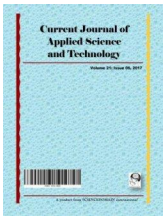

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A Study of Roof Failures in and around Ibadan, Nigeria: Causes, Effects and Remedy

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

A random survey was carried out on the preponderances of roof failures and possible causes in Ibadan, a city in Oyo State of South-Western Nigeria. The survey was carried out using structured questionnaire, interview schedule; focus group discussion (FGD) and personal observations with photographs recording. Information of interest and which were included in the instruments were the types of roof, materials used in the construction of roof trusses and sheathing, age of roof, maintenance practices, causes of failure and their subsequent consequences.

The survey revealed that all categories of roof of different ages are affected in all locations of the city both at the urban and rural areas. The identified causes of roof failures include Poor workmanship, design error; age and environmental forces, materials inadequacy, roof geometry and topographical with relative frequency of occurrence of 30.48%, 14.76%, 10.28%, 18.64%, 14.08%, and 11.76% respectively. The study revealed further that roof failure has economic, social and emotional effects on the affected people. Routine maintenance programme, proper construction, provision of courtyard, adequate drainage, good slope and roof overhang will minimize incidences of roof failures and are these therefore recommended.

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1. INTRODUCTION

Roof failure is a common occurrence in several parts of Nigeria, and all categories of buildings in the different regions are affected. Roof failure is not peculiar to Nigeria as several countries of the world including the developed nations experience roof failure. In Britain, current statistics suggest that about 70% of the insured loss costs of storm relate to domestic property includes roof failure [1]. The roof is an important component of any building and its total failure invariably renders the structure over which it is built unsuitable for habitation. Whenever there is total failure of roofing system, it is often associated with dangers to other buildings and passersby. It also affects facilities such as electric lines. The problems arising from roof failures are crucial in the development of any community and efforts must be made to minimize or where possible eliminate them. An understanding of the causes and patterns of failures of roof is necessary.

Roof according to the World Health Organization (WHO) is one of the important requirements for a house to be considered suitable for healthy habitation [2]. The importance of roof is found to be due to the overall protection it gives to properties, animals and human beings in a building against inclement weather while on the other hand a house with other elements of buildings such as partition walls, beams or columns, without a roof leaves both human and properties to the harsh effects of weather.

The protection and comfort which building roofs should provide to occupants, the contents of buildings and external walls are frequently threatened by failures in the roofing system. The cost of repairs or a complete replacement of a failed roof could be enormous. These include cost of repair in terms of material and labour; the cost of alternative accommodation pending the repair of the roof; the cost of treatment for injuries sustained by persons that the roof has fallen on; the cost of treating ailments such as pneumonia to persons directly affected by roof failures; the cost of replacing property loss in the affected building, and the trauma and psychological disorientation for those living within any building whose roof has failed. Investment in building maintenance is huge all over the world. In most countries, it represents almost 50 per cent of the total turnover of the construction industry [3].

Nigeria's climate is generally governed by latitudinal variations with a pronounced dryness up north compared to the coast that is wet. Rainfall is the key climatic variable, and there is a marked alternation of wet and dry seasons in most areas. The rainfall pattern is controlled by two air masses namely the moist northward-moving maritime air coming from the Atlantic Ocean and dry continental air coming south from the African landmass. The outset of raining season is usually in February or March in the coastal and south-eastern part of Nigeria. High winds and heavy but scattered squalls often mark the beginning of the rains in Nigeria with accompany damage to roofs. Olomola [4] reported that the temperature of the zone is generally high throughout the year with temperatures ranging between 21°C and 37°C and with high rain intensity. There are many topographical and altitudinal variations in the zone that promote different climates within short distances from one another. These features favour roof failures and it is necessary to take precautions to guide against them [5]. All these environmental forces contribute to the factors resulting to damages to the building especially the roof.

