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Assessment of External Building Finishes: A Case Study of Selected Buildings in Akure, Ondo State, Nigeria

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ABSTRACT

The multidimensional problems facing buildings in Nigeria have reached an endemic proportion. They manifest in quantitative, qualitative and also in maintenance terms. The climate across the country aids the deterioration of building materials particularly those used in the facades as there is need to extend the lifespan of these external building finishes because of the economic, health, aesthetic and structural problems being experienced by the occupants of the buildings. An increasing number of cases of poor maintenance of plastered and painted facades characterized by early and unexpected onset of defects and damage to the surface have been noticed in the study areas which has culminated into spending huge amounts of money for such maintenance activities; This paper identifies the different nature and influence of these factors in order to arrive at cost effective ways of preventing and dealing with such defects. Also it establishes the planning horizon over which the various costs that arise during the intended lifetime of the finishes are incurred. Buildings raging from residential (bungalows and multi-storey apartment) to institutional and commercial including those with mixed used that exhibited the external finishes under the changing climatic challenges were carefully observed and analysed through the use of structured questionnaires. The paper concludes by recommending continuous and regular inspection of external surfaces every ten years, provision of a thick porous coating which will give the best weather-proofing and durability results on solid walls and achievement of good and physical adhesion of rendering to the rigid substrate free from dirt, oil, grease and loose particles.

Keywords: *Maintenance, external finishes, climate, deterioration,defects*

1. INTRODUCTION

The global construction industry has been witnessing significant increase in building maintenance cost over the years. A significant amount of money, time and resources is being spent on maintenance and repair activities. Aluko and Akingbohungbe (2010) opined that the defects in buildings that call for maintenance are usually caused by inappropriate design, faulty construction techniques, substandard building materials, weathering of materials; cumulative effect of rain, wind and sun; pollution, earth movement and load bearing capacity among others. In Nigeria, the cost of maintaining Festac Building, National Stadium and various Housing Estates all in Lagos has been on the astronomical increase.

In Singapore, for example, the annual maintenance expenditure for residential buildings has risen from$11/m2 to $38/m2 over a period of about 10 years (Building and Construction Authority Pilot Study Report 2000). Out of the total maintenance cost incurred for a building, a significant proportion is spent on maintenance of facades. The maintenance and upkeep of the external finish of the building is seen as an essential component of any building programme because of its decorative or aesthetic purpose thus epitomizing the image of the building and provides protective functions to the underlying layers of the building (Boussabaine and Kirkham 2004; Hajj and Horner 1998).

However, with time, external finishes undergo deterioration and suffer loss in their decorative and protective functions. With age, deteriorating effects gradually and increasingly begin to show on the colour, texture and conditions of these external finishes.

The external building finishes therefore may not perform as expected and fail to provide the desired functions for the intended time possibly due to exposure to adverse environmental conditions, poor workmanship, inadequate quality of finish material, bacteria, fungi (biological agents), wind and erosion. The coefficient of thermal expansion also affects coating durability in tropical temperatures, especially with high diurnal ranges. (Chew and Harikrishna 2005). There is the need to clearly identify these factors so as to reduce or possibly eliminate such defects.

2. EXTERNAL FINISHES AND CLIMATIC FACTORS

External surfaces of building enclosures and its coatings are directly affected by climate. Climate is one of the factors causing deterioration of building envelope and coatings. (Chew and Harikrishna 2005). Norvaišiene, Miniotaite and Stankevicius (2003) classified atmospheric factors into natural (precipitation, wind, temperatures, solar radiation) and complex chemical and biological processes caused by air pollution. (Ramanauskas and Stankevičius (2000) maintained that the durability of external finishes is determined by the following properties;

(a) Frost resistance, i.e. the capability of a moisture-saturated material to resist temperature fluctuation through freezing and thawing cycles

(b) Moisture resistance, i.e. the capability of a material to resist the periodical moisturizing and drying cycles

(c) Corrosion (chemical impact) resistance, i.e. the resistance to solutions of dissolved aggressive destructive chemical agents. UV radiation, causing photochemical reactions on surfaces, can also be considered as a chemical impact.

Haneef, Dickinson and Johnson (1999) summarized the mechanisms that contribute to deterioration as

1 Physical mechanisms. The presence of water is known to be a key factor in promoting the fracturing and erosion of building envelope and coating. Water penetrates the pores and cracks and causes mechanical stresses both by freezing and by the hydration and subsequent crystallization of salts.

