An Assessment of Fire Safety Provisions in Industrial Buildings in Nigeria

By

Ekerete Udo UMOH
Department of Architecture
Akwa Ibom State Polytechnic

ABSTRACT

The necessity for safety awareness especially for fire safety is due to the fact that the design and construction of a building contributes substantially to the severity of fire in building. The study assessed fire safety provisions in industrial buildings in Nigeria. This study adopted both descriptive and case study survey research design. The adoption of the design is due to the nature of the research. It describes the extent of prevention and control of fire through effective planning and design. As regards case study, the concept of quantitative approach was adopted in this research for effective data collection, literature review, and interview strategy. The population of the study consisted of all experts in architecture, civil engineering, structural engineering, electrical engineering, mechanical engineering and other sections of environmental science. Also included are workers of paint manufacturing industries in Akwa Ibom State. The sample size consisted of 150 respondents, selected using stratified random sampling technique. The principal source of data to be used was from both the primary and secondary sources. A structured questionnaire was used in collecting primary data. Secondary data was obtained from Textbooks, journals, magazines, unpublished articles, research and project reports in a related field, manuals containing policy statements on housing. The data were analyzed using such statistical techniques as regression analysis found to be appropriate for the study. The statistical techniques helped in testing the hypothesis at 0.05 alpha level. The study concluded that there is significant relationship between the major causes of fire incidents in a paint factory and the redemptive measure used. Also, fire safety measures significantly influence the level of prevention and control of fire in paint factory. One of the recommendations drawn was that building owners and property developers should ensure that their buildings are well equipped with active and passive firefighting equipment.

KEY WORDS: Fire, Hazards, Safety, Industrial Buildings, Paint Industries

Introduction

Building design process is an uninterrupted series of actions by design team members such as architects, structural, mechanical, electrical and fire safety engineers, to achieve a comprehensive building design (Park, 2014). The design process according to Balcomb and Curtner (2000) involves four stages which include: pre-design (PD), schematic design (SD), design development (DD) and construction documents (CD). Design stages are realized using two patterns which can be either: conventional linear design or integrated design. In the linear design approach, architects primarily manage the design progress and request engineers and other consultants to take part when the design has advanced (Park, 2014). This method is effective for a small and uncomplicated building project, which is carried out by few stakeholders.

The study maintained that fire safety plays a major role in building operations and should be properly coordinated with other subsystems early in the design stage to provide efficiency, reliability and performance. He further stated that consideration for fire protection is carried out by the architects in conjunction with the structural engineers. While architects design the building layout-including the exterior and interior walls, structural engineers produce structural calculations that meet fire safety regulation. In addition, inclusion of an experienced fire engineer in project design team according to the National Institute of Building Sciences, (2015) is crucial at all stages of the design to occupation. This is to ensure the construction of a reliable and safe building for occupants' habitation. Although architects are not trained to be fire scientists, it is important for them to be aware of the fundamental principles of fire safety and prevention (Rasbash, 2004), because of their roles as principal designers. Architects should also ensure they are acquainted with specific safety issues of a structure being planned, as well as obtaining necessary advice and information from fire specialist early in the design stage (Megri, 2009).

Statement of the Problem

One of the problems facing industrial buildings in Nigeria is the occurrence of fire. In recent times there has been increase in cases of fire outbreak in factories in various parts of Nigeria, from Lagos, to Ibadan, etc. In Akwa Ibom State, Champion Breweries located at the industrial layout, Uyo was gutted by fire in 2013. These incessant cases of fire outbreak resulting in loss of revenue and human lives is of great concern to the business community and building professionals, not only in Nigeria but all over the world. Studies have shown that building designs contribute greatly to the magnitude of fire in such buildings with severe consequences on safety of life and property. In view of these massive losses of lives and property to industrial fire, there is need to research into the main causes of fire outbreaks in industrial buildings and identify the effective preventive and control measures that can be adopted to stem the menace.

Aims and Objectives of the Study

The main aim of this research is to assess the level of fire prevention and control requirements in a paint factory. To achieve this aim, the following specific objectives will be explored:

1. To identify the major causes of industrial fires.
2. To assess the influence of fire safety measures on the level of prevention and control of fire in a paint factory.