In the past, many attempts have been made to solve the problem of roof failures. These included the use of various roofing materials, the different construction methods; construction of block wall on the roof, the use of roofs of different shapes and planting of wind breakers. These methods are not full proof as there are still records of damages even with these in place. The construction of wall on the roof makes roof to be susceptible to leakage because the roof/wall interface may not be adequately taken care of. Wind breakers, if too close to the house can be broken during wind storm and cause damage to the roof. An understanding of the effects of environmental factors and performance potential of materials of construction would be useful in the design and construction of appropriate roof structures. Despite the antecedents of roof failure, its scourge and havoc it promises to wreck in future going by its trend, individuals and governments had for long-time not paid adequate attention to roof failure disaster. An improvement on roofing quality and durability in the zone therefore will mean the understanding of the environment, economy, design, construction practices as well as maintenance culture of the people. It is the incessant cases of roof failure

and the exacerbating damages associated with it that has necessitated this research.

The objectives of this work are:

i) To identify the causes of roof failures commonly experienced in Ibadan metropolis South-western Nigeria,
ii) To identify the effects of roof failures, and,
iii) To work out ameliorating measures to minimize the incidences of roof failures.

2. LITERATURE REVIEW

2.1 Roof Failures

Eleven major types of roof failure were identified in a previous work, these include rust, leakage, tearing-off, open lap, truss damage, nail withdrawal, wood decay, sagging, ponding, discolouration and blown-off. The four prominent types of failure are rust; leakage; nail withdrawal and wood decay. Although blow-off is the least failure in occurrence of the eleven identified roof failures, its effect is more severe than any of the other failures [6].

Failure can be defined as any form of behaviour in the roof that seems to threaten the safety of the roof in terms of serviceability or which could lead to total collapse. There are three broad categories of failures, (a) Ultimate limit state generally connected with collapse, (b) Serviceability limit state connected with deflection and vibration, (c) All other limit state connected with special requirements, for instance, aesthetics, fatigue, fire resistance, and water tightness [7].

2.2 Ultimate Failure

This type of failure is the structural collapse of the roof, it may be slow structural collapse known as plastic failure or sudden failure. These types of failures are usually disastrous in nature and more widely publicized than the serviceable failures. An example of ultimate limit state failure is roof blown-off [8].

2.3 Serviceability Failure

These are fairly frequent form of structural failures observed in roofs. They appear in form of deflection and cracks on a structural member, or a breakdown of waterproofing cover which could result into water penetrating the roof, in case of concrete, initiating corrosion of reinforcements and in wood structure, causing decay and eventual deterioration. They could lead to disruption of services and interruption of business activities [8].

2.4 Special Requirement Failure

This is a functional purpose requirement that has to do with special requirements other than the limit states considered for some special functions other than that of the normal roof functions. For example, in studio design, special precautions are built in the roof to reduce the noise penetration and the acoustics of the roof. The requirement in radiation protection building is to prevent leakage of radio-active elements; here the special requirement is to prevent porosity [1].

3. METHODOLOGY

This study was carried out at Ibadan in Southwestern Nigeria and all categories of buildings were considered in the study. The temperature in Ibadan was generally high throughout the year and the annual range is usually low, between 3^{o} and 6^{o}c. The survey was carried out using structured questionnaire, interview schedule; focus group discussion (FGD) and personal observations with photographs recording. Information of interest and which were included in the instruments were the types of roof, materials used in the construction of roof trusses and sheathing, age of roof, maintenance practices, causes of failure and their subsequent consequences.

The instruments were validated by experts in the building industry and pre-tested at Moniya in Ibadan, using respondents who did not form part of the final sample for the study. The pre-testing was very useful as it enabled the instruments to be revised eliminating redundant questions and including vital questions that were previously omitted. Altogether, the roofs of randomly selected 1,894 buildings were examined during the survey carried out in Ibadan metropolis, in Southwestern Nigeria. Also about 200 people that were affected were interviewed to know the effects of roof failures on the affected people. The sample size was determined using the following procedures; one street from each district of the town was chosen for study. The selection was based on previous records of the propensity of roof failure from the State Ministry of Environment. The chosen district was stratified into four groups. A 25 percent (25%) sample size of the buildings within each street that was chosen were selected by systematic random sampling method. The first house in each street

was selected by random sampling while every fifth house was picked systematically. Thirty buildings per location were investigated. A reconnaissance survey of the district was carried out together with field assistants to acquit the field assistants with the survey requirements. Thereafter, the district was broken into four sub-divisions, two persons to each area to carry out the administration of questionnaires, FGD and interviews.

