STRATEGIES FOR MINIMIZING ENVIRONMENTAL INFLUENCES ON SERVICE LIFE OF EXTERIOR WALL PAINT IN A TROPICAL CLIMATE

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Abstract— External walls are decorated with various materials for beautification, protection or for other reasons. Coating materials are usually in solid or in liquid form. The solid materials are bound or pasted while liquid materials are sprayed or painted to walls. Application of solid materials such as tiles for the exterior wall is in decline due to the energy saving requirements. Paint is the most common material used as wall coating in Nigeria and building maintenance is not given necessary attention in policy formulation in the country coupled with the economic problems, cases of frequent maintenance characterized by early and unexpected defects on both public and private building's façade should be avoided. Maintenance is an aspect of the building that requires a large amount of money hence deliberate effort aimed at preventing accelerated deterioration is desirable. This paper reviews the service life of paint and the effects of environmental factors responsible for its accelerated deterioration in a tropical area. Literature review of the factors that affect the service life of paint was done. 124 (one hundred and twenty four) buildings that were constructed or refurbished within the last 15 (fifteen) years, in Ilaro town, were grouped according to their usages, with the involvement of necessary professionals. Visual survey and structured questionnaires were used to extract information on the occupants and owners of selected buildings. The influencing factors were grouped under two major categories - natural and artificial and these were evaluated and discussed.

Keywords: environmental factors, minimizing, Service-Life, walls paint

I. INTRODUCTION

External walls of buildings in major cities of developing countries like Nigeria are usually covered with plastered bricks on which painting is usually applied to provide aesthetics function. However, such function may be of short duration given constant threat service life of external wall paint finish caused by environmental factors. In particular, these factors diminish the durability of paint finish on external wall surfaces. This is more evidenced in warm and humid environments due to the combination of two different weather conditions. For instance, painting in warm weather forces latex paint to dry very quickly which can make film formation or curing possibly be incomplete and thus compromises the durability of the paint finish in the long run (Bosveld, 2016). This is more problematic when the temperature reaches 95^0 F and above.

Again, humidity also poses problems for paint finishes (Deziel, 2017) because it slows evaporation of water-based paint finishes most especially when the paint is applied to external building walls. Even when solvent-based coatings are applied during high humidity moisture still causes crack or bubbles upon the dry of the paint. This, in particular, can, therefore, result in drips and dirt due to dust contamination. Thus, it is in this respect that research for evaluating and suggesting ways of minimising environmental variables relative to external wall paint service life is imperative and demanding. More importantly, a study of this nature with a special focus on cities and sub-urban areas in developing countries deserves academic attention. Realistically, the evaluation of the service life of the paint needs to be assessed within the scope of defects that occur due to poor performance or failure of the paint. This practice has been recognized by empirical research studies (e.g. Teo, Chew and Harikrishna, 2005). The standard has a tendency to provide reliable outcome and framework for future estimation of paint by stakeholders in the painting and coating industry.

Accordingly, the current research study will rely on this benchmark to estimate the service life of external wall paint finish. Further, considering existing literature in the field of painting or coating most especially in developing countries this study advances knowledge on how to limit or minimise environmental influences on the service life of exterior wall paint in a warm and humid environment. In addition, it promises to provide a better understanding of paint finish service life estimation measurement framework and environmental factors influencing such paint service life validity period. The study focuses on dwelling terraced buildings in cities and sub-urban areas in Ogun State. The State has a tropical climate with much rainfall in summer than in winter (Climate Data, 2018), partly tropical hot and humid (World Data, 2018). However, special focus is on Ilaro town – an area of the State where the climatic condition, on average, is usually warm and humid (National Bureau of Statistics, 2010). Specifically, the only typology of housing covered by the tentacle of the current study was terraced building properties with solid brick external walls found in the sampled areas in the study area.

Literature Review

The extant literature provides that there are many defects that can be associated with external wall paint finish. The most empirically discovered defects are peeling and flaking, chalking, mildew, crazing, efflorescence, crackliness, uneven discoloration, algae growth, water seepage, and delamination (Teo *et al*, 2005); loss of appearance, peeling, crack, flaking, chalking, discolouration, mildew growth, delamination and dirt (Aiyegbajeje and Oguntimehin, 2018). Practically, a large number of these defects are majorly caused by environmental factors though empirical research to this effect is yet unknown. Meanwhile, the evaluation of the service life of the paint needs to be assessed within the scope of defects that occur due to poor performance or failure of the paint. This practice has been recognized by empirical research studies (e.g. Teo *et al*, 2005).

