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Research Article
Investigative Study of Biodeterioration of External Sandcrete/Concrete Walls in Nigeria

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Abstract
This study was aimed at investigating the factors responsible for the proliferation of biological growth on sandcrete walls and the effect of biological growth on walls. Two hundred randomly sampled buildings were examined for the presence of biological growths on their walls. Other characteristics such as walls texture, rendering/plastering status, painting status, age of building, nature of soil surface/cover amongst others were recorded in a log specially designed for this research. The approximate compressive strengths of the walls were determined *in-situ* using rebound hammer. Moss and algae collected from affected walls were subjected to elemental characterization using X-ray fluorescence test. Of the two hundred buildings investigated, 130 (65.3%) had one form of biological growth or the other. Most of the buildings affected by biological growths were between 10 and 20 years of age. About 88.6% of buildings unaffected by biological growths were rendered while 57% of those affected were not rendered. About 73% of affected walls had a rough surface thereby favouring the attachment of organisms. About 71% of buildings affected by biological growth were erected on unpaved soil thereby enhancing contact of walls with soil moisture. Majority of affected walls (63%) have compressive strength less than 10 Nm m^{-2}. Moss and algae samples collected from walls were found to bear a striking elemental resemblance with cement which indicates that the major nutrients for the metabolic activities of these deteriorative species are obtained from cement paste in sandcrete and concrete matrix.

Key words: Sandcrete, algae, moss, compressive strength, biocides, moisture

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The ecosystem is swarming with different organisms of different species and varying sizes. These biological organisms have an incredible ability to adapt to almost any environment and anthropogenic activities have created many new habitats for different kinds of organisms. Owing to the composition of construction materials, certain organisms find concrete-based structures a suitable habitat to live on (Johansson, 2011). The material and chemical compositions of concrete and sandcrete which are the most widely used construction materials in the world today have over time provided most of all those suitable conditions that aid biological growth. They have been found to be very suitable environments for the habitation of most of these microorganisms especially external structural members that have been exposed to environmental and climatic factors like rain, seepage, sunlight etc. The term biodeterioration refers to any undesirable change in the properties of a material caused by the vital activities of organisms resulting in impairment of quality (Rose, 1981). The effects of biodeterioration are evident everywhere and its accompanying progressive deterioration has perhaps the broadest impact on the long-term performance of infrastructure systems and the largest potential economic and environmental consequences. Organisms inhabiting concrete and sandcrete walls therefore play a key role in the biologically-induced deterioration (biodeterioration) of most historic buildings, artistic sculptures and other forms of construction in indoor and outdoor environment due to colonization by a great variety of organisms, including bacteria, archaea, fungi, algae, lichens, mosses, plants and higher organisms (Ettenauer, 2010). De Graef *et al*. (2005) observed that 30% of weathering of concrete and stone construction is due to biological sources.

The debilitating activities of these minute organisms on concrete and sandcrete structures have attracted the attention of researchers. Owing to the simple ecological and nutritional needs of these organisms, they develop easily on outdoor objects, especially where the surface exhibits high water content (Kumar and Kumar, 1999). Milde *et al*. (1983) identified the presence of thiobacilli on the corroded concrete walls of the Hamburg sewer system. Sand and Bock (1984) identified *Thiobacillus neapoplitanus, T. intermedius, T. novellus* and *T. thiooxidans* in the concrete sewer network of Hamburg and a positive correlation between the cell numbers of *T. thiooxidans* and the grade of corrosion. Sand and Bock (1991) found that microorganisms such as chemolithotrophic and chemoorganotropic bacteria, cyanobacteria, algae, fungi and lichens contribute substantially to the deterioration of mineral materials such as natural stone, concrete, ceramics and glass. Arino *et al*. (1995) studied the detrimental effect of lichen on ancient mortar and concluded that the nature and amount of the mortar components greatly influence the colonizing species and the patterns of alteration. Shirzadian *et al*. (2008) found that the presence of mosses, algae, aquatic and terrestrial plants in bridge causes chemical and mechanical deterioration and that loss of heavy metal from bridge structural material reduce the material strength causing degradation and weathering of bridge components. Gomez-Alarcon *et al*. (1995) observed that strains of the genera Penicillium and Fusarium excreted oxalic, fumaric and succinic acids with corrosive effects on stony materials. Ortega-Calvo *et al*. (1995) noted that opportunistic species of cyanobacteria and chlorophytes, present in soils and in the air, are commonly found on the surfaces of monuments. Their growth represents a significant input of organic matter to the stone, as estimated through chlorophylla quantification. Monuments provide unusual niches for the growth of algal communities, as in the case of black sulfated crusts, or endolithic and hypogeal niches, where more specific processes and/or communities occur. Dubosc *et al*. (2001) showed that biological stains are due to two different kinds of microscopic algae, Chlorophyceae and Cyanophyceae, whose presence depends on the amount of moisture on the concrete wall. Portlandite and hydrated products in ordinary Portland cement when dissolved by the excreting organic acids of algae, form the corresponding calcium salts of the attacking acid. It is the solubility of the above calcium salt that primarily controls the rate of deterioration in hydrated OPC concrete and not the strength of the acid. Table 1 summarizes the deteriorative effects of biological growths on structures as well as their health effects.

