Enhancing Effective Fire Safety in Buildings Using Design

*Hannatu A. Idris 1, Binta F. Yahaya2, and Umar F. Muhammad3

1Department of Architecture, Baze University Abuja, Nigeria
2Department of Architecture, Kano University of Science and Technology, Wudil, Nigeria
3Department of Architectural Technology, Isa Mustapha Agwai I Polytechnic, Lafia, Nasarawa State, Nigeria.

* hannatu.idris@bazeuniversity.edu.ng bintayahaya4@gmail.com ufmnoble1433@gmail.com

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Abstract

Achieving optimum design solutions, with regards to fire and fire safety conditions, is an uncompromisable endeavour. As such, considering the destruction that has been occurring if treated lightly, every architectural design must consciously and constantly bear in mind, the goal of avoiding such disaster. Resting on this premise, this paper aimed at identifying major design approaches that need to be adopted to achieve optimum fire safety in buildings, right from the design stage. The paper adopted a narrative literature review approach to identify grounded design considerations related to fire and fire safety. One of the findings was that a design must be carried out with the conscious intention to provide a high level of safety affordances to occupants of buildings and their properties in case of fire outbreaks. Much of the affordances should be related to smoke, which tends to be more dangerous than the fire itself. The paper is highly significant for any architectural design since it sees to avoid the likely destruction of everything and everyone that a person has possessed or has ever loved.

Keywords: safety affordance; fire safety; architectural design;

1. Introduction

One of the ways to achieve good fire safety conditions and records is to be able to realize optimum design solutions as regards fire, in terms of functionality and cost-effectiveness of the whole system. Due to the difficult predictability of fire outbreaks in the built environment, it is equally difficult to achieve absolute protection for life and property from the devastation which may ensure, in case it happens. However, that does not mean extensive and intensive efforts should not be spent in ensuring protection right from the design phase, through the life cycle of buildings.

Furthermore, even though attaining fire safety may be seen as expensive, it must be acknowledged that too little expenditure on the aspect could result in expensive levels of life [1] and property losses to both individuals and communities. Based on the consequences of fire outbreaks in buildings, laws, and regulations are produced to govern and control the design, as well as the use of buildings. The laws and regulations may usually be influenced by communities since they happen to be the most critical stakeholders in their buildings.
These laws and regulations are basically, both prescriptive and restrictive in the way they are applied.

Researches have looked into techniques that focus on assessing risks to the life of buildings’ occupants, in terms of; interaction between fire growth and spread, human behavior and functionality for example,[2], [3] or performance of fire systems installed in the buildings. In other words, systematic methods have been developed, based on risk assessment and the costs involved, to rationally design fire safety and property protection systems in cost-effective buildings. Models have been developed for risk assessment [4], to use in estimating the risks to the safety of life, as well as the consequences of fire outbreaks in buildings.

Governments have been spending many grants in supporting the development of such risk assessment modeling since it has proved important for the identification of fire safety system designs that are cost-effective. For example, the Commonwealth Government grant allocations to the Victoria University of Technology and Australian Centre for Building Fire Safety and Risk Engineering, in 1991 [5].

With the recognition of the need for having reliability in managing effects of fire hazards in buildings, came the appreciation of the need to maintain an adequate level of hazard management, required at the levels of both authorities and community. Moreover, it is never wise to depend entirely on only one component for managing fire hazards. A fire safety system should be seen as constituting subsystems such as passive and active [6]. As such, each subsystem needs to be given utmost considerations in the course of design. This is so much so since there is hardly a fire safety system that can work 100% perfectly without the slightest chance of failure arising from one subsystem or another, especially when subjected to fire situations. It has been noted that changes in the spatial arrangement of Housing is vastly influenced by region, design trends, society, and related culture [7].