The service life of painting refers to a period in which paint materials when applied on objects (buildings in this case) are said to fulfill, equal or exceed required minimum performance standard (Aluko, 2018; ISO 15686-1:2000; Sarja and Vesikari, 1996). When the period is shorter than expected standard there is a tendency for paint finish to diminish and causes problems. It is important to mention that the determination of service life of external wall paint finish in the current study depends on the defects caused by environmental or weather factors. Thus, the study provides an improvement to prior studies (e.g. Teo et al, 2005; Aiyegbajeje and Oguntimehin, 2018; Aluko, 2018). Further, the principal idea behind constructing and painting external wall structures is that the wall must be airtight and provides aesthetic functions. However, environmental and weather conditions put tremendous demands on exterior paint.

The most significant factors of these environmental and weather conditions are water and moisture, sunlight and ultraviolet (U.V.) radiation, and changing humidity, temperature Changes. Sources of moisture in the wall are driving rain water leakages through connections or construction faults, unprotected construction works or internal condensation. This is harmful if the wall has limited drying potential and there is no ventilation gap behind the facade. If the insulation material is foam plastic or other water vapor tight material or if the insulation material is such that can absorb very little moisture, water leakages are very risky because they cause significant defects to the exterior wall paint finish. Excessive moisture levels may cause mould leading to the growth of algae and microorganisms on the paint finish. This may be a risk considering also the indoor air quality.

In addition, direct sunlight has the potentiality of degrading binder and pigment of paint which, for instance, can result in chalking, erosion and colour loss. Lower quality paints and interior wall paints generally fail in these ways much earlier than quality exterior wall paints (Resene, 2017). Meanwhile, the level of effects of direct sunlight on paints generally depends on the type of binder. For instance, waterborne paint binders usually resist the effects of direct sunlight better than the binders in solventborne paints. One of the reasons is because waterborne paint binders tend to be transparent to U.V. radiation than solventborne binders. The relative humidity educates us how much water vapour there is in the air compared with how much it can actually hold. The ability of the air to hold water vapour lessens dramatically as temperatures fall and the evaporation of water from a paint film may cease altogether with relatively small temperature changes of just 5°C (Resene, 2017).

When there is high relative humidity, 100% for instance, water possesses little extra energy to get up to the speed necessary to merge in with the traffic and in this case, the paint stops losing water. In a severe situation, the paint will not coalesce and can simply be washed away by dew. In cold temperature, all paints get more glutinous or and therefore become much harder to apply. This is more problematic for solventborne enamels because solventborne paint will remain soft and be vulnerable to physical damage (Resene, 2017). However, lower temperatures and high humidity will significantly slow down the dry time of waterborne paints. On the other part, when the painting is carried out in very hot conditions water evaporates out of the paint very quickly and as a result, the paint will thicken up and be very difficult to apply throughout the exercise. This will make it difficult to keep a wet edge and brush or roller marks not flowing out as expected. Paint brushes will tend to clog up and cans of paint can skin over quite rapidly (Resene, 2017).

Moreover, Teo *et al* (2005) had empirically discovered significant problems such as crazing, chalking, efflorescence, cracklings, uneven discoloration, algae growth, faking or peeling, water seepage, and delamination as defects to external paint finish in Singapore. The co-authors further found that the defects are caused by weather, materials composition of the paint used, degree of workmanship and building characteristics. Although there is a geographical difference of locations between Teo *et al* (2005) and the current study the former research failed to provide a comprehensive empirical analysis of environmental influences and how such influences can be minimized. On the other side of the coin, Tator (2015) theoretically analyzed environmental influences as factors responsible for coating deterioration which include energy (solar and heat), permeation (moisture, solvent, chemical and gas), stress (drying and curing-internal stress; vibration-external stress; impact and abrasion) and biological influences (microbiological, mildew, and marine fouling), comprehensive information was provided about uncontrollable aspects of the external paint defects. The study provides that environmental induced effects can only be minimized but unavoidable in the long run; however, the study suffers empirical validation.