2 Chemical mechanisms. Some deposited chemical agents react with surfaces. Sulphur compounds have been indicted as the most critical factors in this regard, mainly because they are often acidic and can have high concentrations in city and suburban air; however, nitrogen compounds should be considered as well. Fluxes of trace gases (e.g., sulphur dioxide) can be high, especially when promoted by biological activity. Dissolution by chemical reactions with contaminants contained in precipitation is one of the most familiar eroding processes, particularly in the case of carbonaceous stone.

3 Biological mechanisms. Many different biological factors have been found to be important. Growths of lichens, mosses, algae, mould, fungi and bacteria are capable of promoting surface deterioration. Some bacteria can synthesize sulphuric (or nitric) acid from airborne sulphur dioxide (or nitrogen oxides).

2.1 Material Degradation and Weathering

Deterioration and decay of materials of building enclosures is caused by chemically active impurities and unstable water-soluble formations migrating and chemically or physically reacting with the structural skeleton of the material. Mineralized water additionally dissolves the unstable formations of a material through further mineralization. Various chemical materials make new, weaker and easily washable products, which after the evaporation of water form deposit crystals of various volume, form and origin. These crystals enter the walls through pores and capillaries and destroy the surface of enclosures and spoil its appearance. Material degradation and loss of characteristic properties, as described by the performance of function, in the course of time in most cases occurs due to chemical or physical deterioration (Thomas, 1999)

Natural weathering is essentially a cyclic phenomenon also involving the wetting and drying of the surface. The detrimental effect of air pollutants on building materials has been recognized for a long time and still causes major concern. (Johannson, 1990).

2.2 Acid Rain and its Effects

According to Weathers and Likens (2006), acid rain is rain or any other form of precipitation that is unusually acidic, i.e. contains elevated levels of hydrogen ions (low pH). Seinfeld, Pandis, and Spyros (1998) define acid rain as water vapour, which reacts with airborne acids and then falls to the surface of earth. Acid rain is a popular term referring to the deposition of wet (rain, snow, sleet, fog and cloud water, dew) and dry (acidifying particles and gases) acidic components (Bormann and Likens, 1974). In Nigeria, numerous gas flaring points and fire outbreaks in oil installations, forest fires, decomposition of littered organic compost and vegetative degradation, rubber processing, use of worn out tires to roast poultry at the abattoir and to make bonfires during festive periods, ore smelting, used vehicles and generators with doubtful combustion efficiency have been indentified as potential sources of acid rain. (Nduka, John, Orisakwe, Orish Ebere, Ezenweke, Ezenwa, Chendo and Ezeabasili 2008) and Berresheim and Davies (1995) enumerated the causes as natural phenomena, human activity and aci deposition.

2.2.1 Natural Phenomena

The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and those from biological processes that occur on the land, in wetlands, and in the oceans. The major biological source of sulphur containing compounds is dimethyl sulphide. Nitric acid in rainwater is an important source of fixed nitrogen for plant life, and is also produced by electrical activity in the atmosphere such as lightning.

2.2.2 Human Activity

The principal cause of acid rain is sulphur and nitrogen compounds from human sources, such as electricity generation, factories, motor vehicles, coal power plants and livestock production. The gases can be carried hundreds of kilometres in the atmosphere before they are converted to acids and deposited. In the past, factories had short funnels to let out smoke, but this caused many problems locally; thus, factories now have taller smoke funnels. Dispersal from these taller stacks causes pollutants to be carried farther, causing widespread ecological damage. Sometimes back, it was rumoured that there was going to be acid rain in Nigeria which caused some panic among the citizens but Babajide (2010) explained that high humidity and that human activities like gas flaring, fumes from generators etc could be the major causes of acid rain. (Plates 1 – 3)

Plate 1: The coal-fired Gavin power plant in Cheshire, Ohio
Source: http://en.wikipedia.org/wiki/File:Gavin-plant.jpg

Plate 2: Hazy Lagos in a gridlock
Source: http://Babajidesalu.wordpress.com

Plate 3: Hazy weather in Lagos
Source: http://Babajidesalu.wordpress.com

2.2.3 Acid Deposition

Dry deposition contributes to the corrosion of materials; in most areas with substantial rainfall, the effect of wet deposition on building surfaces is more pronounced.