Biodeterioration is an almost inevitable result of sandcrete and concrete interaction with the environment, especially when the concrete or sandcrete materials are not adequately insulated from all the factors that favour organic growth. It is also a serious cause for concern on the part of both the structural and environmental engineers since the weakening and subsequent deterioration of concrete and sandcrete members are not usually taken into consideration at the design phase. Its study is therefore of significance for proper design, construction and maintenance of building aesthetics and for the control and ultimate eradication of all the unwanted organic growth on structural members with all their accompanying environmental hazards. The purpose of this research is to survey the presence of visible biological growths on external building walls and their effect on the strength of the walls in Nsukka, Southeastern Nigeria and to discuss possible mitigation measures.

Table 1: Environmental and health effects of specific biodeteriorative organisms

Microorganisms	Deterioration types	Mechanisms	Effects
Cyanobacteria	Aesthetic and chemical	Biofilm, colour alteration, patina, crust formation and bio-weathering	Cough, sneezing, eczema and asthma among the occupants produce toxins; cause a slow and progressive loss of concrete strength
Lichen	Chemical and mechanical	Extraction of nutrients from concrete surface, oxalate formation, carbonic acid production and physical intrusions	Chemical dissimilatory type of biodeterioration. Damage is mainly surface discolouration
Algae	Aesthetic and chemical	Biofilm, colour alteration and black crusts	Produce slime that expand and contract and reduce strength
Mosses and liverworts	Aesthetic and chemical	Discolouration and green gray patches	These moss plants build up and overtime their roots get larger and stronger these roots can cause cracks
Sulphur oxidizing bacteria	Chemical	Black crusts	Release of harmful chemicals that affect strength
Higher plants	Mechanical	Intrusions of roots in cracks, pores leading to collapse and detachment of stone structure	Cracks
Fungi	Chemical	Extraction of nutrients from concrete surface	Shrinkage, discolouration and cracking

MATERIALS AND METHODS

Observatory survey and data collection phase: An observatory survey was carried out by randomly sampling 200 buildings in Nsukka Local Government Area of Nigeria. The data for this phase of the research was collected through the use of logs which were targeted at collecting relevant data for the buildings surveyed. They were filled out by the researchers themselves upon physical observation of the walls being surveyed. The specific information sought are: (1) Presence of biological growth, (2) Are the organisms living or dead, (3) Color of biological growth, (4) Texture of wall, (5) Location of organism on wall, (6) Age of building, (7) Rendering status of building, (8) Frequency of painting of building, (9) Exposure of affected wall to humidity, (10) Degree of Discoloration, (11) Rebound number and (12) Pavement status of building.

Rebound number measurement: The basic *in-situ* experiment carried out at this phase of the research is the evaluation of the strength of walls by the use of rebound hammer. This was made possible by the use of the Schmidt rebound hammer in evaluating the compressive strengths of both affected and unaffected walls. When the plunger of rebound hammer is pressed against the surface of sandcrete, a spring controlled mass with a constant energy is made to hit sandcrete surface to rebound back. The extent of rebound, which is a measure of surface hardness, is measured on a graduated scale. This measured value is designated as rebound number (rebound index). A sandcrete with low strength and low stiffness will absorb more energy to yield a lower rebound value. Just before the commencement of the test, the rebound hammer was calibrated against a test anvil. During the *in-situ* test, light pressure was applied on the plunger to release it from the locked position and allow it to extend to the ready position for the test. The plunger was then pressed against the surface of the sandcrete wall, keeping the instrument perpendicular to the test surface. A gradual increase in pressure was applied until the hammer impacted. The button was then pressed after impact to lock down the reading because it is not convenient to note the rebound reading in that position and the reading was finally taken of an average of about 15 readings.