Locally, Aluko (2018) discovered that the average service life of paint finish is 5 years where the minimum-maximum period is between 2 to 5 years below established lifespan of 5 to 10 years in tropical regions. In a similar fashion, Aiyegbajeje and Oguntimehin, (2018) discovered that average service life of paint finish in the sub-urban tropical areas in Nigeria is 3.25; that is, 3 years 2 months and 5 days. The authors affirmed that the minimum and maximum years are 1.7 years and 4½ years respectively. Meanwhile, both Aluko (2018) and Aiyegbajeje and Oguntimehin, (2018) discovered that building characteristics like sun persistence, humidity and moisture, impact and abrasion, age of buildings, façade, layout, wind effect, rain effect, surface after repaint, type of paint, colour of paint and paint application are significant factors that influence the extent of defect of external paint finish. However, apart from overcoming geographical gap issue, the two empirical studies suffer similar limitations in Teo *et al* (2005). In a nutshell, attempt to provide research solution to these prior studies limitations forms the crux of the current study.

Methodology

The study area is Ogun State. The south-western Nigeria state has a tropical climate with much rainfall in summer than in winter (Climate Data, 2018), partly tropical hot and humid (World Data, 2018). However, special focus is on the area of the State where the climatic condition, on average, is usually warm and humid. In line with this consideration, Ilaro town was purposively sampled. Sub-urban Ilaro town with geo-position $6^0$53`20” N and $3^0$0`51” E (World Data, 2018) has much rainfall in summers than winter. According to the National Bureau of Statistics (2010), the town experiences relative high humidity of rainfall particularly from the end of every first quarter to late October in each year. Meanwhile, the only typology of housing covered by the tentacle of the current study was terraced building properties with solid brick external walls found in the sampled area which were constructed or refurbished within the last fifteen years.

The study adopts a dual sample survey technique – visual survey and interview survey. The visual survey, as a primary data collection instrument, was conducted to obtain information on physical environments of the study area and again about the incidence of defects on the external wall finish in terms of environmental influences. In the main, the researcher virtually surveyed fifty houses that were either constructed or refurbished in the last fifteen years. During the exercise, the selected representatives or inhabitants were interrogated orally to provide the year period they started noticing defects to their external wall paint finish from the year of construction or refurbishment. Furthermore, for wider coverage of informed perception about strategies for minimizing the effects of environmental factors on the service life of exterior wall finish interviews through well-structured questionnaires were conducted among a group of paint professionals. This group consists of scholars and paint professionals in the study area. The questionnaires provide information about possible solutions and methods on ways to counter or reduce the effects of environmental factors on the external wall paint finish. The scholars selected involve lecturers in the School of Environmental Study at the Federal Polytechnic, Ilaro (FPI) and practicing painters in the study area. It is believed that scholars are more versed in theory (paint related courses) and professional painters better in practice.

In other words, the sampling frame for the interview surveys consists of the study target respondents which include lecturers and professional painters. According to FPI Bulletin (2017), there are sixty-nine (69) lecturers in the School of Environmental Studies. Electronic messages were sent to those lecturers; however, just two-thirds of the figure (amounting to 46 Lecturers) showed potential interest to participate in the study through. Furthermore, the study pre-test survey indicates that there are fourty (40) professional painters plying their trade in the selected town. This figure is significantly higher than the estimate provided by Aiyegbajeje and Oguntimehin (2018). The reason for the increase is due to factors such as more influx of fresh graduates of both formal and informal learning system into the industry who ply their trade in the study area and inclusion of neighboring towns. In all, the study population figure is one hundred and forty-three (86).

Further, a sample size of 71 was obtained from the research population of 86 participants. This was determined scientifically via Krjecie and Morgan (1970) sample formula as applied in Saka and Amusa (2017). Following the application, samples were selected based on the contribution of each element of the group to the total research population. This procedure has been recommended by Bowley (1926). In the main, thirty-eight (38) academic lecturers and thirty-three (33) paint professionals were selected as sample representatives for the study. On the empirical evaluation of the study developed mitigation strategies, z-test at 5% level of significance was employed to test hypotheses for validating such strategies. The use of such a method was based on satisfying conditions of unknown population standard deviation and sample size of the study was found higher than thirty.

