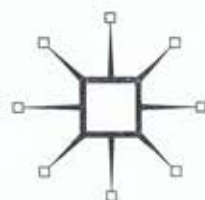


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A survey of roof failures in Oyo State of Nigeria

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Abstract

Rising incidences of roof failures in recent times in many parts of Oyo state, Nigeria have become a matter of concern and a survey was undertaken to investigate the pattern of failure, causative agents, consequences and possible remedial measures aimed at curtailing these occurrences. The survey adopted the use of questionnaires, interview schedules and focus group discussions. Information considered of relevance to the study was the type of roof, materials used for construction, type of buildings and topography of the environment. Besides being blown off, which is the popularly acknowledged index of failure, a number of roofs were found to have failed in their primary function of offering protection against rain and reduced solar radiation even when they were not blown off. Wind is a major causative agent of roof failures as it either completely removes the roof or tears it, leading to leakages. Corrosion was also a major factor resulting in leakages. The consequences of roof failures include damage to personal belongings and exposure of inhabitants and livestock to inclement weather conditions, and in some cases livestock were lost. Added to these are the psychological trauma to which victims are subjected and progress retardation as in many cases, no meaningful family projects can be executed while waiting for the roof to be replaced. As panacea, the adoption of a good maintenance culture, good workmanship and consultation of experts in the selection and construction of roofs are recommended.

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roof failure, roof repairs, roof maintenance, roof blown off, roof performance

INTRODUCTION

The roof is the most important component of a building. It is that portion of the building that offers protection against sun and rain, without which the content of the structure would be damaged. Added to this, is the regulation of the inclement environmental

conditions to provide a suitable environment. As important as it is, the roof is also the component of the building that is most abused and subjected to agents of degradation. Besides its subjection to repeated wetting and drying, and various components of the sun rays, it can be equally exposed to snow and wind and as such the extra loads arising from these external sources must be adequately supported by the roof.

Although modern architecture has given rise to different methods of roof design and construction, and hence roof types, all roofs can be broadly classified into two types on the basis of slope: flat and pitched roofs. Roofs having pitch angles not exceeding 10° are defined as flat while for higher pitch angles, they are referred to as pitched. While flat roofs may be subjected to ponding, there is an improved drainage system in pitched roofs that accounts for their use in cold climates where frost may be a problem. Pitch roofs are less prone to leakages as even when there are small holes, the water can drain over them. The most popular of the pitch roof types is the gable roof. Economic, aesthetic, size and shape of buildings are some of the factors influencing the choice of roof type.

The desirability for a roof over a building is as old as mankind. Modder (1991) reported that the desirability for a roof to offer protection was possibly responsible for early man's preference to live in caves and hollow trees even when his safety might be threatened. Thus, caves and hollow trees served as natural protective cover for regulating environmental factors in the early ages. Modern man later developed an artificial protective cover. The bamboo roof and thatch roof made of dried straw and reeds were the first set of these artificial roofs that came into existence. Improvement in technology has resulted in the development of assorted materials for roofs construction including wood, concrete, metal, rubber, limestone, clay and ceramics.

Roofs are susceptible to weather effects and failures. A roof is said to have failed if it is no longer capable of performing any of its desired functions and such failures could be either structural or thermal. The ultimate and more easily noticeable type of structural failure is roof collapse while thermal failure manifests itself in the form of reduced ability to act as barrier to heat flow from the atmosphere to the building interior (Kumar and Stathopoulos, 2000; Al-Sanea, 2002; Charles, 2002). Other indices of roof failure include leakages, condensation and rusting or corrosion (Wooley, 1953).

The performance of a roof is measured based on its life span and the effectiveness of its components to retain their strength, chemical and physical properties, appearance and resistance to all forms of failure. Most roof failures occur at bolted connections that were either inadequately secured at the time of construction or that have since failed due to deterioration. Many roof designers often fail to take into account a number of design factors such as tolerance and factors of safety, and these could result in roof failure. Other factors that could cause failure in roofs are the effects of wind and fire, poor workmanship, age, poor maintenance, height of the building and the use of cheap and substandard materials (Warseck, 2003; Roberts, 2006). The consequences of roof failures are usually devastating to the extent that they sometimes claim lives, and valuable property and possessions can be destroyed.