The survey of roofs was undertaken during the dry season periods of three years to observe structural designs, materials used and their fabrication/erection patterns as well as those other factors that could cause failure. During the raining seasons of these same years, survey was repeated to determine the cases of failure.

Both the failed and the sound roofs were investigated to see if there would be any noticeable differences in the form, design, construction and materials of the failed roofs and those that were still structurally sound, to further evaluate the likely causes of failure in those that failed. During the field work, samples of timbers at point of use, from failed roofs and intact roofs were collected for investigation.

4. RESULTS AND DISCUSSION

4.1 Reliability of the Survey Instrument

To test for the reliability, the test-retest method was used. 40 contractors/suppliers from the University were randomly selected and the questionnaire was administered on them. After one month, another administration of questionnaire was carried out. When the two sets results were correlated, the co-efficient of correlation indicated a high relationship between the two sets of results. A correlation co-efficient 0.84 significant at 0.05 confidence level was obtained. The Spearman Brown correlation co-efficient was used.

4.2 Indices and Measurement of Roof Failures

Failures in roofs can be identified by various methods which include visual observation, physical measurements and calculations. These indices which were employed during this study are presented in Table 1 and are further discussed. They include visual observations, measurements, and calculations where necessary.

4.3 Causes of Roof Failures

There are some factors that are primarily the causes of roof failure while others that may not be primary causes of roof failure can influence roof failure. The primary causes include the topography of the building location, roof geometry, design problems, poor construction and installation practices, lack of maintenance, climatic factors, imposed load on the roof, materials of construction and aging. Factors that can influence roof failure include poverty of the building owner which in many cases makes building owners to seek for bold-off wood instead of good materials to construct, ignorance, topography of the building location and roof geometry.

4.3.1 General causes of roof failures

There are six major causes of roof failures that had been identified in the study area. These are poor workmanship, design error, age and environmental forces, materials inadequacy; Roof geometry and topographical Location (Fig. 1).

4.3.1.1 Poor workmanship

Much of the damage to roofing system is due to substandard construction, often due to inadequate training or supervision during building, rather than poor design. The outcome of the surveys carried out showed that lack of engineering knowledge of some of the carpenters are major contributor to the causes of some of the roofing systems that were poorly constructed in some areas. There were situations where the roofing members were structurally adequate, the mode of erecting were grossly inadequate probably because the artisans involved are inexperience or unknowledgeable. Another militating factor is the lack of adequate resistance to the overturning forces of wind. As a result of improper design of roof member, little or no consideration were paid to roof anchorages, this therefore made the roof to be prone to blow-off. Mode of joints and placing of joint members also posed a great deal of danger to the roof covering materials; no due considerations were given to end distance and space distance as the workers followed their own intuition. Apart from the wrong joint rule that were not observed, the sizes and depth of nail penetration to give a firm holding of joined members were not taken seriously and thereby causing members distortion during wind storm which resulted in the

failure of such joints and consequent collapse of some of the roofs. The survey revealed further that the type of joints and the assumed loading pattern of roof timber joints in some cases were found to be inadequate leading to premature deterioration when the roof is subjected to constant vibrations and that might have caused some of the distortions and failures. Some joints were not given adequate lap length as in some of the laps during roof construction where the end or side laps are not adequate. It was found out also that roof failures occurred when the corrugated roofing sheets are laid in the wrong direction with respect to the direction of the prevailing wind thereby encouraging water back splash resulting in leakages. The major cause of leakage in roof with respect to the covering materials is the non-compliance with design specifications and manufacturers requirements, especially where roof slopes have been constructed below the manufacturer's recommended minimum level Another cause of leakage failure in roofs was found to be due to poor construction method, if during roof construction, the end or side laps are not adequate or if the corrugated roofing sheets are laid in the wrong direction with respect to the direction of the prevailing wind, there will be water back splash resulting in leakages. This leakage if not rectified immediately often resulted in rusting of the fasteners which invariably caused weakening of the entire roofing system.