Sample collection and laboratory analyses: Biological samples on the affected walls surveyed were collected by scrapping adequate quantities of the different biological growths into sampling containers for subsequent laboratory testing. An appropriate assessment of biodeteriorative organisms observed and collected from sandcrete walls requires a combination of microbiological and material characterization techniques. Identification of the major types of organisms was done by the microscopic observation of the interface biofilm collected from affected walls. In order to analyse the microbiological composition of the samples, a portion of the material was placed for 1-2 h in water to ease the removal of the biofilm, thus enabling a primary study of the populations in their natural state. Another portion of material was placed in petri dishes with agar bold basal medium to enhance algal growth. Cultures were grown in a chamber with a photoperiod of 16/8 h light/dark, light intensity of 15 ± 3 μmol m^{-2} sec^{-1} PPF (Photosynthetic Photon Flux) and a temperature of 20.0 ± 0.5 °C. Primary cultures were used to obtain unialgal replicates using the streaking plate method. In order to highlight some of the traits used in taxonomy, lugol solution and India ink were employed. Identifications were based on taxonomic criteria and this identification was made possible by viewing the given biological samples under the microscope. While identifying the specimens composing the sampled biofilms, a species was noted as dominant when it represented more than 50% of the total biomass. The X-Ray Fluorescence (XRF) test was also used to carry out the basic elemental and mineral characterization by way of evaluating the percentage oxide composition of the given samples and trace/ rare earth analysis was also carried out. This was done at the Nigerian Geological Research Center in Zaria, Kaduna State.

RESULTS AND DISCUSSION

Two hundred buildings were surveyed at this phase of the research. The different conditions observed on the given walls were recorded on the logs and a total of 200 logs were filled out. Of all the buildings randomly surveyed, it was found that 130 buildings (about 65.3%) were affected by biological growth and the remaining 70 buildings (34.7%) weren't affected (Fig. 1a). Forty seven buildings out of the 130 affected buildings were affected by moss while 15 of them were affected by a mixture of moss and other biological forms. The remaining 68 of them had other forms of biological growth on them.

As can be seen in Fig. 1b, these organisms hardly exist alone. Most of them are found in colonies and as can be seen from the chart, about eighty three (41.5% of total number surveyed) buildings of the one hundred and thirty (65% of the total number surveyed) affected buildings had growth comprising of two or more major growth forms that collectively act on and cause damage on the structure. The only growth form that was found to really survive independently was the moss plant. This is obvious as the other affected buildings that didn't have a collection of different major growth types all had moss predominantly growing on them. The inference that can be drawn from this is that most of the smaller biological growth types would tend to act collectively but the larger growth forms (moss especially) could survive without the presence of other growth forms provided all the factors that ideally favour biological growth are present.

Figure 2a shows a distribution of the occurrence frequencies of the different biological colorations encountered *in-situ*. It was observed that most of the organisms showed colours that ranged from freshly green to dark black, with a few exceptions giving off colours like red and blue-green. The different colours reflect colonization by different types of biological growths resulting in a highly discolored and unsightly façade. The portion of the walls closer to the ground is usually most affected because of interaction with soil

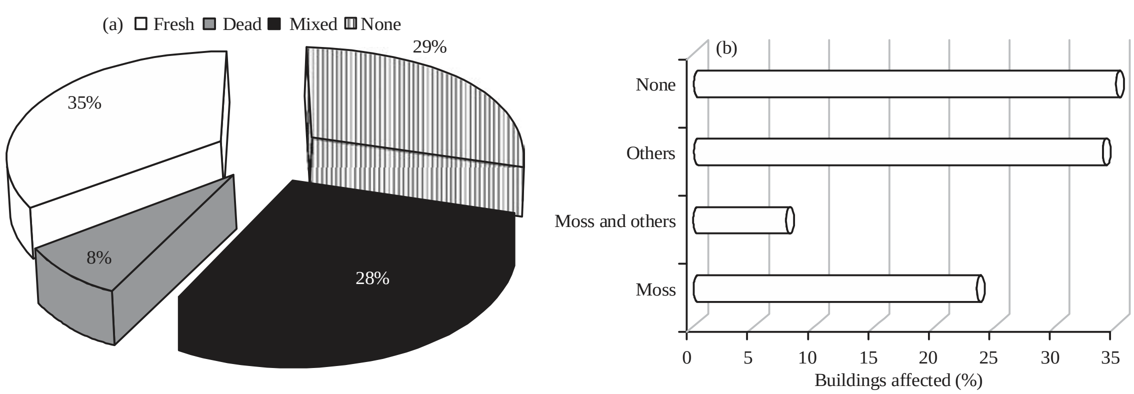


Fig. 1(a-b): (a) Life status of organisms found on walls and (b) Dominant organisms