Research Questions

The following research questions will be answered:

1. What are the major causes of fire incidents in a paint factory?
2. What is the influence of fire safety measures on the level of prevention and control of fire in a paint factory?

Research Hypothesis

The following hypotheses will be tested at 0.05 levels.

1. There is no significant relationship between the major causes of fire incidents in a paint factory and the redemptive measure used.
2. There is no significant influence of fire safety measures on the level of prevention and control of fire in a paint factory.

Concept of Fire and Its Origin

Fire is the process of combustion, ignited through the chemical reaction of heat, oxygen, and fuel. The fuel is heated to its ignition point until gas is released from its surface called oxidation (Fessler, 2006). As heat is released, it feeds back into the combustion process, creating a continuous chemical reaction. The result of this process emits energy, light, exhaust, and heat. In ancient times, fire was seen as the primeval element, one of the many myths competing for the origin of how Architecture was formed. Fire is associated with energy, with the thermal adaptation needed for human life, and for handling and producing the materials, such as metal, glass, food, that are fundamental in survival (Meo, 2010).

Generally, fire is connected to energy, light, purification, illumination, creation, destruction and metamorphosis. It has the properties of hot and dry, and once people ignited the first fire and gathered around it, it meant overcoming the hostility of the environment and adhering to the natural human needs. This has defined the first form of civilization and community. Langenbach, (2013) observe that all buildings are designed around fire, the idea of fire infiltrates every aspect of contemporary architectural construction guided by building codes and fire regulations. The relation of this element in Architecture remains a passive one as buildings are constructed to resist and decelerate the effects of combustion. Fire is ultimately one of the largest influences of the built environment, whether it is present or not.

Principles of Fire Safety

Every fire is somewhat unique. Still, design professionals can do a great deal to enhance their background in fire safety by knowing useful generalizations concerning the requirements of fire-safe buildings (Herbert, 1998). The fire safety principles are adopted primarily to protect life. Herbert (1998) summarized the principles as follows:

- Management of fire safety;
- Avoidance of outbreaks of fire;
- Early detection of fire and early warning to staff and guests to facilitate an adequate response;
- Compartmentation of building and provision of escape routes, which are protected from fire and smoke;
- Limitation of the development and spread of fire;
- Containment of fire and smoke to the room where the fire originates;
- Early suppression of fire, where this is feasible;
- Effective evacuation procedures; and
- Access and facilities for the fire service.

Major Causes of Industrial Fire and Explosion

Industrial fires and explosions cost companies and governments billions of naira every year, not to mention the loss of life, which cannot be described in monetary terms. According to the most recent fire statistics from the National Fire Protection Association (NFPA), an average of 37,000 fires occurs at industrial and manufacturing properties every year. According to Hassan (1999), there are five most common causes of industrial fires and explosions:

Combustible Dust: Often overlooked, and highly deadly, combustible dust is a major cause of fire in food manufacturing, woodworking, chemical manufacturing, metalworking, pharmaceuticals industry. The reason is that just about everything, including food, dyes, chemicals, and metals even materials that are not fire risks in larger pieces has the potential to be combustible in dust form. However, this small explosion isn't the problem. The problem is what happens next. If there's dust in the area, the primary explosion will cause that dust to become airborne. Then, the dust cloud itself can ignite, causing a secondary explosion that can be many times the size and severity of the primary explosion. If enough dust has accumulated, these secondary explosions have the potential to bring down entire facilities, causing immense damage and fatalities.

Fig. 1 combustible dust Source: Hassan, 1999

Hot Work: Hot work is one of the leading causes of industrial fires across all industries. Although hot work is commonly equated with welding and torch cutting, there are many other activities including brazing, burning, heating, and soldering that poses a fire hazard (Megri, 2009). This is because the sparks and molten material, which reach temperatures greater than 1000°F, can easily travel more than 35 feet. Hot work is also a major culprit in combustible dust fires, as the sparks generated from the work can ignite dust in the surrounding area. In practice, the surfaces of equipment and devices may warm up to a dangerous extent either normally or due to malfunction. Ovens, furnaces, drying devices, waste-gas outlets, vapor pipes, etc. often cause fires in explosive air spaces. For prevention, safe distances should be observed, and regular supervision and maintenance will reduce the probability of the occurrence of dangerous overheating.