The rate of roof failures in Nigeria has increased alarmingly in recent times and they are regularly reported in the print and electronic media. These failures inflict hardships on already poor communities and efforts must be made to address the situation. The work reported in this paper was undertaken to identify the main causes of roof failure in Oyo State, Nigeria and make recommendations that could curtail this regular hazard.



Figure 1: Geographical location of Oyo State, Nigeria

MATERIALS AND METHODS

This study was carried out in Oyo state of Nigeria (Figure 1), which lies between latitudes 6.5° and 9° north of the Equator and between longitudes 3° and 5° east of the Greenwich Meridian. The State has high savanna vegetation with trees of moderate height in the north and rain forest with tall trees and palms towards the south. The State has altitudes ranging from 200 to 450 m above the sea level, annual rainfall ranging from 1000 to 1500 mm and design wind velocities ranging from 96 to 145 km/h (Nigerian Standards Organisation, 1973; Menakaya and Floyd, 1976).

Structured questionnaires, interviews and focused group discussions were used as instruments for data collection. 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 culture, frequency of maintenance, causes of failure and their subsequent consequences.

The instruments were validated by experts in the building industry and were pre-tested at Moniya 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.

The types of buildings surveyed cut across industrial (2 per cent), residential (80 per cent), religious (4 per cent), educational (8 per cent) and others (6 per cent); with ages varying from recent construction to as much as 40-year-old roofs. These buildings included those that appeared to be in good condition and those that had collapsed.

Those that appeared sound but were found with defects were considered in the analysis of results, while those without defects were discarded. A total of 600 roofs spread across the state were identified with one form of defect or the other.

RESULTS AND DISCUSSION

Roof types and buildings for which they were used

Although all types of roof could be found in the area surveyed, pitched/gable roofs were the most predominant (55 per cent), while 16 per cent were flat roofs. Although there was no restriction as to the use of roof for a particular type of building, most residential buildings used the gable roof, large halls such as theatres and places of worship used monitor roofs. Monitor roofs were also used in industrial buildings such as processing and poultry houses. Shed roofs were used by buildings in farm produce markets. Ease of construction, ventilation and symbolism are some of the factors that influence the choice of roof.

Materials used for roof construction

Of the roofs surveyed, 60 per cent were made from corrugated iron sheets, 23 per cent were asbestos, 9 per cent concrete and 8 per cent aluminium, while others such as tiles accounted for less than 1 per cent.

Although natural fibres are cheaper alternatives, durability has limited their use to a few rural buildings. Asbestos roofing sheets with a relatively low thermal conductivity were preferred by most poultry farmers because of its insulating property except where the cost was prohibitive.

Although aluminium has a high thermal conductivity that should discourage its use, it was found in use by most industries for its ability to resist corrosion. To reduce the heat absorbed, it is usually painted to give a reflective surface.

The most common material used for roof trusses is wood. It is relatively cheap and readily available, and easily worked. These qualities give wood trusses an edge over iron for small- to medium-sized buildings but in larger ones such as industrial buildings, steel trusses are used to provide stability against increased wind loads due to the height of these buildings. Trusses from oil palm trunks were also observed in some buildings. Concrete was only occasionally used because of its expense.

Failures identified and possible causes

The types of failures observed during this study can be broadly divided into two, collapse and non-collapse. Collapse entails the complete removal of the entire roof from the building, while in non-collapse failure the roof is still in place but may suffer one problem or the other that inhibits it from maximum performance. Such failures include rusting, leakage, open lap, tearing off, truss damage, nail withdrawal, wood decay, sagging and discolouration. The results of the study are shown in Figure 2.

Wind was the primary cause of roofs being blown off and could be further aggravated by poor workmanship, the use of inferior quality materials and poor attachment of the roof to the underlying walls. For example, in many cases it was observed that weak metal straps had been used for attachment and the top of the wall on which the wall plate is seated was uneven which subjects the straps to stresses such that any additional external load imposed will cause it to fail.