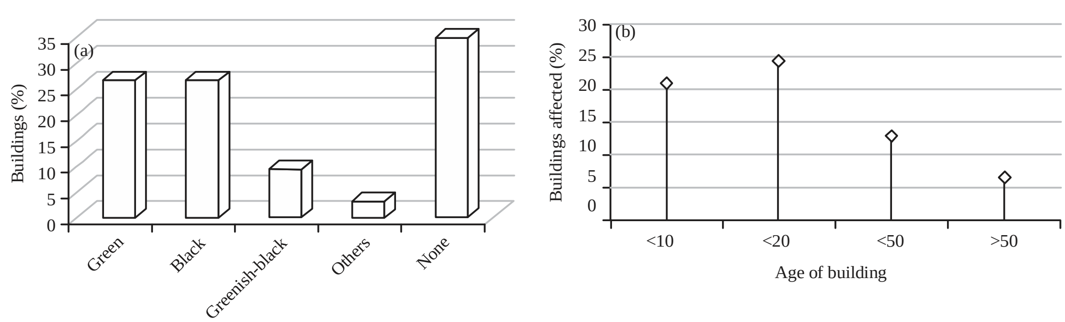


Fig. 2(a-b): (a) Colours of organisms observed and (b) Ages of affected buildings moisture. Figure 2b shows that these organisms thrive on structures between ten and twenty years old. This implies that the high activity of cement paste in fresh sandcrete does not allow the organisms to thrive. However, as hydration reduces to a minimal and pH becomes tolerable with the passage of time, these organisms begin to establish their presence. At the initial stage of these growths, they assume a brightly greenish colour but when the availability of substrate becomes a limiting factor they begin to die, leaving behind a black colour.

Effect of wall surface texture: The major factor responsible for the growth of these organisms is moisture while the limiting factor is the substrate. If it is possible to eliminate moisture from sancrete and concrete walls, then these growths can be controlled or even entirely eliminated. This is the main objective of humidity and temperature control in indoor environments. The most affected structural component is usually the fencing walls which are constantly exposed to rain. Hence it may be necessary to provide simple roof-like covers to keep away rain from walls. Other factors that were found to favour the growth of these organisms on walls include: (i) Rendering status of walls, (ii) Texture of wall (smooth or rough), (iii) Painting status and (iv) Nature of surface on which the wall stands. Figure 3 shows that a wall standing on paved surface is less likely to be affected than a wall standing on bare soil. It was observed that for the unaffected members, majority (67%) of walls investigated was standing on paved surfaces and just 33% on bare soil; whereas for the affected walls 71% of them were erected on unpaved. This is because a paved surface will keep away water from the wall thereby reducing moisture level which favours the growth of these organisms. The upward seepage of moisture present in the underlying soil strata of the unpaved ground serves as a source of additional humidity necessary for development of biological growth for the overlying or sandcrete wall. This moisture is usually locked out by the impervious nature of the pavement on the paved compounds, invariably denying the overlying sandcrete walls additional moisture necessary for biological growth. Wei *et al.* (2013) observed that organisms that attack concrete structures are favoured by elevated relative humidity (between 60% and 98%), long cycles of humidification and drying and low pH. Hyvarinen (2002) observed that moisture is the single most important factor for biological growth on façade. Walls can absorb moisture due to leakage from the roof and plumbing, capillary movement of water from the soil, direct exposure to rain, water logging/runoff and rain splash. It was observed that the biological growths are usually denser in the rainy season than in the dry season due to drastic reduction in moisture availability. This was corroborated by Adan (1994) and Korpi *et al.* (1998), who noted that though rapid drying of walls decreases the viability of microorganisms, some fungi can tolerate fluctuating moisture conditions.

It was observed that about 88.6% of unaffected walls were rendered. This means that majority of rendered walls was unaffected by biological growth. The reverse was however observed to be the case for the unrendered buildings where 57% was affected and 43% was unaffected. This implies that rendering of walls reduces the growth rate of biodeteriorative organisms. Rendering makes the exterior of the wall less pervious and hence more resistant to the penetration of

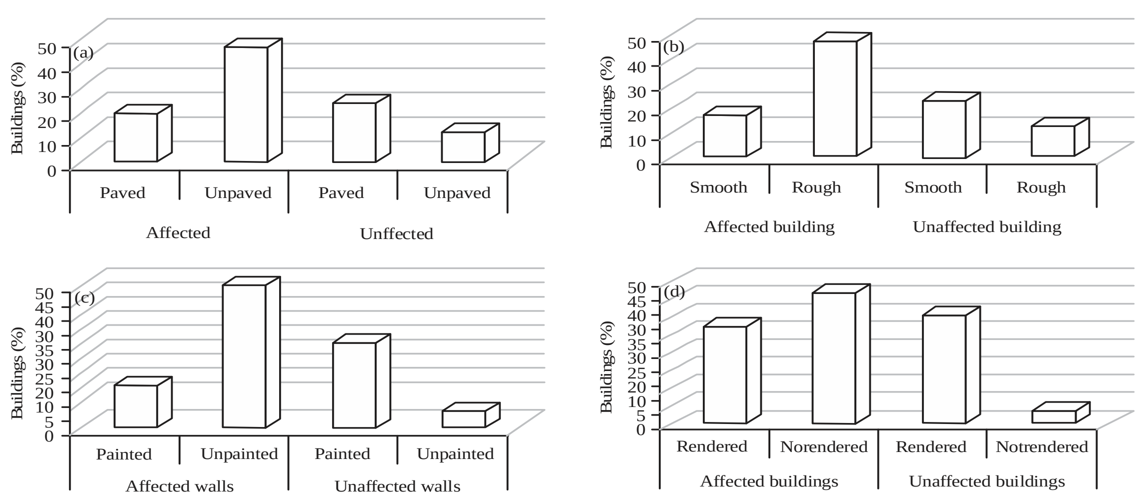
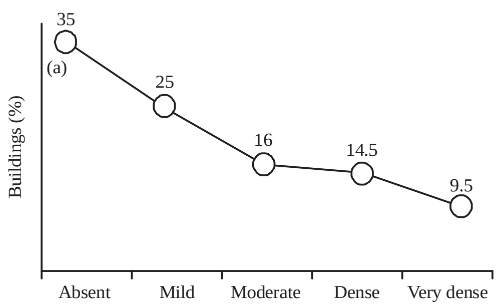


