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A Study of Operational Readiness of Egress System in Students` Halls of Residence: The Case of Obafemi Awolowo University, Ile-Ife

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Abstract
Fire poses a serious threat to lives and properties when uncontrolled. In the event of fire emergencies, egress system is an important component required for occupant safety. Thus, the operational readiness of all the elements within the egress system is paramount to safe and orderly evacuation of building occupants. This paper presented the results of an investigation conducted on the operational readiness of egress system in students` halls of residence within Obafemi Awolowo University, Ile-Ife. The study employed quantitative and case study approaches to examine their fire safety preparedness. Field measurements were undertaken to document the dimensions of egress system components: width of stair, travel distance, space between balusters, height of handrails, headroom and riser height, tread length and pitch of stair. To assess whether the existing stair qualities are appropriate for the current population, past and current students' population were collected from which occupancy growth rate was determined. The measured data were compared with the provisions of National Building Code of Nigeria [2006], British Standard Institution Group [2008] and Stairway Manufacturers Association of Virginia [2009]. The result showed an average of 300% increase in population of the occupants without increasing the capacity of the egress system. The results of comparative analysis of egress system components revealed narrow width, unequal treads and non-uniform risers of steps and other inaccuracies of stair components. The study concluded that in the event of fire outbreak occupants' lives could be threatened, bottlenecks and confusion may be created when occupants are trying to escape.
Keywords: Fire Safety, Egress system, Student housing, Operational readiness, occupancy growth.

1. Introduction

Fire is crucial for the development of human society Xin and Huang 2013], and it has been of much use to us since man learned of its potentials and usage [Mydin, 2014]. However, among different types of disasters, fire poses a serious threat to lives, properties and environment when uncontrolled [Adetunji, 2012; Rubaratuka, 2013; Nadzim and Taib, 2014].Fires can lead to injuries and death to occupants of a given premise [DiGuiseppi, Roberts, Wade, Sculpher, Edwards, Godward, Pan and Slater, 2012]. Thus, beyond shelter [Botchway and Boatemaa-Oti, 2012] infrastructures along with people's lives need protection against fire outbreaks [Kachenje, Kahila and Nguluma, 2010].

In real life situations, it is practically impossible to eliminate completely occurrence of fire in buildings. However, in the event of fire emergencies, means of egress are important systems required for occupant safety [Amoako, 2014]. They provide alternative route out of a building and incorporated to ensure that any person confronted with fire anywhere within a building is able to find their way out as fast as possible to a place considered safe [Adetunji, 2012]. They are to facilitate and ensure that buildings occupants can exit from the building and travel to a place of ultimate safety outside the building [British Standards Institution Group, 2008]. In general, means of egress are provided so that occupants can immediately, or within a short distance of travel, turn their back on any fire and move away from it to a final exit along smoke-free escape routes [Amoako, 2014]. The absence of these measures in buildings or otherwise leaves occupants at greater risk.

However, a series of studies conducted on the causes of injuries and loss of life incidents during fire emergencies have stressed the importance of operational readiness of egress system. Gairson [2013] pointed out that the operational readiness of egress system is vital to their effective and efficient incident mitigation in the event of fire outbreaks. Frachiah [2016] observed that in the event of fire the best defence against injury and possible loss of life from fire has always depended on strong means of egress; for this reason they must remain usable at all times, Xin and Huang [2013] and Mydin [2014] noted that beyond the provision, regular inspection, maintenance and ensuring that these construction elements remain intact after construction are the keys to good reliability and performance Otherwise, the installed systems may not work reliably as intended or as designed during fire emergencies. Again, Gairson [2013] further argued that in the event of fire outbreaks the primary method of protecting the occupants from the effects of fire is achieved through the proper design of egress systems. Thus, they must provide effective and efficient way of evacuating building occupants. On the other hand, Kachenje et al. [2010] observed that poorly maintained and obstruction of egress systems can contribute to rendering it ineffective and could make them inoperative during emergency and put occupants' lives in danger if a fire was to occur.