Presentation, Interpretation and Discussion of Results

This section starts with a presentation of results from virtual survey exercise. The empirical analysis of information on defects to external wall paint in the study area and service life of external paint finish is presented in Table1. Out of the total seventy-one questionnaires administered through an interview survey, only 55 (35 Lecturers and 20 paint professionals) were returned yielding a retrieval rate of 77.46%. However, only 52 of the returned questionnaires were found effective due to

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missing data on key information from 3 questionnaires. In the main, the study considered only those effective 52 questionnaires for further analyses. This yields 73.23% of the total distribution. A parametric technique analysis, the z-test statistic, was performed and results displayed in Table 1. Hypotheses were tested using probability values from z-test analysis. The two forms of data were both analyzed with the aid of analysis software application, STATA version 12 using a 5% level of significance. All the results from STATA 12 outputs were summarized in the tables below.

Table 1: Z –Test Result for Defects Types and Service Life Estimation

Defects	N (Interview)	Defect Mean	Z – test	Std. Dev	Sig.	N (Virtual)	Construction / Refurbishment Period (Years)	Defect Period (Years)	Service Life (Years)
Discolouration	52	2.155	8.624	.292	.000	15	13	8	5
Efflorescence	52	1.097	0.768	.530	.711	-			
Cracking	52	2.240	9.323	.188	.000	12	10	6	4
Blistering	52	1.711	1.012	.106	.098	-			
Chalking	52	2.145	7.357	.363	.010	10	14	9	5
Flaking	52	1.721	8.350	.169	.243	-			
Microbial Growth	52	2.613	6.941	.372	.000	8	12	8	4
Dirt Deposition	52	2.379	5.377	.228	.000	5	14	8	6
Grand Mean						**10**	**12.6**	**7.8**	**4.8**

Source: Author's Computation from STATA 12 Outputs, 2020

Table 2: Z-test Result for Empirical Validation of Environmental Influences

Factor	N	Mean	Std. Dev	z-test	Sig.
U.V. Radiation	52	3.542	1.034	10.387	.000
Water and Moisture	52	2.751	0.245	9.432	.000
High Humidity	52	3.358	1.345	11.734	.000
Cold Temperature	52	2.994	1.049	5.243	.000
Hot Weather	52	3.523	0.375	4.501	.000

Source: Author's Computation from STATA 12 Outputs, 2018

From the analysis result of data obtained through the virtual survey as revealed in Table 1, it was discovered that discoloration, cracking, chalking, microbial growth and dirt deposition are significant defects caused by environmental factors. This assertion is well informed by defects z – test values greater than the critical value of 1.646 and in particular their significance weights being less than the adopted level of significance. The study approach of estimating the service life of external wall paint finish in a warm and tropical region yield an improved result compared to prior and similar studies in this area of research. From the finding, an average of four years and eight months (4.8 years) were estimated to be the service life of external paint finish in the study area. It was further discovered that an average terraced building surveyed for the purpose of the current study has either been constructed or refurbished in the last twelve and a half years ago (12.6 years).

More importantly, an average surveyed building starts to experience defects to its external wall paint finish in the seven years and eight months (7.8 years) after a period of construction or refurbishment. This finding indicates that there is a need for the provision of means or strategies for improving the service life of external wall paints finish in a warm and humid environment. However, effective strategies could only be feasible developed when factors responsible are fully examined and recognized. In other words, the analysis result of data obtained from a virtual survey provides ground and justification for further empirical analysis. Further, the result in Table exhibits empirical validation of environmental factors that contribute to defects of external wall paint finish in the study area. From the Table, all the environmental influences were found to be significant with the indication that these variables affect external wall paint in one magnitude or the other. This was discovered through the system generated z-test values of the variables and their respective significant values. The author, in consideration of the empirical result in Table 2, provides effective ways and strategies of minimizing the effects of these empirical validated environmental influences. Such strategies are concisely presented in the following Table 3.