Fig. 3(a-d): (a) Pavement status of yards, (b) Texture of affected and unaffected walls, (c) Painting status of buildings and (d) Rendering/plastering status of buildings microbes. Moreover, since rendered walls are usually smoother than unrendered walls, it is therefore more difficult for the organisms to attach themselves to the wall which invariably leads to relative difficulty in biofilm formation on the rendered walls. Rough walls favour the attachment and subsequent establishment of organisms on walls. The effect of rendering has also been depicted by a picture taken during the study (Fig. 4). Figure 5 shows a fence wall with a segment of the rendering cover peeled off. It can be seen that the exposed sandcrete matrix with very rough surface has been totally colonized by biological growth while the portion that still retained the rendering cover has much less growth. Riba-Silva (1995) noted that surface roughness coupled with the availability of moisture and nutrients facilitate colonization of concrete by microbes. Nutrients can be provided by dust, paint and oil on the surface of the walls, rain water and atmospheric particles (Pasanen *et al*., 1993a, b; Chang *et al*., 1996; Buttner *et al*., 1999). Roughness can be substantially reduced by rendering and painting. Most of the affected walls were neither rendered nor painted. Besides, painting provides a protective coating that limits substrate availability to these organisms. This means that the protective coating has to be destroyed before sandcrete itself can be exposed to attack. This is similar to the protective function of electroplating on iron.

Effect of biological growth on the strength of walls: The method adopted for the purpose of evaluation of the decrease in the strengths of buildings was the use of the rebound hammer as described earlier. The rebound numbers obtained in-situ are a reflection of the associated quality of the sandcrete structures tested. Figure 6 therefore, shows the relationship between the average rebound numbers obtained



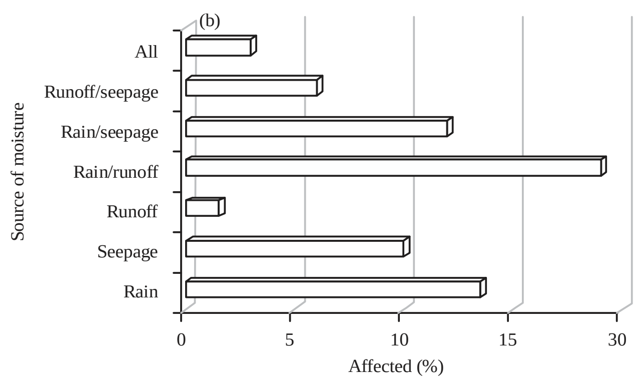


Fig. 4(a-b): (a) Severity of growth and (b) Exposure of walls to moisture

Fig. 5: Effect of surface roughness on the rate of biological growth

from the walls and the quality of the sandcrete material of the wall being tested. According to Sanchez-Silva and Rosowsky (2008), the action of organisms affect the sandcrete mainly by contributing to the erosion of the exposed sandcrete surface, reducing the protective cover depth, increasing sandcrete porosity and increasing the transport of degrading materials into the sandcrete that can accelerate cracking, spalling and other damages thereby reducing the service life of the structure. This reduction in the service life and durability of the sandcrete structures can be properly evaluated by assessing the compressive strengths of the affected buildings. Figure 6 compares the rebound numbers obtained from the walls affected by biological growth and those unaffected by it. It can be seen that most of the walls affected by biological growth (≈63%) gave rebound numbers that are less than 20 which represents compressive strength less than 10 Nm m^{-2}. Figure 6 shows that this is the range for poor delaminated sandcrete. This goes to prove that biological growth plays a significant role in the reduction of the durability of the sandcrete material. On the contrary, Fig. 7 shows that more than 70% of the walls gave a rebound number greater than 20. Though majority of the walls did not give rebound numbers indicative of very good quality owing to poor quality control in the building industry, unaffected walls were generally of better quality than affected ones. The loss in compressive strength can also be attributed to the solubilisation of major cementitious material (calcium carbonate) by microorganisms, thereby reducing the bond between aggregate particles (Pinheiro and Silva, 2003). Sand and Bock (1991) observed 3% weight loss over a period of 12 months due to nitric acid production under optimum growing conditions.