2.3 Effects of Acid Rain on Buildings

Acid rain has been shown to have adverse impacts on forests, freshwaters and soils, killing insect and aquatic life-forms and having impacts on human health. (Miller and Galloway 1987). External buildings finishes have always been subject to attack by weathering; the effects of rain, wind, sun and frost accelerate the rate of this damage. Acid deposition affects marble, sandstone and paint. Cathedrals such as York Minster and Westminster Abbey have been severely affected in recent years. The Taj Mahal in India, the Colosseum in Rome and monuments in Krakow, Poland are continuing to deteriorate. Cologne Cathedral, Notre Dame, Westminster Abbey in Sweden, medieval stained glass windows have been affected by acid rain. (Schulz, Trubiroha, Schernau and Baumgart 2000). In Nigeria, Festac Building, National Stadium and various Housing Estates all in Lagos are typical examples.

3. RESEARCH METHODOLOGY

Data for the study was carried out through case study, a well -structured questionnaire to elicit required information relating to building characteristics pertaining to location, age, type and time of replacement of the finish, ambient environment including proximity to traffic and vegetation, visual survey and photographic prints. Selected buildings were purposively chosen due to the prominence of the external building finishes used in the study area. Buildings raging from residential (bungalows and multi-storey apartment) to institutional and commercial including those with mixed used that exhibited the external finishes under the changing climatic challenges were carefully observed and analysed. The climatic data utilized was obtained from a study carried out by Adedeji, Aluko and Ogunsote (2010) where averages of long term climatic data collected from various meteorological stations in Akure are defined.

Literature review focused on defects occurring in the external finishes, the factors influencing the occurrence of these defects and their durability. These factors were grouped into categories and described.

4. FINDINGS AND DISCUSSION

The observation from the field revealed that (a) climate (b) material composition of external finish used, (c) quality of workmanship and (d) building characteristics can be identified as influencing the occurrence and propagation of defects on the external finishes. The occurrence of defects renders the finishes unsuitable in performing its stipulated functions and consequently affects the durability and service life of the finish. The questionnaires provided information about the influence of the important factors under each of the four categories identified in the review (something that was not completely captured by the visual surveys) and their possible influence and effect on the occurrence of defects on the finishes.

4.1 Climate

Under the realm of Climatic conditions, three main factors namely temperature, ultraviolet radiation from sunlight and moisture are mainly responsible in causing material degradation and hence occurrence of defects and damage to the external building finish. These factors not only act individually to cause degradation but also have a synergistic effect meaning that their combined effects contribute to cause greater degradation of the finish. Tables 1 and 2 present the factors, the major considerations and defects associated with these factors.

Table 1 Factors under building characteristics and associated defects

Factor	Characteristic features	Associated defects
Temperature	Temperature and temperature fluctuations Amount of absorbed radiation depends on colour	Physical weathering and Cracking
Ultra Violet Radiation	Amount of UV radiation influenced by latitude, hours exposed to sunlight and angle of exposure of façade	Discolouration and Chalking
Moisture	Affects substrate and underlying layers of building	Blistering Efflorescence Blistering Efflorescence Microbial growth, Flaking
Wind	Wind speed affects concentration of pollutants hence rate of deterioration. Nature of wind affects dispersion of atmospheric pollutants	Microbial growth Deposit of dirt.

Source: Chew and N. Harikrishna (2005)

Table 2 Building characteristics that affect the durability and service life of External finishes

Factors	Characteristic features/ Considerations	Associated Defects
Orientation	❖ Façades directly exposed to sunlight undergo greater physical weathering leading to chalking of paint. ❖ Facades facing away from direct radiation are comparatively colder and damper providing ideal conditions for algae and other microbial growth ❖ The intensity and duration of sunlight that a surface receives affect the limit of runoff flow, the type of biological stains and hence the pattern of staining.	❖ Chalking ❖ Algae Growth ❖ Staining

Height	❖ Tall buildings are at greater risk to deterioration due to their direct exposure to impacting rain and ultraviolet radiation [Choi 1994] ❖ Wind speed varies with height due to the level of openness as well as the instability of air at higher levels ❖ Costs of maintenance and repair of defects to the façade higher for higher storeys due to additional costs in the form of scaffolding ❖ Safety during work in higher storeys is another concern	❖ Greater rate of weathering and discolouration at higher storeys
Surrounded by other buildings	❖ Presence of adjacent buildings provides a sheltering effect ❖ May result in slower drying period for façade after it has been wetted, leaving it damp for longer periods and therefore promoting biological staining	❖ Biological Staining ❖ Algae growth
Age	❖ Natural tendency of material to undergo deterioration with time ❖ Condition and serviceability period of the underlying substrate layers of the building has an effect on the exterior paint finish ❖ Gradual loss of protective and other properties of the paint finish itself with age	❖ Cracking ❖ Chalking ❖ Flaking/ Peeling