It is therefore very important to have in place, a rational framework or model within which to analyze of quantifying the performance of the different subsystems within the overall system. Notwithstanding, it must be appreciated that quantifying exact levels of protection affordances for both occupants and property against the effects of fire is a difficult task. The difficulty comes about due to the complex interaction between the factors; fire growth and spread [8], fire detection and warning fire suppression and protection strategies, and human behaviour [9]. These interactions have been organized into a risk assessment model (RAM) to make a meaningful reference (Figure 1).

![Figure 1. Risk assessment model (Beck, 1991).](image-url)
In the design of a fire safety system, consideration must be given to the level of safety affordances to occupants of buildings and their properties, and also to the costs associated with providing such safety. In adopting such an approach, designers will be able to evaluate and select the most appropriate solutions which are equally cost-effective. Ideally, maintenance would ensure that the roads always function as efficiently as when they were newly constructed, and so in planning maintenance, due regards must be paid to limitations or resources such as funds, manpower and machineries [10]. This paper presents the major design approaches that should be adopted in the course of ensuring optimum fire safety in buildings, at the design stage.

2. Requirements on Fire Safety on Buildings

Buildings must be designed and also built such that, in the case of fire, some major requirements are fulfilled. Since the primary focus of fire safety is the saving of life, most of the requirements are given, targeting the saving of lives.

Firstly, in case of fire, the building must be designed such that, its load-bearing capacity [11] will certainly be maintained for a specific and extensive period (Figure 2), within which occupants can escape or be rescued. Detailed calculations and verifications of load-bearing capacities of each specified component and element need to be carried out for different materials that are designed to be used for the building. The more detailed the considerations are given in this regard, the more optimized the design of fire safety and protection for a building. Additionally, the level of non-combustibility of materials and products is an important criterion to be included in the design process.

Figure 2. The load-bearing capacity of building components (Beck, 1991).

Please Secondly, the design must ensure that the generation and spread of any eventual fire and smoke will be limited. Moreover, since fire tends to spread, the design must ensure utmost and optimal limits to the spread of fire, not only within a building but also to neighbouring structures. This is where the issue of smoke and fire curtains and insulation comes in (Figure 3). Smoke has been shown to tend to be more dangerous than the fire itself [12], in several cases, as a result of its oxygen depletion and invasiveness in the process of inhalation, which can prevent trapped building occupants from escaping to safety.
The smoke and fire curtains are specified to be made from a heat-resistant fabric [13], used in the case of industrial or commercial buildings mostly. In the case of smaller buildings like residential ones, however, fire doors [14] are used. These elements work in retarding the flow of smoke, either by preventing it from reaching various areas of a building or direct it through a purposefully provided route. They can be installed as either fixed or automatic, depending on the architect’s specifications, building purpose, as well as the added design value intended. When such a system is considered overall, they keep parts of the building accessible, at the same time, protecting vital escape routes, thereby allowing more time for evacuation.

3. Fire Safety Design Considerations

Design considerations may be viewed from two major perspectives; the first one is from the perspective of the spatial organization of the building spaces or functions, while the second is from the perspective of building components, elements, and materials [15]. Notwithstanding the perspective from which a designer approaches the issue, for any fire safety design to be functional and robust, prior detailed knowledge of certain critical factors must be acquired. These include; firstly, the design team, to include fire safety engineering (FSE) personnel [16]. Such personnel would consequently include a fire protection engineer possessing adequate experience and knowledge in fire protection and life safety design. Moreover, the engineer needs to be involved in all phases of the design.

Secondly, knowledge of design standards and criteria must be put into use [15] by the design team. Examples of these are, statutory requirements, voluntary requirements addressing owner's performance needs, and insurance company requirements. Closely related to this factor is the building construction requirement with its elements such as; type of construction, allowable heights, and areas. Others are; requirements for exposures and separation, type of occupancy, and exit enclosure. Further considerations under this are the requirements for fire detection and notification or alarm system, including the survivability of the system in case of fire [17]. Criticality of mass notification of those inside, and even those in the vicinity, outside the building, of fire events, cannot be over-emphasized, due to general personnel safety and health.

