alternative materials as substitutes to more expensive conventional ones such as cement, steel, sand, granite, gravel and wood. In recent years, many researchers have established that the use of laterite as a substitute for the conventional fine aggregate component of concrete (sand) or as a supplementary fine aggregate can effect a drastic reduction in construction cost and also provide more environmentally friendly concrete. According to Dinakar *et al.* (2008), the three fundamental elements for supporting an environmentally friendly concrete technology for sustainable development are the conservation of primary materials, the enhancement of the durability of concrete structures, and a holistic approach to the technology. With respect to conservation of primary materials, the principal action to be taken in order to reduce utilization of non-renewable resources and its negative impact on the environment is reduction in the consumption of cement, aggregates and water. Along these lines, Adepegba (1975a,b), Lasisi and Ogunjimi (1984), Osunade (1994, 2002a,b), Salau (2003), Olusola (2005) and Udoeyo, *et al.*(2006) have demonstrated that laterite as a partial or whole replacement for sand in the fine aggregate fraction of concrete is one of the best alternative materials for production of environmentally friendly concrete.

Many research studies have been carried out on laterized concrete; most of these studies focused on its mechanical and elastic properties. Limited work has been carried out on the durability aspects of this emerging construction material as it is probably with concrete that is made with sand as fine aggregate. Although studies on the compressive strength of laterized concrete have shown encouraging results, the lack of sufficient technical data has limited its wider application in construction work. The dearth of research data informed the need for this further work to evaluate other relevant characteristics of laterized concrete necessary for the development of standards and codes to enhance a safe application of the concrete. Researchers still need to evaluate the durability performance of laterized concrete so as to provide the industry with the necessary information that helps in making decisions concerning the material use.

The durability of conventional concrete exposed to various environmental conditions (atmospheric carbon-dioxide and reactive ions, together with water and oxygen) has been studied and can thus be predicted. The questions that come to mind are: Will laterized concrete exposed to similar environmental conditions exhibit the same durability performance? Or can we obtain a similar behavioural pattern for laterized concrete? Will partial or whole replacement of sand as fine aggregate in concrete with laterite produce better sulphate resistant concrete than conventional concrete? BS8110 (1997) warns that concrete made from materials or techniques not covered by British Standards may exhibit different properties from those made with conventional materials, hence, their performance and suitability should be established by appropriate tests before recommending them for use. In this research work the effect of exposure of laterized concrete to wetting-drying cycles of magnesium sulphate solution is investigated.

2. Experimental Procedures

2.1 Materials

Laterite, sharp sand, washed granite and ordinary Portland cement were the major materials that were used in this research work. All the materials were sourced from within Ile-Ife in Ife Central Local Government Area of Osun State, Nigeria. The cement was manufactured by West Africa Portland Cement at Sagamu and conformed with the requirements of BS EN 197-1 (2001). The granite used as coarse aggregate had a uniform size not exceeding 19mm while the laterite and sharp fine aggregate were of maximum size of 5mm.

2.2 Specimens

The test specimen was 100mm cube meeting the requirements of BS EN 12350-1, EN 12390-3 and EN 12390-2. The wooden modes were fabricated in semblance of BS EN 12390-1 specifications.

2.3 Exposure and testing

The specimens were cured in accordance with BS EN 12390-2. The curing method that was adopted in this research was wholly water-submerged as it has been adjudged to be the best method for laterized concrete (Falade, 1991). After 28 days of continuous curing in water, the laterized concrete specimens were exposed to sulphate environment for a maximum period of six months. Specimens were subjected to sulphate solution and drying in an ambient temperature. A wetting-drying cycle consisted of 4 days of full immersion in sulphate solution and 3 days of drying at ambient temperature.

This one-week repeat cycle specimens were tested at 2 weeks interval for a period of 24 weeks. On the day of the tests, the specimens were removed from the exposure tank and their surfaces moped clean with dry foam to remove weak reaction products and loose materials from the specimen. The weight and dimensions of the specimens were measured.

The compressive strength test was carried out by using ELE 2000kN compression testing machine conforming to BS EN 12390-4&6 in accordance with BS EN 12390-3.