Another militating factor against roof failure is that there is complete lack of supervision during roof construction by experts. The general practice has been that the clients often engages the services of carpenters that do not take into consideration the environmental uniqueness of the site coupled with variances in roofing materials. The practice is to go by the rule of thumb in erecting the pitch of a roof whether asbestos, long-span or aluminum roofing is to be used. This attitude had left so many roofs to be structurally insufficient to withstand the environmental forces of attack.

Table 1. Indices and measurement of roof failures

S/N	Failure	Indices	Measurement
1	Blow off	Lifting and carrying away of total or part of roof	Visual observation; determination of overturning and resisting moment; and determination of wind pressure and suction
2	Sheet removal	Detachment of sheet coverings from trusses	Visual observation; finding the trajectory path and distance of travel
3	Nail removal	Gradual withdrawal of nail fasteners from roof members.	When the joint is weakened by the withdrawal of nails as to cause joint failure. Determining the load bearing capacity of the joints
4	Rust and/ or discolouration	Change in colour of sheet covering materials	Visual observation, rust cases bubbles to form under paint
5	Truss Damage	Tearing of or broken truss of a roof	Visual observation
6	Wood Decay	Deterioration of wood quality by water/moisture penetration	The wood texture is softened and disintegrates; measurement of wood density and stress will be carried out.
7	Leakage	When the roof covering can no longer exclude rain water from penetrating into the house	The dripping of water in the house.
8	Open lap	When the sheeting overlap is open to ingress of water	The line of lapping is loose as to cause flapping of sheets.
9	Sagging	When roof cave in such a way as causing an excessive deflection greater than stipulated in the code	The depth of sagging is measured by tape
10	Ponding	Collection of water on roof due to inadequate drainage of the way.	Visual observation and dripping of water when the covering materials are not water-tight.

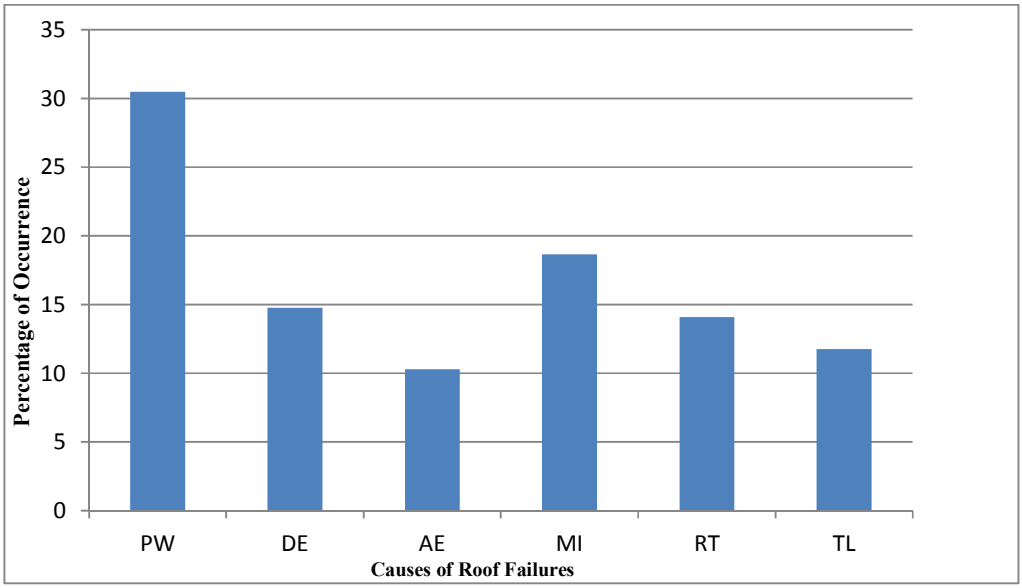

Fig. 1. Causes of roof failures

Source: [9]