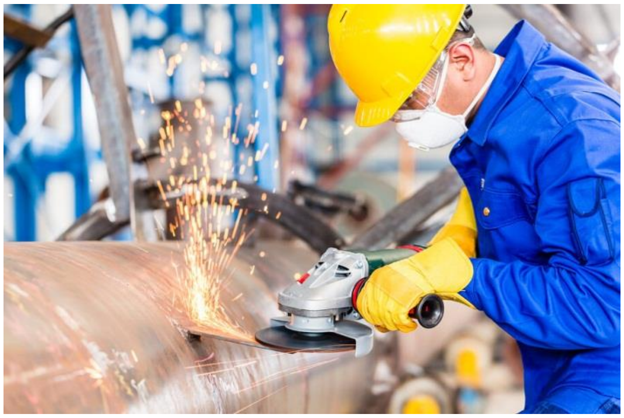

Fig. 2 Hot work. Source: Hassan, 1999

Hot work disasters can be prevented by following proper safety procedures such as:

- Avoid hot work if possible, or ensure that the area is clear of flammable or combustible materials.
- Train personnel on the hazards associated with hot work, any site specific hazards, the proper policies and procedures, and the use of safety equipment. Supervise the work.

Flammable Liquid and Gases: These fires, which often occur at chemical plants, can be disastrous.

Fig. 3 Flammable Liquid. Source: Hassan, 1999

There is danger inherent in any work involving flammable liquids and gasses. Available safety precautions should be taken to mitigate these risks:

- Know the hazards: One major component of prevention is simply knowing the safety information for every liquid on your premises. This information is available on the material safety data sheet (MSDS) that comes with such products.
- Store flammable liquids properly and Control all ignition sources except for when you're intentionally heating the flammable materials.
- Provide personal protective equipment

Equipment and Machinery: Faulty equipment and machinery are also major causes of industrial fires (Hassan, 1999). Heating and hot work equipment is typically the biggest problems here in particular, furnaces that are not properly installed, operated, and maintained. In addition, any mechanical equipment can become a fire hazard because of friction between the moving parts. This risk can be brought down to practically zero simply by following recommended cleaning and maintenance procedures, including lubrication.

Fig. 4 Equipment and Machinery Source: Hassan, 1999

Strategies for preventing fires due to equipment and machinery issues fall into three main categories:

***Awareness**:* You can’t prevent risks you don’t know exist. Neither can your employees. Provide safety awareness training.

Cleaning and housekeeping**:** Keep your equipment and machinery and the area surrounding it clean. Equipment, especially electrical equipment that is covered with dirt or grease constitutes a huge risk

Maintenance**:** Follow the manufacturer’s recommended maintenance procedures for all of the equipment and machinery. This will keep equipment working in tip-top shape.

Electrical Fire Hazards: Electrical fires are one of the top five causes of fires in manufacturing plants. Here a non-exhaustive list of specific electrical hazards: Wiring that is exposed or not up to code, Overloaded outlets, Extension cords**,** Overloaded circuits**,** Static discharge.

Any of the above hazards can cause a spark, which can serve as an ignition source for combustible dust, as well as flammable liquids and gasses.

Fig. 5 Electrical fire hazard. Source: Hassan, 1999

As with the previous risks, the key to preventing electrical fires is awareness and prevention. This involves training, maintenance, and following best practices. Here are a few to put into practice right now: Do not overload electrical equipment or circuits.

- Do not leave temporary equipment plugged in when it is not in use.
- Avoid using extension cords, and never consider them permanent solutions.
- Use antistatic equipment where required by NFPA or OSHA.
- Follow a regular housekeeping plan to remove combustible dust and other hazardous materials from areas that contain equipment and machinery.
- Implement a reporting system so that anyone who observes an electrical fire risk can report it without consequences.