3. Results and Discussion

Table 1 presents the 28-day compressive strength of laterized concrete cure in water. It served as the basis for comparison of what happened subsequently to the specimens after their exposure to magnesium sulphate solution. The results are in consonance with all the previous studies on laterized concrete.

Table 1: 28-Day compressive strength of laterized concrete specimens cured in water

Percentage replacement of sand (%)	Compressive strength (MPa)			
	1	2	3	Mean
0	28.20	29.40	29.40	29.00
20	26.10	25.30	24.20	25.20
40	18.20	17.60	17.60	17.80
60	12.80	13.20	14.20	13.40
80	10.80	12.20	10.30	11.10
100	10.20	8.80	9.80	9.60

Some previous studies of external sulphate attack on ordinary Portland cement (OPC) concrete show that reactions involve calcium silicate hydrate (C-S-H) and the aluminate component of hardened cement paste [Tian and Cohen, (2000); Skalny *et al.* (2002); Shannag and Shaia, (2003); Santhanam *et al.* (2003)]. As a result of these reactions, expansion and cracking are caused directly or indirectly, by ettringite formation, while softening and disintegration are caused by destruction of C-S-H. The test specimens did not show any distinctive visual features of damage such as cracking and spalling. As a result, the presence of ettringite was very remote (Aye and Oguchi, 2011). This is in conformity with identified behavioural pattern of magnesium sulphate by Skalny *et al.* (2002) that unlike the attack of other alkali sulphates, attack by magnesium sulphate is characterized mainly by a loss of strength and disintegration of the concrete under attack, rather than by an expansion and scaling. This type of sulphate attack falls into first form of sulphate attack according to Al-Amoudi (2002) which is akin to eating away of the hydrated cement paste and progressively reducing it to cohesionless granular mass leaving the aggregates exposed. He concluded by saying that this type of deterioration may lead to reduction in the cross-sectional area of the structural component (i.e. loss in weight of concrete) and decrease in strength. This mode of failure which is attributed mainly to the formation of gypsum and it is known as the acidic type of sulphate attack.