Where: PW = Poor workmanship; DE = Design error; AE = Age and environment; MI = Material inadequacy; RT = Roof type; TL is topographical location

4.3.1.2 Material inadequacy

The question of resources in labour and materials does not frequently arise in advance countries in sufficient degree to influence choice of structure. In developed countries, however, particularly in 'emergent' countries, inaccessible areas, or areas subject to extreme natural phenomena, the question of resources may be extremely relevant. Local building methods and materials are sometimes worthy of adoption, particularly when low cost buildings are to be erected. Experiments will indicate the most suitable materials and methods to be used, and these will vary from place to place- steel, concrete bricks and blocks.

The survey revealed that, due to the high cost of the standard structural roofing members, the would-be house owners who usually adopt direct labour techniques in their projects normally go in for off-cuts and undersized structural timber members which are relatively cheaper but structurally inadequate. The roof structures formed from these timbers are usually prone to various types of failures which include warping, sagging and decay. The lightweight nature of most of roof structures formed this way from smaller timber sections makes them highly susceptible to damage from suction caused by strong winds and that also contributed greatly to the collapse of some of the roofing system.

4.3.1.3 Design error

Structural inadequacy was found to be one of the major causes of the collapse and ripping off of some of the roof structures. The result of the random surveys of roof undertaken indicates that only 48.47% our roofs are said to be designed, while more than half of the roofs (51.43%) were left to the discretion of the carpenters and the house owners (Table 2).

Table 2. Distribution of roof designers

Type	No. of building roofs	Percentage
Architect/Engineer	918	48.47
Carpenter	880	46.46
Others	96	5.07
Total	1894	100

Source: [9]

The growth design approach that relies basically on experience, intuition, common sense and the rule-of-thumb were employed in their design. In such a situation, those artisans who possess these qualities are able to size structural roofing members without having to resort to design code, theories and rigorous computations since they have the understanding of what the correct sizes of the roofing members should be. Artisans, who are less experienced, do not have the requisite

sense to size structural roofing members, so they rely mostly on the rule-of-thumb which unfortunately resulted in very defective roofing systems which in most cases also contributed to roof failures. Some vital questions to ask while designing are often overlooked; the questions include what are the criteria to be used in choosing materials? Are the required strength factors and tolerances, the needs for flexibility, fire -resistance, corrosion resistance all valid? Is the system over-engineered? Can material contents be reduced without any loss of performance? Is the design unnecessarily complex? Could changes be made to reduce construction cost or to simplify the assembly?

4.3.1.4 Roof type

The most appropriate form of roof structure for a particular building will depend but not limited to such factors as size and plan or shape of the building, appearance or aesthetic considerations, cost of construction, ease of effecting repairs, nature and magnitude of the loads that may be imposed on it, including the suspension of machinery, possibility of future alteration, lighting requirements and accommodation for services. Wind interacting with a flat or low sloped roof will cause outward pressure over the entire roof similar to the top surface of an airplane wing. As the wind flows over the roof, uplift occurs; the faster the wind, the greater the uplift. Wind blowing in a direction perpendicular to the ridge of a high-sloped roof will cause an inward pressure on the windward side of the roof and an outward pressure on the leeward side. Wind blowing parallel to the ridge will result in outward pressures on the roof surfaces. Winds flowing around eaves, ridges and overhangs cause high uplift forces. The roof slope also determines the water shedding capacity of the roof. The shape either in form of gable or hip roof influences roof resistance against wind uplift. The two major roof geometries observed in the zone are hip and gable. The gable roof is more prone to uplift under wind load than hip roof because hip roof contains more materials than gable roof and the area of exposure in gable roof is more than in hip roof. Due to their complex internal framing and steepness in pitch, wind is prevented from entering underneath the roof shingles, and the overall shape of a hip roof provides durability against wind. The four slopes constituting a hip roof create an eave running all the way around the building, which in turn creates an overhang that can protect against sun and rainfall.