Source: Chew & Tan (2003)

4.2 Climatic Conditions in Akure

From table 1, Akure enjoys a moderate tropical climate with maximum temperatures rarely rising above 33°C and minimum temperatures rarely falling below 20°C. Relative humidity is also moderate with maximum relative humidity rarely rising above 86% and minimum relative humidity rarely falling below 40%. There is some form of precipitation throughout the year, even though there are distinct wet and dry seasons. (Adedeji, Aluko and Ogunsote, 2010). There is usually more than six hours of sunshine, even during the rainy season. Such conditions provide ideal conditions for algae growth on external finishes.

Table 3: Average Climatic Conditions in Akure (1983-2004)

Akure (1983-2004)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Maximum Temperature (°C)	32.1	33.5	33.4	32.3	31.6	29.0	29.0	28.2	29.1	30.4	32.2	31.4
Mean Monthly Minimum Temperature (°C)	17.9	20.0	21.7	22.0	21.1	20.8	20.2	20.1	20.2	20.6	21.2	19.8
Mean Daily Maximum Relative Humidity (%)	66.3	65.1	75.9	78.4	79.6	83.2	86.6	85.8	84.6	79.2	75.2	70.7
Mean Daily Minimum Relative Humidity (%)	43.6	40.0	48.2	54.0	56.5	59.1	62.8	64.1	61.4	60.3	50.0	43.2
Precipitation (mm)	10.9	33.5	65.6	79.1	154.4	169.5	209.9	245.7	178.8	180.3	49.0	34.1
Hours of Sunshine	7.9	8.1	7.4	8.4	8.1	7.5	6.9	6.3	7.6	7.6	8.0	7.6
Mean Wind Velocity (m/s)	0.9	1.1	1.2	1.1	1.1	1.1	1.2	1.1	1.2	1.1	1.1	1.1

Source: Adedeji, Aluko and Ogunsote (2010)

4.3 Type of Buildings

The buildings along Arakale road were classified as residential, commercial, religious and mixed use. 62% of the buildings were used for residential and commercial purposes while 38% were used mainly for commercial purpose. This suggested that majority of the buildings (98%) were put to constant use. There was only one religious building (St Thomas Anglican Church) in the study area.

Table 4: Type of buildings

Type	Number	Percentage (%)
Residential	13	22.41
Commercial	22	37.93
Mixed use	22	37.93
Religious	1	1.72
Total	58	100

4.4 Age of Buildings

Analysis of data on the age of buildings in table 5 revealed that 46.55% of the buildings were built over 50 years ago while 50% were built within the period of 10-40 years. Only 3.45% were recently constructed. There was loss of protective properties and the conditions of the underlying substrate were in shambles in most of the buildings. Over 40% of the buildings external finishes have not been replaced for the past 10 years while over 50% underwent some replacement within 10-50 years and above as shown in table 6. The religious and two commercial buildings which constitute 3.41% had glass and ceramic tiles as its finishes and were built within the last 10 years, so the effect of weather had not taken its toll on these finishes due to the period of construction of the buildings. Plates 4-5. Generally, the external finishes were in a state of deterioration as a result of age of the buildings. Microbial growth, cracks, flaking and peeling were noticeable in some of the buildings. Plates 6-7

Table 5: Age of buildings

Age of Buildings (Years)	Number	Percentage (%)
Above 50	27	46.55
Between 30 – 40	16	27.59
Between 10 – 20	13	22.41
Below 10	2	3.45
Total	58	100

Source: Authors field Survey (2011)

Plate 4: A Religious Building at Alakure junction recently repainted
Source: Authors field Survey (2011)

Plate 5: A building along Arakale road with Tiles and Glass finishes and recently constructed
Source: Authors field Survey (2011)

Table 6: Time of replacement of buildings finish

Time	Number	Percentage (%)
Above 50	2	3.45
Between 30 – 40	8	13.79
Between 10 – 20	24	41.38
Below 10	23	39.66
Total	58	100

Source: Source: Authors field Survey (2011)

Plate 6: A building along Arakale road showing microbial growth on the plaster finish
Source: Authors field Survey (2011)

Plate 7: A building along Arakale road showing its state of deterioration
Source: Authors field Survey (2011)