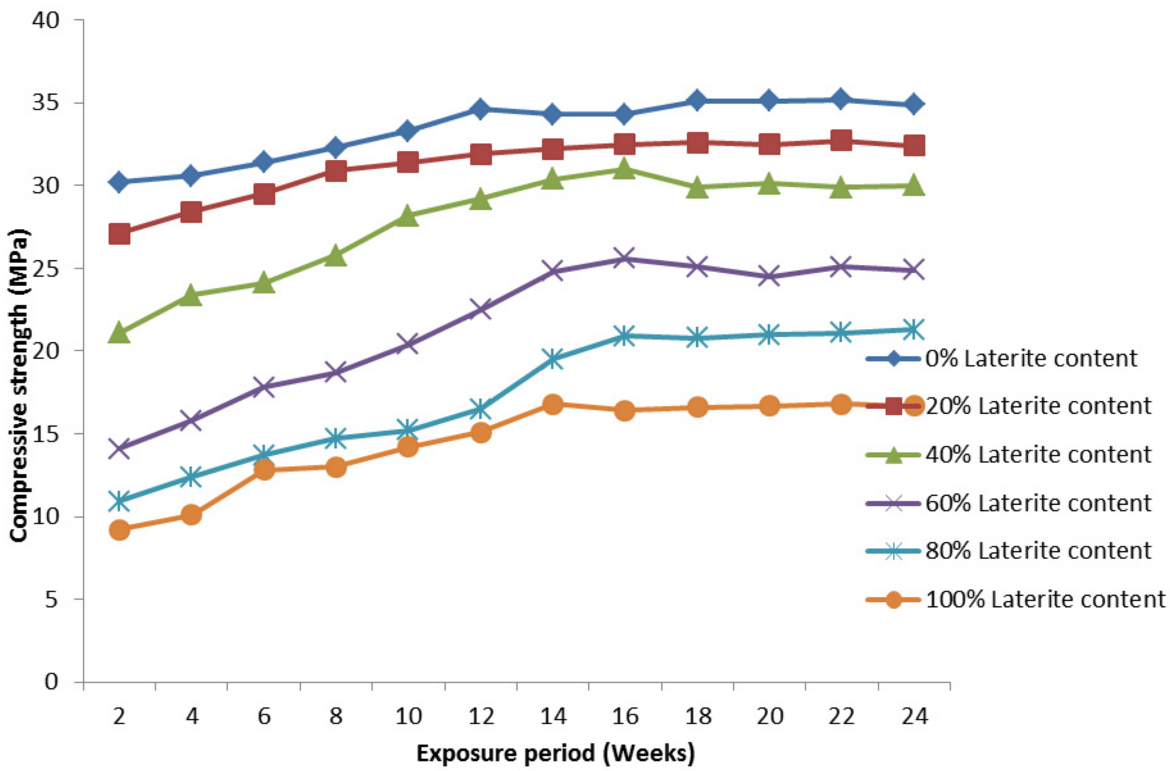

Fig. 1: Effect of Cyclic Exposure on Compressive Strength of Laterized Concrete Exposed to 0% Sulphate Concentration

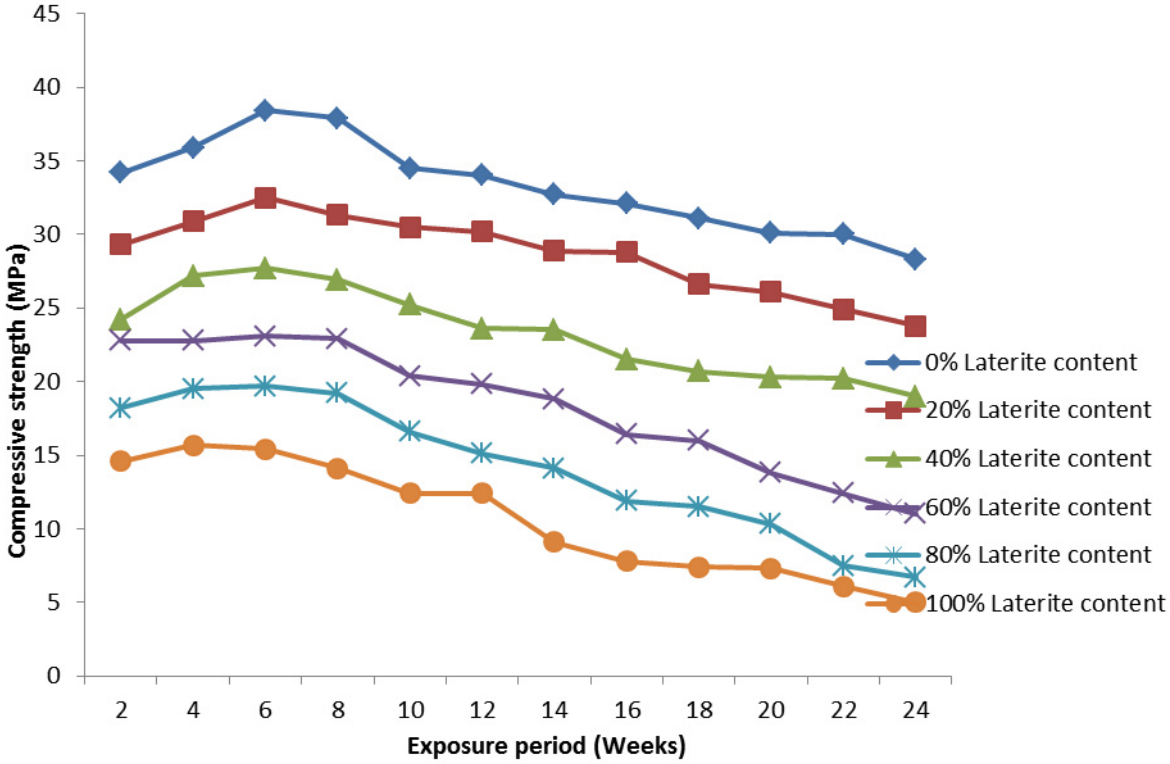

Fig. 2: Effect of Cyclic Exposure on Compressive Strength of Laterized Concrete Exposed to 3% Sulphate Concentration