4.3.1.5 Topographical location of building

The force, direction and moisture content of air flows are strongly influenced by topography. Air could be diverted by mountain ranges. Roof blown-off is also found to be more pronounced on hill top because of higher wind speeds resulting from the venturi effects of the hills A descending air mass will rarely give any precipitation, therefore rainfall characteristics vary sharply between locations on windward and leeward slopes of mountain ranges. The effects of topography on precipitation, wind, moisture have great influence on roof failure. Table 3 shows the relative occurrence of topographical effects on roof failure.

Table 3. Roof blow-off pattern based on topography location

Location	Frequency	%
Plain	89	32.00
Valley	44	15.67
Up-Hill crest	146	52.33

Source: [9]

The buildings on slopes and summit of hills do not only enjoy the positive influence of wind flow, they also enjoy better geotechnical characteristics and also the soils from gentle slope are more geo-technically stable than those from flat sites. Soils along slope are better drained and more laterised than those from flat sites. This phenomenon is responsible for the higher amount of gravel-size particles, lower amount of sand-size particles, lower plasticity and higher strength characteristics exhibited by soils along slope than those in flat site [10]. As a result of this better geotechnical characteristics, dampness or moisture ingression into the roof leading to failures such as decay can be prevented.

4.3.1.6 Age and environment

The constraints placed upon roof performance are not only confined to the properties of the roof materials; social, environmental and ecological constraints also exist. They gain increasing importance as population densities increase, more natural resources are consumed, and increasing environmental pollution becomes incompatible with the need to have a sound roofing system. Climate change could affect the quantity of the wind hazard; and the operation and effect of wind on the building. Over-intense development has effectively covered the ground with concrete. This has dramatically reduced the

capability of the ground to absorb precipitation, with a consequent escalation in the amount of moisture present in a particular site. This excess moisture can find its way into the foundation and thereby undermine the integrity of the foundation; there could also be possible moisture ingression that can lead to roof failure of failures. Most walls used in building houses in the western part of Nigeria are absorbent media for water. Underground water within the foundation level, water on bathroom floors and water linking from poor conditioned drainage pipes are adsorbed and transported to the roof through walls and forming films of water on wooden roof thereby causing decay.

Age equally plays an important role in determining roof failures, when the materials of construction experiences stress reversal for a long time; there is the likelihood that the material will fail thereby leading to the eventual failure of the roof.

4.4 Effects of Roof Failure

Roof failures have social, economic and psychological consequences on the affected people. Owning a house provides social security, as the owner is not subjected to insults or intimidation by a landlord. This security could be lost when the roof of a building collapse and rendered the building unfit for habitation. The cost of repairs of damaged roof could be enormous, because of the daily increase in the prices of roofing materials. The situation is even worse in rural areas where early replacement of damaged roofs become almost impossible due to low level of financial resources available to building owners. Survey showed that numerous Government-owned schools in rural areas have had their roofs blown off and left un-repaired for upwards of three years. Delayed actions to replace collapsed roofs during the rainy season may lead to much greater damage to the wall structures which are mainly earth materials thereby exposing the contents of the house to damage. Worst off, any delayed response to replace these collapsed roofs during the rainy season can lead to total collapse and erosion of the mainly earth wall structures that are supporting the roof. In this case the total house can be left to collapse and may not be replaced even in the distant future, thereby reducing the national housing stock and worsening the housing situation in the country. Furthermore, the FGD held during the survey revealed that when roof fails especially when it is blown-off and it is not replaced on time, anxieties, pains and adverse emotional reactions from the house owners follow the incidence.

The sheathing membrane of roof structure provides a good protection for a building because of its umbrella action in quickly removing the rain water and shielding it from sunshine and other weather elements. Therefore roof damage could result in loss of fortunes or valuable properties. Delayed actions to replace collapsed roofs may lead to much greater damage to the wall structures thereby exposing the contents of the structure to pilferage. The cost of repairs of damaged roof could be enormous not just because of the daily increase in the prices of roofing materials but the special skill required for roofing. While other artisans such as mason, iron benders and painters are employed at a cost of ₦1, 500.00 for a day's job, carpenters depending on their experience in roof construction are project paid between ₦ 2, 500.00 and ₦ 3, 000.00 per day. Tables 4 and 5 which are the case studies of some selected institutions in Southwestern Nigeria show that the cost of roofing a new building constitute between 12% and 20% of the total cost of the project while that of rehabilitation work will take between 21% and 46% of the total rehabilitation cost.