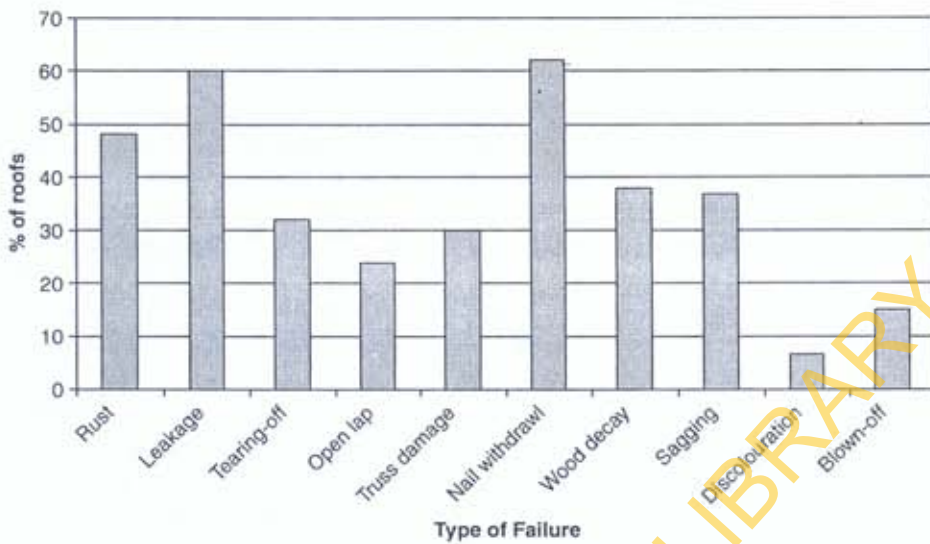


Figure 2: Types of roof failure reported

The appearance of holes in roofs due to wearing of the washers under fixing nails, punctures from external loads falling on the roof or rusting, provides an avenue through which water can penetrate a building. In addition, wooden elements are subjected to moisture damage and deterioration sets in.

Poorly secured roofing sheets can tear off even in low winds and subsequently provides an avenue for further damage and in extreme cases the whole roof may be blown off. The topography of the environment where a building is located is an important factor in its susceptibility to being blown off. Of the roofs surveyed that had been blown off, 52 per cent were located on plains, 20 per cent on slopes, 18 per cent in valleys and 10 per cent on uphill crests. These results are not surprising since buildings on plains and without wind brakes are directly exposed to the full force of the wind compared to the other topographical areas where some of wind energy is dissipated before hitting the building.

Of those roofs blown off 53 per cent were of the gable type, 30 per cent of irregular shape and 17 per cent flat roofs. Roofs were blown off most frequently in the evenings, at the onset and end of the rainy season and more often rural compared to urban areas.

Losses incurred in roofs failures

For new projects a roof accounts for between 10 and 20 per cent of the total building cost, while for rehabilitation it is even higher ranging from 20 to 45 per cent of total cost (University of Ibadan Maintenance Department, 2005). When roof failures occur, the first major loss is the roof itself that must be replaced if the building is to be put to further and effective use. Other losses for example might be in schools where roof failures cause destruction of furniture and important student documents and textbooks, thereby affecting the quality of education, while in residential buildings damage to essential home appliances can be a significant consequence of roof failure which in turn affects the quality of life of the residents affected. Against this background, a quantitative and qualitative assessment of losses incurred in roof failures was attempted. Data for quantitative analyses were not available since in most cases the victims do not keep such information as they are not insured. In rare cases where the government has come to the

aid of such victims, the amount of compensation is not tied to the extent of losses incurred. Qualitatively roof failures expose the contents of a building including humans to inclement weather causing severe damage to property and exposing the inhabitants to potential health risks. In many cases, residents who have lost their roofs may not have an alternative and have to contend with living under the rain and sun as shown in the examples in Figure 3. Roof failures can subject victims to significant stresses and psychological trauma as they worry and wait to get their roof replaced or repaired.

Although there were no reported cases of loss of human lives in the present study, livestock were reported lost either due to falling roof components or from exposure to adverse weather and environmental conditions following roof loss.