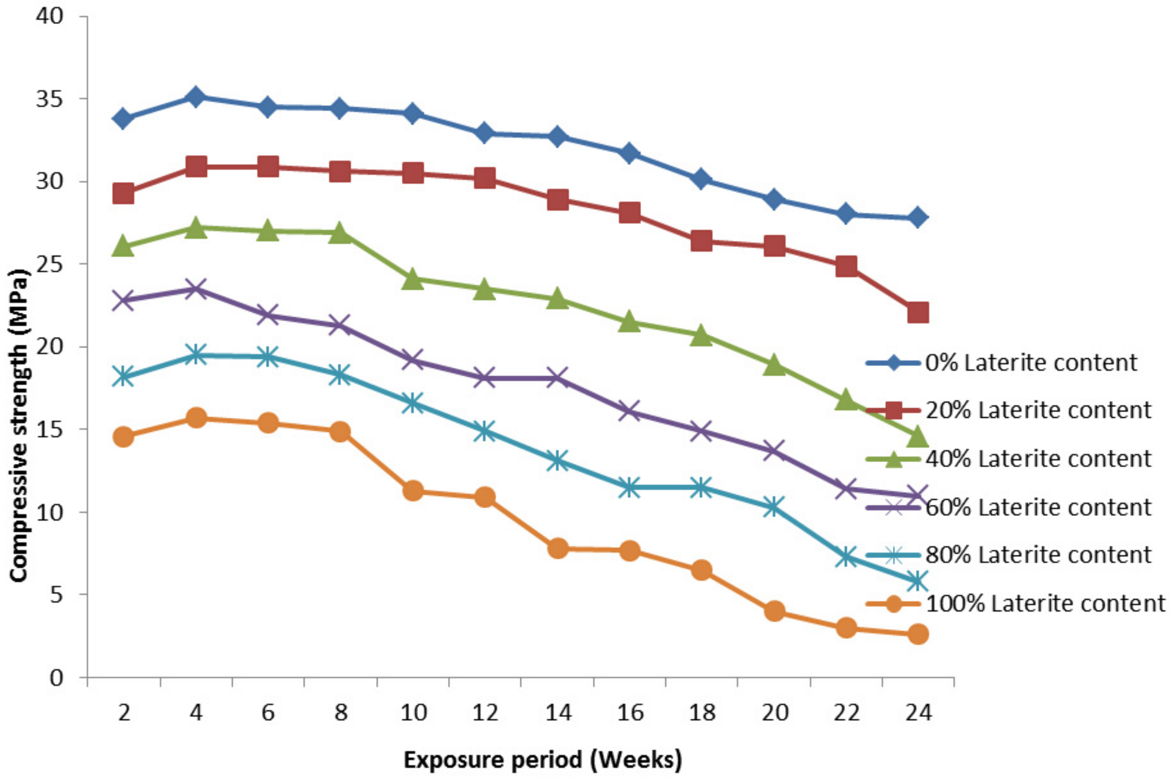

Fig. 3: Effect of Cyclic Exposure on Compressive Strength of Laterized Concrete Exposed to 5% Sulphate Concentration

The results were presented in Figures 1 to 3. There were no visible signs of damage in all specimens. This means that the presence of ettringite was very remote (Aye and Oguchi, 2011). When subjected to the cyclic sulphate exposure, compressive strength of laterized concrete initially increased but later, between 6 and 8 weeks began to fall. This may be due to the fact that the sulphate exposure period (4 days in a week) was too short to have any significant effect on the specimen. Salt crystals formed in the pores during the drying period might block the penetration of solution to some extent during the immersion period. By comparing the results obtained after 24weeks of exposure with that of Ata (2012), it was noted that cyclic exposure had an accelerated effect on the sulphate attack of the specimens as reflected by the compressive strength results. This corroborates Neville (1995) findings that intermittent exposure of concrete structures to sulphate laden solution increases the rate of sulphate attack.

5. Conclusions

Drying-wetting (cyclic) exposure of conventional and laterized concrete to magnesium sulphate solution increased the rate and magnitude of loss in their compressive strength. Conventional and laterized concrete subjected to cyclic exposure of magnesium sulphate solution of 3% and 5% concentration levels experienced a higher loss of compressive strength vis-a-vis a similar concrete subjected to continuous exposure of the same solution.

Concentration levels of magnesium sulphate solution influenced the severity of its attack on conventional and laterized concrete. The higher the magnesium sulphate solution concentration the higher the loss in compressive strength of concrete exposed to it.