4.5 External Finish Materials of the Buildings

The external building finishes used in the study area are paint, mortar plaster, ceramic tiles, glass, stone and brick. The predominant building finish used was paint which was 72.41% followed by cement rendered wall (20.69%). Ceramic tile, glass, stone and brick were rarely used as each constituted 1.72 %. (Table 7). In the painted surfaces, the effect of greater rate of weathering was observed as cracks were noticeable and there **was** general loss of appearance, stains, peeling off, separation of layers and flaking of the paint. Building façades were directly exposed to sunlight and were subjected to greater physical weathering leading to chalking of paint. (Plates 8 and 9). Apart from paint, 20.69% of the buildings were rendered with cement plaster. Most of the buildings in this category were of one-storey types and of mixed use; the lower part being used for commercial purposes while the upper storeys were mostly residential. It was observed that buildings whose façades were directly exposed to sunlight underwent greater physical weathering and facades facing away from direct radiation are comparatively colder and damper providing ideal conditions for algae and other microbial growth. Discolouration and deposit of dirt were common features of these buildings. (Plates 10-11). The intensity and duration of sunlight that a surface receives affects the limit of runoff flow, the type of biological stains and hence the pattern of staining. (Chew and Tan 2003).

Table 7: External Finish materials of the buildings

Type of Finish	Number	Percentage (%)
Painted Wall	42	72.41
Cement rendered wall	12	20.69
Tile / Glass finish	1	1.72
Glass Finish	1	1.72
Stone finish	1	1.72
Brick wall	1	1.72
Total	58	100

Source: Authors field Survey (2011)

Plate 8: A building along Arakale showing the flaking of paint and separation of layers
Source: Authors field Survey (2011)

Plate 9: A building along Arakale road showing physical weathering
Source: Authors field Survey (2011)

Plate 10: A building along Arakale road showing dirt on the plastered surface
Source: Authors field Survey (2011)

Plate 11: A building along Arakale road showing discolouration of paint and dampness of the finish
Source: Authors field Survey (2011)

4.6 State of Buildings

The analysis of the state of buildings in table 8 showed that 12.07% were in sound state, 43.10% requires minor repairs while 44.83% needed major repairs. Findings show that most of the buildings in the neighbourhoods were in very poor state as only about 12.07% of them were in sound condition. A greater proportion of the buildings required minor or major repairs to bring them to good quality. Plate 12. The state of repairs of the buildings takes into consideration the soundness of the roofs, walls, floors and external finishes. The soundness of wall and floor means absence of cracks, surface wear, tearing or peeling off of surface plaster and paints.

Table 8: State of buildings

State	Number	Percentage (%)
Sound	7	12.07
Require minor repair	25	43.10
Require major repair	26	44.83
Total	58	100

Source: Authors field Survey (2011)

Plate 12: A building along Arakale road showing the poor state of condition
Source: Authors field Survey (2011)

5. RECOMMENDATIONS

Some form of control can be exerted on the factors falling under the categories of climate, surrounding environment of a building, material composition, degree of workmanship, building design and detailing. Particular attention should be paid to;

- A general inspection of plastered surfaces should be made about every ten years. If the plaster is painted then the inspection can be made when redecoration is undertaken. New paints should not inhibit the natural evaporation from a lime render and contribute to build up of damp in the wall.

- A thick porous plaster coating will give the best weather-proofing and durability results on solid masonry walls.

- Substrate to receive tiling and rendering must be rigid and sound. For concrete surfaces, the weakness of substrate is often due to the presence of loose particles not properly remedied prior to the application of the finish

- Whatever the type of tiling or rendering to be applied, good and physical adhesion of rendering to the substrate is only achieved if the substrate is rigid free from dirt, oil, grease and loose particles.

- Particular attention should be paid to the undulating surface where the thickness of the rendering is likely to be uneven. This can give rise to variable stresses and cause debonding.

6. CONLUSION

The identification and assessment of the various factors influencing the occurrence of defects on the external finish provides a systematic way of incorporating durability and service life considerations in the design stage itself. A comprehensive assessment of the various factors affecting the lifespan of external building finishes has been presented in this study. The major factors that influence the service life of the building finishes have been identified and grouped under four categories– climate, material composition of the finished used, degree of workmanship and building characteristics. In order to keep maintenance cost to a minimum, it is necessary to strive for prevention of any possible occurrence of defects in the first place by eliminating or minimising the influence of these factors and accordingly cater to their effects during their formulation and design process as well as during the application process; this would ensure that the desired service life for the finish is attained.

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