CONCLUSIONS

Although all types of roof could be found in the area surveyed, pitched/gable roofs were the most predominant accounting for about 55 per cent, while only about 16 per cent were flat roofs. Ease of construction, desirability for adequate ventilation and symbolism are some of the factors that determine the choice of roof. Wood was the main material for truss construction in small to medium buildings, while for large buildings steel trusses were often used. Roof sheathing included galvanised iron sheets, asbestos and concrete. Roof failures manifested in the forms of leakages, corrosion, and in extreme situations total collapse of the roof. Location, quality of workmanship and topography were found to play major roles in roof failures. Although data for quantitative estimates of roof failure losses were not available, qualitatively victims experience psychological trauma, damage and loss of personal belongings and in some cases loss of livestock.

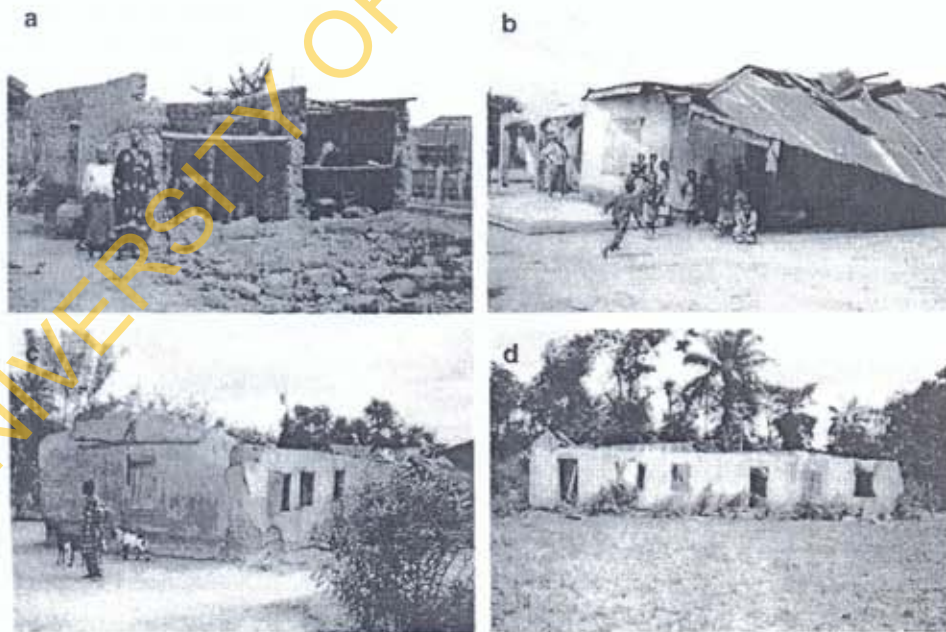


Figure 3: Examples of roof failure in Oyo State, Nigeria: (a) residential building with the roof gone yet the occupants reside therein, (b) occupants refuse to vacate a building despite the glaring dangers ahead, (c) livestock and humans have to contend with inclement weather as there is nowhere a roof to be found, (d) close down or study under the sun and rain because the school building is rendered roofless by wind

In addition, education of children was significantly affected when damage to school buildings was reported.

RECOMMENDATIONS

- (a) It is recommended that a maintenance culture be developed by which people should examine their roofs regularly. This will enable them to detect weak or damaged components as well as leakages which might lead to further deterioration thereby reducing costs as repair is almost always less expensive than replacement.
- (b) Good quality workmanship plays an important role in the performance of a roof. It should be ensured that the top of the wall on which the wall plate is seated is level and plumb so as to reduce the stresses induced on the metal straps that binds the roof to the wall.
- (c) Corrosion comes with age and reduces the thermal insulation of the roofing material. A corroded roof should be scrapped and repainted with red oxide and aluminium paints to improve the heat and light reflection and reduce the temperature within the building.
- (d) Most roofs, like the entire building below them are constructed without recourse to the engineers or builders who designed them, and it is only when they fail that the blame goes to these experts. It is important that appropriate experts are consulted in the choice of material and erection of roofs at the outset.

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