Elemental composition of algae and moss from sandcrete walls: Gaylarde *et al*. (2003) identified three modes of biological damage of concrete structures as follow:(i) Physical or mechanical (by eroding or perforating concrete), (ii) Fouling or soiling, by forming a layer of coloured film and (iii) By chemical reaction using a structural component as food source or by excreting waste products that affect the material. Besides, Shinkafi and Haruna (2013) observed that some constituents of concrete are utilizable by organisms. Hence samples of visible deteriorative organisms were collected and

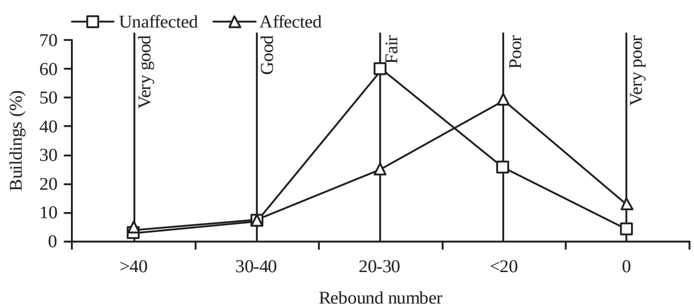


Fig. 6: Comparative strength of affected and unaffected walls

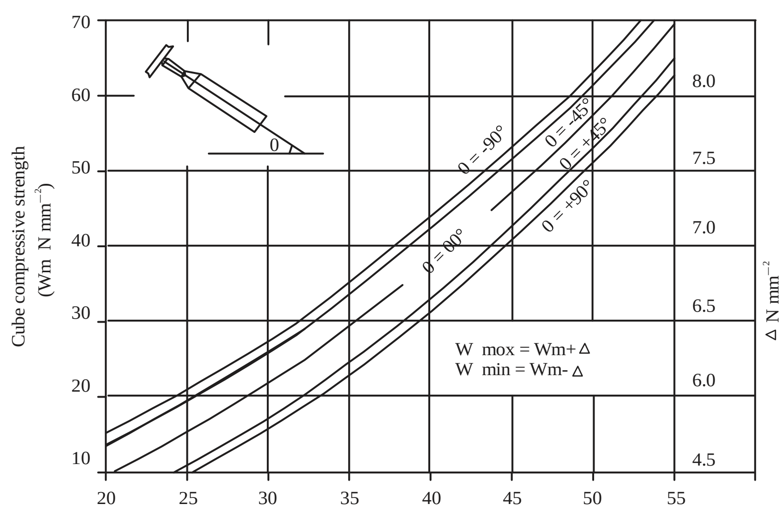


Fig. 7: Graph used in the correlation of cube compressive strength to rebound numbers. (Source: The Constructor.org)

subjected to X-Ray Fluorescence test (XRF) with a view to determining the presence of major cement constituents in the biological mass. The XRF tests were carried out to determine the percentage composition of all the oxides present in the samples collected from sandcrete walls and to compare them with the percentage oxide composition of cement which is a major component of sandcrete. The various trace elements present in these samples were also evaluated in order to effectively ascertain the elemental composition of these samples. The results of these tests are therefore shown in the Fig. 8. Figure 8a shows the percentage compositions by mass of moss and algae collected from walls as well as the percentage samples. Obviously, these organisms bear a striking elemental resemblance to cement which is the major constituent of sandcrete. However, cement has a higher percentage of CaO_2 but a lower percentage of SiO_2. It can be observed that SiO_2 and CaO are the main oxides present in cement which is the major component in sandcrete. According to Block (1991), organic and inorganic acids produced by the organisms enhance the solubilisation of concrete constituents, thus rendering them amenable to assimilation by the organisms. This interaction therefore leads to the intake of these and storing them up for their metabolic needs thereby creating a deficiency in the affected sandcrete material. It would appear that a major process of sandcrete deterioration is the solubilisation and subsequent assimilation of the cement paste in the sancrete matrix by the organisms. This gradual but continuous process leads to a loss in the strength and integrity of the sandcrete material giving rise to spalling, cracking and crumbling. This is indicative of a parasitic relationship.

From the XRF analysis, it can be concluded that the samples collected are composed elementally of the following elements: vanadium, chromium, copper, zinc, nickel, strontium, indium, europium, mercury and rubidium (Fig. 8b).