History of Paint Manufacture

Paint factory is a place of paint production characterized by the use of machinery, the large-scale of machinery differentiates factory production from simple manufacture. In factory, standardized goods are produced and sometimes sold more cheaply by the factory system, and occasionally the goods are better than those made by Artisans. Paint is a thin protective or decorative coat or a subdivision of surface coating. Painting, the art of laying color on a surface, therefore necessitated the development of paint. Paint was first developed in the prehistoric times when the early men recorded most of their activities in colors on the walls of their caves (Darton, 2001). These crude paints consisted of colored earth or clays suspended in water. However, the use of paint dated as far back as 1500 B.C. when the earliest paint works discovered in caves of Lascaux, France, Attemira and Spain were believed to have been done (Darton, 2001).

It was reserved, however, for the masters of 17th century perfectly to realize this ideal art, and in their hands painting as an art of representation is widened out of its fullest possible limits and the whole of nature in all its aspects becomes for the first time the subject of the picture. The development of painting since the 17th century gave rise to the modern and more specialized method of paint production (Itten, 2000). The need for industrial architecture has been a matter for major concern to professionals and it has evolved through the periods, moving in phase with the march of civilization, occupation and the advancement in technology.

Paints are classified into two principal types such as Resin based paints (Gloss finishes) and Latex based paints (Emulsion paints). The major difference between the two is only in the types of vehicle used and cost.

Measures to Ensure Fire Safety in Paint Industries

Fire precautions in buildings are required to prevent premature structural failure and to limit fire spread (Herbert, 1998). He also asserts that for these purposes, the following provisions are necessary:

- Sub-division of the building into a number of fire compartments;
- Elements of structure to be provided with appropriate fire resistance;
- Compartmentalization of places of special fire risk;
- Restrictions to linings of walls and ceilings so as to limit their contribution to the development of fire and to have adequate resistance to the spread of fire along their surfaces;
- The provision of fire doors to limit the spread of fire and smoke; and
- Limitation of fire spread at junctions between building components, service penetrations and in cavities.
- Structural fire precautions are also necessary to protect the means of escape.

Method

This study adopted both descriptive and case study survey research design. The adoption of the design is due to the nature of the research. It describes the extent of prevention and control of fire through effective planning and design. As regards case study, the concept of quantitative approach was adopted in this research for effective data collection, literature review, and interview strategy. The population of the study consisted of all experts in architecture, civil engineering, structural engineering, electrical engineering, mechanical engineering and other sections of environmental science. Also included are workers of paint manufacturing industries in Akwa Ibom State. The sample size consisted of 150 respondents obtained from 30 architects, 30 civil engineers, 15 structural engineers, 30 electrical engineers, 15 mechanical engineers and 30 workers in local paint manufacturing companies. They were selected using stratified random sampling technique. The principal source of data to be used was from both the primary and secondary sources. A structured questionnaire was used in collecting primary data. Secondary data was obtained from Textbooks, journals, magazines, unpublished articles, research and project reports in a related field, manuals containing policy statements on housing. The data were analyzed using such statistical techniques as regression analysis found to be appropriate for the study. The statistical techniques helped in testing the hypothesis at 0.05 alpha level.

Results and Discussions

Table 1. Distribution of the respondents by Gender

Gender	Freq	%
Male	103	68.67%
Female	47	31.33%
Total	**150**	**100**

From the above result it was observed that the highest percentage of the respondents (68.67%) were male, while the least (31.33%) were female.

Table 2. Distribution of the respondent by Age

Age	Freq	%
LESS THAN 30YRS	4	2.67%
31-40	34	22.67%
41-50	92	61.33%
51 & ABOVE	20	13.33%
Total	**150**	**100**

From the above result it was observed that the highest percentage of the respondent (61.33%) were of the age range of 41-50, seconded by 34(22.67%) of the respondent with the age range of 31-40. This was followed by (13.33%) of the respondent who were 51 and above years, while the least respondent (2.67%) were less than 30years.