In all cases of exposure, conventional concrete experienced less loss in compressive strength than laterized concrete.

References

Adepegba, D. (1975a).”A comparative study of normal concrete with concrete which contained laterite instead of sand” *Building Science*, Vol.10. pp.135-141.

Adepegba, D. (1975b). “The effect of water content on the compressive strength of laterized concrete” *Journal of Testing and Evaluation*, JTEVA, Vol.3, pp.449 – 453.

Al-Amoudi, O.S.B.(2002).”Attack on plain and blended cements exposed to aggressive sulfate environments” *Cement and Concrete Composites*, Vol.24, pp.305-316.

Ata, O. (2012). “Durability characteristics of laterized concrete exposed to sulphate environments”. *An unpublished Ph.D. Thesis,* Department of Building, Obafemi Awolowo University, Ile-Ife.

Aye, T. and Oguchi, C.T. (2011).”Resistance of plain and blended cement mortars exposed to severe sulfate attacks” *Construction and Building Materials*, Vol.25, pp.2988-2996.

Aye, T. and Oguchi, C.T. (2011).”Resistance of plain and blended cement mortars exposed to severe sulfate attacks” *Construction and Building Materials*, Vol.25, pp.2988-2996.

British Standard Institution (1997). *The structural use of concrete: Part 1, Design, Materials and Workmanship*, BSI, BS 8110, London.

British Standard Institution (2000). *Testing fresh concrete*, BS EN 12350: Parts 1-6, BSI, London.

British Standard Institution (2000). *Testing hardened concrete*, BS EN 12390: Parts 1-8, BSI, London.

British Standard Institution (2001). *Composition, specification and conformity criteria for common cements*, BS EN 197: Part1, BSI, London

Dinakar, P.; Babu, K.G. and Santhanam, M. (2008).”Durability properties of high volume fly ash self compacting concretes” *Cement and Concrete Composites*, Vol.30, pp.880-886.

Falade, E. (1991).”Influence of method and duration of curing and mix proportion on strength of concrete containing laterite fine aggregate” *Building and Environment*, Vol.26, pp.453 - 459.

Lasisi, F. and Ogunjimi, B. (1984). Source and mix proportions as factor s in the characteristics strength of laterized concrete. *Int. Journal for Development Tech*., Vol.2, No3, pp.8-13.

Neville, A.M. (1995). *Properties of Concrete,* Addison Wesley Longman Limited, England.

Olusola, K.O. (2005). “Some factors affecting compressive strength and elastic properties of laterite concrete”. *An unpublished Ph.D. Thesis,* Department of Building, Obafemi Awolowo University, Ile-Ife.

Osunade, J.A. (1994). “Effect of grain size ranges of laterite fine aggregate on the shear and tensile strengths of laterized concrete.” *International Journal for Housing Science and its Applications,* Vol.4, No2, pp.8-15.

Osunade, J.A. (2002a).”Effect of replacement of lateritic soils with granite fines on the compressive and tensile strengths of laterized concrete” *Building and Environment*, Vol.37, pp.491-496.

Osunade, J.A. (2002b).“The influence of coarse aggregate and reinforcement anchorage bond strength of laterized concrete” *Building and Environment*, Vol., pp.491-496.

Salau, M.A.(2003).”Long-term deformations of laterized concrete short columns” *Building and Environment*, Vol.38, pp.469-477.

Santhanam, M.; Cohen, M.D. and Olek, J. (2003).” Mechanism of sulfate attack: a fresh look Part 2: Proposed mechanisms” *Cement and Concrete Research*, Vol.33, pp.341-346.

Shannag, M.J. and Shaia, H.A. (2003).” Sulfate resistance of high-performance concrete” *Cement and Concrete Composites*, Vol.25, pp.363 - 369.

Skalny, J.P,; Odler, I. and Marchand, J. (2002). *Sulfate attack on concrete*, Spon Press, New York.

Tian, B. and Cohen, M.D. (2000).”Does gypsum formation during sulfate attack on concrete lead to expansion?” *Cement and Concrete Research*, Vol.30, pp.117-123.

Udoeyo, F.F.; Iron, U.H. and Odim, O.O. (2006).”Strength performance of laterized concrete” *Construction and Building Materials*, Vol.20, pp.1057-1062.