Presentations and deteriorative effects biological growth on concrete in study area: The study area lies between latitudes 6°30' and 7°06' North and longitudes 6°54' and 7°54' East and an altitude of 430 m above mean sea level. It falls within the humid tropical rainforest belt of the Southeastern

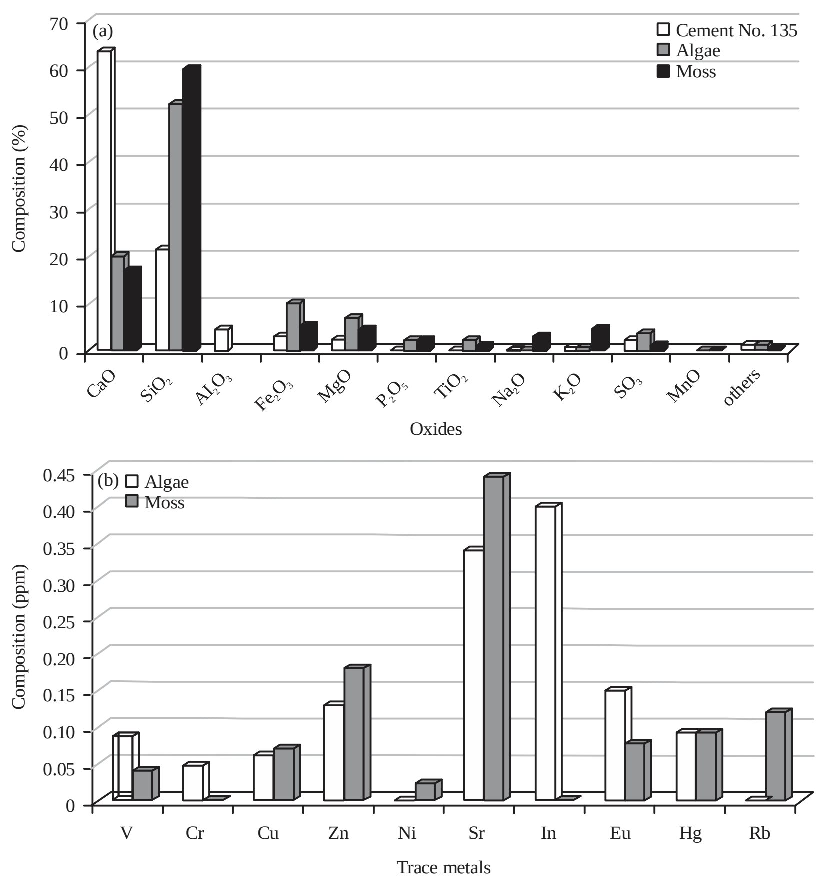


Fig. 8(a-b): (a) Elemental composition of moss, algae and cement and (b) Trace elements contents of algae and moss

Nigeria. It has two distinct seasons: Dry and rainy seasons. The rainy season commences in April and ends in October, followed by the dry season. The annual rainfall ranges between 9372.22433 mm and the relative humidity can sometimes exceed 90%. All the climatic parameters mentioned above, favour the colonization of concrete structures by biological growth. Air humidity and microclimate is critical for sporulation, spore release and survival of spores. The main environmental factors affecting mould growth in building structures are humidity and temperature; moisture being the crucial factor. For most part of the rainy season which spans about nine months, the walls are always kept wet by repeated cycles of rain and drizzles. During the rainy season, it can rain/drizzle twenty six days of the month. The constant rain coupled with the prevailing weather conditions keeps the relative humidity at a high level. Relative humidity of 80-90% is a critical humidity level for growth of mould fungi but also temperature, exposure time and surface of materials are important factors. Laboratory studies have shown that most dust mites require a relative humidity in excess of 45-50% for survival and development but they feed and multiply more rapidly at higher relative humidity (Arlian, 1992). Owing to the prevailing conditions, fence walls are easy targets for biological colonization. Figure 9a is a very common sight in the study area especially if the wall is not rendered or painted. Painted and rendered walls present more resistance to biological colonization. It is also common to see buildings under construction massively colonized by biological growths, especially if there is prolonged delay in completion (Fig. 9b). The danger of this is that these biological growths appear soon after completion, having established a foothold earlier. Figure 9d shows large cracks appearing in a wall severely weakened by biological growth.

Possible mitigative measures: Currently, there are no steps taken to tackle the problem of biodeterioration of concrete in the study area. Besides, many people are not aware or conscious of the structural and environmental implications of these biological growths. They are only aware of the aesthetic damage which is commonly addressed by scraping off worn out paint and repainting. Generally, measures for mitigating the growth of biological organisms on concrete fall into preventive and corrective, or passive and active measures. Almost all preventive measures are passive. Preventive measures are treatments given to concrete during construction to prevent colonization by biological organisms while corrective measures are methods adopted to remove biological organisms already established on concrete structures. Common corrective measures include brushing, sweeping, sand blasting, dry ice (CO_2) blasting, pressure washing, microwave, ultraviolet rays and gamma rays (Bott, 2011; Haile and Nakhla, 2010). However, these methods