Table 3. Distribution of the respondent by professions

Professions	Freq	%
Architects	30	20%
Civil engineers	30	20%
Structural engineers	15	10%
Electrical engineers,	30	20%
Mechanical engineers	15	10%
Workers in locally paint manufacturing companies	30	20%
Total	**150**	**100**

From the above result it was observed that the highest percentage of respondents (20%) were Architects, Civil engineers, Electrical engineers and workers in locally paint manufacturing companies while the least percentage of respondent (10%) were Structural engineers and Mechanical engineers.

Hypothesis Testing

Hypotheses One

There is no significant relationship between the major causes of fire incidents in a paint factory and the redemptive measure used. In order to test the hypothesis, two variables were identified as follows:

1. Major causes of fire incidents in a paint factory as the independent variable.
2. Redemptive measure used as dependent variable.

The two variables were subjected to regression analysis in order to generate the predicated (y) value of y (redemptive measure used) for x^1 as the value of x (major causes of fire incident in a paint factory); (See Table 4).

Table 4: Model summary of the relationship between the major causes of Fire incident in a paint factory and the redemptive measure used

Model	R	R-square	Adjusted R-Square	Std Error of the Estimate
1	0.98a	0.96	0.96	0.35

***Significant at 0.05 level; df= 148; N= 150; critical R-value = 0.197**

The above table 4 shows that the calculated R-value 0.98 was greater than the critical R-value of 0.197 at 0.05 alpha levels with 148 degree of freedom. The R-Square value of 0.98 predicts 98% of the relationship between the major causes of fire incidents in a paint factory and the redemptive measure used.

The rate of percentage is highly positive and therefore implies that there is significant relationship between the major causes of fire incidents in a paint factory and the redemptive measure used. It was pertinent to find out if there is significant relationship exerted by the independent variable (see Table 5).

Table 5: Analysis of variance of the difference in the relationship exerted by the independent variable

(a)

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	448.70	1	448.70	3778.45	.000b
Residual	17.58	148	0.12		
Total	466.27	149			

Predictors: (constant), major causes of fire incident in a paint factory.

(b) **Dependent variable**: redemptive measure used.

Table 5 shows the calculated F-values as significant (3778.45). As the computed critical value R-value (0.000^a) is below probability level of 0.05. The result therefore means that there is significant relationship exerted by the independent variable (major causes of fire incident in a paint factory) on the dependent variable which is redemptive measure used.

Hypotheses Two

There is no significant influence of fire safety measures on the level of prevention and control fire in a paint factory. In order to test the hypothesis, two variables were identified as follows:

1. Fire safety measures as the independent variable.
2. Level of prevention and control of fire in a paint factory as dependent variable.

The two variables were subjected to regression analysis in order to generate the predicated (y) value of y (level of prevention and control fire in a paint factory) for x^1 as the value of x (fire safety measures); (See Table 6).

Table 6: Model summary of the influence of fire safety measures on the level of prevention and control of fire in a paint factory

Model	R	R-square	Adjusted R-Square	Std Error of the Estimate
1	0.87a	0.75	0.75	0.86

***Significant at 0.05 level; df= 148; N= 150; critical R-value = 0.197**

The above table 6 shows that the calculated R-value 0.87 was greater than the critical R-value of 0.197 at 0.5 alpha levels with 148 degree of freedom. The R-Square value of 0.75 predicts 75% of the influence of fire safety measures on the level of prevention and control fire in a paint factory. The rate of percentage is highly positive and therefore implies that there is significant influence of fire safety measures on the level of prevention and control fire in a paint factory. It was pertinent to find out if there is significant difference in the influence exerted by the independent variable (see Table 7).

Table 7: Analysis of variance of the difference in the influence exerted by the independent variable.

(a)

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	335.67	1	335.67	452.03	0.000b
Residual	109.90	148	0.74		
Total	445.57	149			

Predictors: (constant), fire safety measures.

(b) **Dependent variable**: level of prevention and control fire in a paint factory.

Table 7 shows the calculated F-values as significant (452.03). As the computed critical value R-value (0.000^a) is below probability level of 0.05. The result therefore means that there is significant difference in the influence exerted by the independent variable (fire safety measures) on the dependent variable which is level of prevention and control fire in a paint factory.