Table 3: Strategies for Minimization of Effects of Environmental Influences

Factor	Strategies
Ultra Violet (U.V.) Radiation	○ Apply quality paint ○ Use waterborne paint binders ○ Use paint with U.V. inhibitors ○ Stay out of direct sunlight and follow the shade around the building
Water and Moisture	○ Use higher quality waterborne paints ○ Application of fungicides ○ Prior to painting, mould present should be treated with mould killer
High Humidity	○ Decorators should be aware of calm and still autumn afternoons when the skies are blue ○ Avoid painting on a porous surface ○ Get the help of a heater or dehumidifier ○ Paint late in the morning when temperatures are rising
Cold Temperature	○ Stand the paint in the warm water ○ Add thinners to paint ○ Waterborne paints are applied at temperatures above 10^0C and solventborne and industrial paints at least 5^0C above the dew point ○ Study local topography and altitude as well as sea-level-pressure
Hot Weather	○ Avoid painting when the heat is too much ○ Hot weather addictive can be added to the paint ○ The surface should be pre-wetted with water before the application of waterborne paints ○ Do surface preparation through surface washing and scrapping ○ Consider your colour because unlike lighter colours darker colours absorb more

	heat and energy ○ Place some ice cubes in the painter's bucket before inserting the liner and filling with paint ○ Adopt "chasing-the-shade" system when it is too hot ○ Endeavour to paint in the morning when it is cooler

Discussion of Findings

The study empirically validates effective strategies at minimizing the effects of environmental factors that affect the service life of external wall paint finish in a tropical climate. More importantly, this study adopted an approach that evaluates service life of external wall paint finishes within the scope of defects that occur due to failure of the paint as caused by environmental factors. The data collected for the study were obtained from a warm and humid environment. Thus, guarantees reliable results that could be generalized. From the analyses, key findings emerged. Firstly, the study discovered that significant defect such as cracking; discolouration; chalking; microbial growth; and dirt deposition are found on external walls of buildings in warm and humid regions in Ogun State. This finding is consistent with previous studies (such as Aluko, 2018; Aiyegbajeje and Oguntimehin, 2018; Teo et al, 2005). The result serves an upgrade to prior studies in the sense that the study specifically focuses on environmental influences relative to defects and service life of external wall paints in a tropical region.

Moreover, the empirical finding showed that the average service life of paint finish on external walls in a tropical climate like the study area is 4.8; that is, 4 years and 8 months when specifically consider environmental factors. An approach that evaluates service life of external wall paint finish within the scope of defects that occur due to failure of the paint as caused by environmental factors significantly improves existing knowledge and understanding. In terms of standard, this is relatively a longer period when compared with the previous finding by Aiyegbajeje and Oguntimehin (2018). This finding shows the importance of the approach adopted by the current research. However, the result is consistent with finding by Aluko (2018) where an average of 2 to 5 years was found and established lifespan of paint finish in tropical regions. The implication of this finding is that external paint finish in tropical regions will increase if adequate attention is paid to environmental induced influences.

Furthermore, a significant model indicates that significant environmental factors such as U.V. radiation, water and humidity, high humidity or changing humidity, cold temperature and hot weather significantly influence the service life of exterior painting in a tropical climate, a case of the study area. This finding is consistent with prior findings by Aiyegbajeje and Oguntimehin (2018); and Taitor (2015). In line with the finding of significant environmental factors that influence the service life of external wall paint finish the study in Table 3 suggested minimization strategies that can be implemented to reduce impacts of the empirically examined environmental factors. These strategies provide crucial durability input to the paint formulation and design process of external wall paintings.

Conclusion

From the data analysis on external walls paint finish in a sub-urban tropical region there is evidence of significant defects of paint finish caused by uncontrollable environmental factors. These defects are cracking; discolouration; chalking; microbial growth and dirt deposition. Consequently, these defects occur at an average of four years and eight months leading to upgrade of external wall paint finish service life when analyzed in the direction of environmental influences. In addition, environmental factors that influence the service life of external wall paint finish in the study area are ultra violet radiation, water and moisture, high humidity, cold temperature and hot weather conditions. The study, therefore, affirms that the service life of external paint finish in tropical regions will increase when special considerations are paid to environmental factors. More importantly, durability and aesthetic functions of external wall paint finish are effectively guaranteed when strategies for minimizing environmental influences, as suggested by the current study, are efficiently implemented.

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