Fig. 9(a-d): Deteriorative effects of biological growth on walls, (a) Fence wall exposed to rain, (b) A building under construction, (c) Biodeterioration of wall paint and (d) Crack due to biodeterioration present some concerns because the growths usually return after some time and most blasting methods result in the emission of pollutants into the air. Preventive measures include reduction of water/cement ratio, smoother finishing, coating with paints containing biocides, partial replacement of cement, coating with zinc oxide and coating with photocatalytic substances. Pinheiro and Silva (2003) found that smooth mortar surfaces were less susceptible to biological growth than rough mortar. Type III rubbed finish creates a dense smooth surface similar to wet-sand tiles that decrease biological growths (Kurth, 2008). Hyvarinen (2002) found that 0.5% zinc oxide used in rendering can effectively keep off biological growths. It has also been found that acrylic paint coating can prevent biological growths. However, paint containing barbendazine (a biocide), N-octyl-2N-isothiazolin-3-1 and N-(3, 4-dichlorophenyl)N,N-dimethylamine was found to keep away biological growths for only thirty five weeks (Shirakawa *et al*., 2004). It has also been found that decreasing water/cement ratio of concrete reduces free water which aids biological growth (Dubosc *et al*., 2001). However, significant reduction in water/cement ratio can drastically affect incomplete hydration of cement and overall workability of concrete, thereby compromising strength. Kurth (2008) also suggested moderate replacement of cement with supplementary cementitious materials such as fly ash, ground blast furnace slag, silica fume and metakaolin. The use of heavy metals as an additive to concrete has also been suggested as a possible mitigation measure, however, the adverse environmental and health impacts of these heavy metals preclude their use. Photocatalytic nano titanium dioxide coating has been purported to be the most effective method (Fonseca *et al*., 2010; Kurth, 2008). When exposed to sunlight, photocatalytic titanium dioxide becomes strongly hydrophobic, thereby keeping away moisture from the concrete and making it unsuitable for biological colonization.

Unfortunately, most of the methods employed in the prevention and removal of biological growth on concrete components present severe environmental and public health challenges that are as detrimental as those posed by biological growth. In fact, the only advantage of these methods is the restoration of aesthetics as well as deferment of environmental and health impacts. Many mechanical methods result in the release of particulate matter into the atmosphere whereas chemical methods are susceptible to leaching. There are also concerns that the photochemical action of titanium dioxide can catalyze the formation of ground level ozone via the oxidation of ammonia to NO and NO_2. Table 2 summarizes important information concerning major mitigation measures.

Table 2: Particulars and impacts of mitigation options

Types and *method	Materials	Environmental/health impact	*Application interval	*Cost	Nature	Remarks
Mechanical corrective						
Sand blasting	Silica beads sand, steel grits, copper slag, walnut shell and bits of cocoanut shell	Silica beads and sand dust are associated with lungs disease,	Once or twice per year	High	Active	Scars concrete surface
Soda blasting	Sodium bicarbonate	Can affect the pH of soil and water	Once or twice per year	High	Active	*Labour intensive
Dry ice blasting	3 mm ice pellets, CO_2	None	Once or twice per year	Medium	Active	*Labour intensive
Pressure washing	Water propelled at high pressure	Abrasion of concrete surface	Once or twice per year	Medium	Active	* Labour intensive
Chemical preventive						
Biocides	Quaternary ammonium, aldehyde, alcohols, phenolics, organic acids and isothiazolinones	A wide variety of ailments nervous system impairment, lungs damage	Variable	Medium	Passive	*Labour intensive
Chemical preventive						
Photochemical coatings	Titanium dioxide	Increase in ground level ozone due to photochemical breakdown of NH_3; Associated with lungs and heart disease	Once every 5-10 years	Medium	Passive	Requires adequate light for optimal activity. Immobilization by building materials could inhibit activity; can remove odour
Zeolite	Zeolite compounds	No known health effects. Slight inhibition of growth of sensitive plants	Once or twice per year	Medium	Passive	Resists bacterial induced deterioration
Temperature and humidity control	-	None	Continuous	High	Passive	Suitable for indoor environment. Mostly applicable in pipelines and boilers

*Source: Hassan *et al*. (2014), PP: Physical preventive

CONCLUSION

In conclusion, biological growth has been shown by this study to be a major issue in our immediate environment that is capable of causing negative aesthetic, structural and health related problems. During observatory survey phase of this study, it was discovered that most of the individuals encountered had not even the slightest inkling of the negative impacts of biological growth on their health and on the reduction of the durability of their buildings and majority of them just let the biological growths grow into large biofilms.

It is therefore, the recommendation of this study that the public awareness levels be raised on the effects of these biological organisms on sandcrete. Microbial sandcrete technology has in recent times proved to be better than many conventional technologies (including biocides) because of its eco-friendly nature, self-healing abilities and increase in durability of various building materials. More research work should be put into this field is in order to improve the feasibility of this technology from both an economical and practical viewpoint and to increase our understanding of the possibilities and limitations of biotechnological applications on building materials; so we can provide enhancements of compressive strength, reduction in permeability, water absorption, reinforced corrosion of sandcrete materials.

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