In addition to all those issues, the design must take into account, the behaviour of fire itself, referring to how it may, be ignited, develop and spread. Design should also look at the fire loads, acquired through fire load surveys, which have to do with the types, amounts, weights, and distribution of materials that are combustible in a building. Other aspects are basic scenarios of fire outbreaks, and the fire safety objectives.
3.1 Spatial organization and fire safety

Design, as the organization of space [18], should be the primary consideration to address the required fire safety for buildings. The importance of spatial organization in fire safety is not restricted to a building itself but extends to the external space around it. Design of a building for fire safety needs to begin with the site since, in events of fire most times, external firefighting assistance becomes necessary. Integrating performance associated with site access, suppression, and separation distances will ensure quality site design. Sites need to be designed with layouts as uncomplicated as possible, to afford easy and quick location and access to fire outbreaks.

Building compartmentation is the concept of separating different spaces within a building [19] by introducing fire-resistant barriers between them which will serve as retarding fire spread. These barriers may be fixed; for example. Building up of walls to separate spaces including ceiling space and roofing sheets. They can also be movable barriers such as fire doors and curtains.

3.2 Building components and fire safety

It cannot be overemphasized that, fire safety plays a crucial role in contributing to the feeling of safety, and as such, should always constitute an important design criterion for the choice of buildings materials. Looking at fire safety in terms of building components, elements, and materials, a design must take into cognizance, the classification systems adopted for aspects such as the reaction of products generally, but particularly building products to fire. Hence, the performance of products, concerning reaction-to-fire, must be extensively studied. Another aspect here is to deal with adequate and appropriate detailing in the building structure [20], with regards to, building element joints and services installations. This would constitute conditions like fire stops, to prevent the spread of fire among the elements and other parts of the building. Active fire protection systems are also critical under this grouping. These systems refer to technical subsystems like; fire detection and alarm systems, fire suppression, and smoke control systems. The construction of a high-quality road network directly increases a nation’s economic output by reducing journey times and costs, making a region more attractive economically [21].

Suppression here includes items like sprinkler installations, which provide special benefits especially for items and surfaces that are required to remain exposed or visible.

Furthermore, the quality of construction workmanship needs to be adequately specified to ensure that all the planned fire safety precautions are taken into consideration, and are eventually built-in. There is also the structural integrity and stability of building elements and components [22], which must be studied concerning their fire resistance; such elements include; columns, beams, frames, panels, and claddings. These can be summed up as structural fire performance or fire resistance of building elements. In essence, the elements must be able to withstand a fully developed fire and fulfill the performance requirement of load-bearing capacity (earlier Figure 2). Furthermore, the external performance of roofs in the event of fire must be considered. Special consideration needs to be given to green or vegetative roofs in the case of access for firefighting; the design of adequate roof hatches is very critical. Electrical safety constitutes another part of the design carried out bearing in mind the effect of fire outbreaks. Emergency power for elements such as lighting, and exit signages need to be addressed. The design should be such that, power compartments or rooms are fire screened adequately, since even electrical circuits may be the cause of fire
outbreak or its spread. The lack of data on the outlined characteristics of potential feedstock biomass could severely hamper the design, development, and scale-up of future bioenergy and biofuel conversion systems [23].

In the aspect of fire suppression, carefully conceived design of suppressants supply has to be taken care of [24]. Ample knowledge of both water-based and non-water-based suppression systems must be brought to bear on the design. That should be accompanied by an appropriate design of standpipes and hose outlets, which must, themselves, be protected against fire.

4. Conclusion

While this paper does not offer an argument for rising incidences of fire outbreaks, it nevertheless, set out to tackle the problem of fire outbreaks and fire safety, from the perspective of design. The paper rested on the premise that, even if fire outbreaks are declining, there is always the need to continue refreshing the solutions that are scattered within literature and institutional regulations. This paper is most significant to design/building regulators, architects/building-related designers, and also building owners. It has re-echoed the fact that building design requires more than the architect or any group alone, but rather, a compulsory collaborative endeavour, especially regarding fires.

References