Discussion of Findings

The results of the data analyses in tables 4 and 5 were significant due to the fact that the obtained calculated R-value 0.98 was greater than the critical R-value of 0.197 at 0.05 level with 147 degree of freedom. This result implies that there is significant relationship between the major causes of fire incidents in a paint factory and the redemptive measure used. The result is in agreement with the research findings of Herbert (1998), who stated that fire prevention measures are key elements in the fire safety management of industrial buildings. This involves the identification and elimination of potential fire hazards both inside and outside the building, the establishment of good house-keeping practices, periodic inspections and the diligent application of safety rules. The result of the analysis caused the null hypotheses to be rejected while the alternative one was retained.

The results of the data analyses in tables 6 and 7 were significant due to the fact that the obtained calculated R-value 0.87 was greater than the critical R-value of 0.197 at 0.05 level with 147 degree of freedom. This result implies that there is significant influence of fire safety measures on the level of prevention and control of fire in a paint factory. The result is in agreement with the research findings of experts and other researchers in the field. The result of the analysis caused the null hypotheses to be rejected while the alternative one was retained.

Conclusion

The study revealed that the major causes of industrial fires are: combustible dust, hot work, flammable liquids, faulty equipment and electrical faults. It also revealed that in some of the factories visited, there were complete absence or insufficient fire prevention facilities. On ways of preventing industrial fires, the study identified regular maintenance of equipment, proper storage of hazardous materials and periodic training and education of those at risk as the most feasible and effective measures that can prevent and control fire in industrial building. Besides the above, based on the findings of the research work, the following conclusions are deemed necessary: There is significant relationship between the major causes of fire incidents in a paint factory and the redemptive measure used. Also, fire safety measures significantly influence the level of prevention and control of fire in paint factory.

Recommendations

Based on the analysis of results and findings, the following recommendations are hereby made:

1. Building owners and property developers should ensure that their buildings are well equipped with active and passive firefighting equipment.

2. The installation and maintenance of special equipment and sensors to ensure their functionality in the industrial buildings can help to hinder the occurrence of fire or possibly reduce its effect where its control becomes inevitable.

3. Government should revisit the fire code and resuscitate its administration and implementation, compliance with fire code regulation should be made compulsory for building owner, users and occupiers of public building.

REFERENCES

Balcomb, J. D., and Curtner, A. (2000), *Multi-criteria decision-making process for buildings*. In Energy Conversion Engineering Conference and Exhibit, 2000. (IECEC) 35th Intersociety (Vol. 1, pp. 528-535). IEEE

Darton, M. (2001), *Illustrated Books of Architects and Architecture*, Tiger Books International, London

Fessler, H and Daniel M. T. (2006) A Burning Desire: Steps toward an Evolutionary Psychology of Fire Learning. Emmitsburg, MD: [National Emergency Training Center],

Hassan, H. (1999). Fire and Safety Management in Buildings. *The Professional Builders Journal.* June/July. 32-35

Herbert, G. (1999), *Fire safety in hostels.* London: McGraw-Hill, Inc. pp 771

Itten, J; (2000). *The Elements of Color*. F. Birren (Ed.). New York: Van Nostrand Reinhold. J J. Canes 2003 – Cognitive flexible & adaptability to environment.

Langenbach, R. (2013) *Better than Steel*? (Part 2). Structures and Architecture New Concepts, Applications and Challenges, 122-39.

Megri, A. (2009), *Teaching the integration of safety and fire protection elements into the building design process*, American Society for Engineering Education 2009, American Society for Engineering Education.

Moe, Kiel (2010) *Thermally Active Surfaces in Architecture*. New York: Princeton Ar- chitectural Press.

National Institute of Building Sciences (2015), *Fire Protection* - by the WBDG Secure/Safe Committee [Online] accessed on 12/02/16 from https://www.wbdg.org/design/fire_protection.php

Park, H. (2014), *Development of a holistic approach to integrate fire safety performance with building design*, PhD Dissertation, Worcester Polytechnic Institute.

Rasbash, D., Ramachandran, G., Kandola, B., Watts, J., and Law, M. (2004), *Evaluation of Fire Safety*. John Wiley and Sons.