Table 4. Roofing cost as a percentage of total cost of new building project

Project name	Contract sum (₦)	Roofing cost (₦)	Percentage
Construction of Telephone Operators' Office University of Ibadan	554,516	67,700	12.21
Construction of Estate Office University of Ibadan	16,906,765	2,334,930	13.81
Construction of students Affairs office University of Ibadan	10,625,307	1,777,775	16.73
Construction of C.I.C.S Building University of Ibadan	27,102, 575	4,415,599	16.29
MacArthur/ICT building University of Ibadan	19,603, 752	4,100,730	20.09

Source: [11]

Table 5. Roofing cost as a percentage of total cost of building rehabilitation project

Project name	Contract sum (₦)	Roofing cost (₦)	Percentage
Renovation of UPE Building Bowen University, Iwo	3,576,613.33	1,104,900.00	30.89
Renovation of Agric Hall Bowen University, Iwo	416,348.87	105,750.00	25.40
Renovation of Maclean Hall Bowen University, Iwo	467,727.27	188,000.00	40.19
Renovation of Science Education Hall Bowen University, Iwo	403, 514.55	87,000.00	21.56
Renovation of Principal's house Bowen University, Iwo	2,500,000.00	1,150,000.00	46.00

Source: [12]

Table 6. Precautionary guide against roof failures

S/N	Guide measure	Failures that will be prevented
1	Routine maintenance programme	All types of failure
2	Provision of adequate slope and roof overhang	Wood decay, rust/discouloration, blow-off ponding, leakage, and sagging
3	Construction which include provision of adequate nail density and proper nailing, paying attention to edge distance, proper anchorage of rafters, good joints and use of well seasoned timber	Sheet removal, open lap, sagging and truss damage, blow-off , nail withdrawal and leakage
4	Provision of good roof drainage and drainage of the whole surrounding	Leakage, sagging, wood decay, and rust/discoloration
5	Provision of courtyard and enough and well positioned openings	Blow-off, wood decay, sagging and leakage

4.5 Remedial Measures

Roof failures can be minimized in the zone by taking some precautionary measures which involves some design, construction, provision of some amenities and maintenance practices.

During the survey, eleven types of failures (Roof rust, leakage, nail withdrawal, Blow-off, asbestos discoloration, ponding, wood decay, sagging, tearing-off, Truss damage and Open lap. Although blow-off is the least failure in occurrence of the eleven identified roof failures, its effect is more severe than any of the other failures.

Remedies of rust; leakage; nail withdrawal wood decay and blow-off cases will take care of the rest six. While treating blown-off, sheet removals could be addressed; in the same vein leakage treatment can take care of failures such as sagging, ponding wood decay and open lap. Rust can also be taken to mean discolouration, however asbestos do not rust but changes colour. Generally, in order to forestall roof failure Table 6 above serves as guide.

Simple visual inspection can reveal obvious signs of problems. Roofs should be checked for debris and sharp items that could damage the roof system. Sharp items should be removed from the roof immediately. Trees that overhang a roof should be trimmed or cut back to reduce the potential for tree debris on the roof. Keep the roof or building area free of floating debris, as this is an excellent source of both borer and mechanical damage. If the roof has gutters and downspouts, they should be inspected and, if clogged, the debris should be immediately removed. When inspecting gutters, check for sagging, because it will prevent water from draining properly and result in roof failure such as leakage and wood decay.

5. CONCLUSION

The study revealed that poor workmanship, design error, age and environmental forces, materials inadequacy, roof geometry and topographical location have been identified as the major causes of roof failures. The study revealed further that roof failure has economic, social and emotional effects on the affected

people. Routine maintenance programme, proper construction, provision of courtyard, adequate drainage, good slope and roof overhang will minimize incidences of roof failure are therefore recommended.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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