Besides, literature is littered with cases of injuries and loss of life incidents due to ill preparedness of egress system and violations related to securing emergency exit doors shut, often with chains and padlocks and blocking the escape routes [United States of America Fire Administration, 1991; Grosshandler, Bryner, Madrzykowski and Kuntz, 2005; Gairson, 2013; Amoako, 2014; Frachiah, 2016. Cases of injuries and deaths due to incorrect dimensions such as narrow width, unequal treads and risers of steps and other inaccuracies of stair components and overcrowding have been reported also in the literature [British Standard Institution, 2008; Botchway and Boatemaa-Oti, 2012; Rubaratuka, 2013;Gairson, 2013].

Thus, Amoako [2014] pointed out that ensuring the proper operation of all the elements within the egress system is paramount to safe and orderly evacuation of building occupants. In addition, the adherence to fundamental life safety provisions, despite greater cost or inconvenience, could save countless lives. According to Seattle Fire Department [2006] lives and property could be saved by being prepared before fire strikes. Proulx [2001] pointed out that adequate level of fire safety preparedness is essential to reduce the time delay to start evacuation.

In tertiary institutions, there are various students' hostels on campuses comprising different typologies and multiple occupations. However, in terms of the rate of actual fatalities due to fire, students housing structures have not been the nation's greatest killer. However, this study is necessary because fire can take place in buildings at any time and it might not warn before it strikes [Mydin, 2014]. The fact that fire can occur in a building at any time and from various sources means that it is essential to prepare for fire emergencies to be able to respond quickly, efficiently and effectively [Ayres, 2009]. On the other hand, as the life of any one human being is of infinite value, issues of fire safety measures in buildings and their operational readiness should not be ignored [Adetunji, 2012]. In addition, Botchway and Boatemaa-Oti [2012] pointed out that multiple occupation structures like these have the risk of fires breaking out because of overloaded electrical circuits which is a factor created by increasing student population, negligent, uncaring attitude and lack of maintenance [Renewals Team, 2007; Chalmers Insurance Group, 2010).; Nadzim and Taib, 2014]. Moreover, involvement in a fire can be a devastating experience and the consequences can be distressing and fatal [Australian Bureau of Statistics, 2013]. That's why wherever one live and work, it's important to practice fire safety to prevent fire accidents [Gairson, 2013; Nadzim and Taib, 2014; Amoako, 2014]. The ways of protecting occupants from these dangers also merit serious attention [World Fire Statistics Bulletin, 2012]. Above all, the many unexpected fires in student housing which gutted completely some rooms in 2012 and 2013have made this study necessary.

The study assessed the level of fire safety preparedness of egress system in student housing blocks at Obafemi Awolowo University campus, Ile-Ife. The specific objectives of the study are to (i) investigate how changes in population over time have affected the ability of the egress system to cope with current population in emergency situation (ii) determine the compliance level with the provisions of NBC [2006].

2. Fire safety code requirements for means of egress

Section 2.76 of NBC [2006] defined means of egress as a continuous and unobstructed path of travel from any point in a building or structure to a public way considered "safe" and consists of three separate and distinct parts: exit access (portion within the building leading to the exit such as corridors, hallways and passageways), exit (door and associated hardware including latches and release mechanisms that secure the building from the outside) and exit discharge (discernable path leading from the exit and extends to a public way considered "safe"). According to Fire Inspection and Code Enforcement [1998], a mean of egress can also be categorised into vertical and horizontal means of travel.

As pointed out in the previous section, in the event of a fire emergency, means of egress is one of the essential passive fire protection measures provided to facilitate evacuation of building occupants. However, according to Amoako [2014], there are critical minimum design criteria and management issues that means of egress components must fulfilin order to ensure orderly evacuation of building occupants. Thus, the National Building Code of Nigeria [NBC, 2006] prescribed the following basic considerations, criteria and guidelines as well as minimum dimensions for each component of means of egress intended to provide safe evacuation of building occupants.

2.1 Width of stairways and exit doors

Sections 7.17.2, 7.17.3 and 7.17.3.1 of the NBC [2006] specified that interior exit stairways shall be not less than 1118 mm in width and shall comply with section 10.17.3 through to 10.17.5. Or the width computed in accordance with Table 10.9 (labelled as Table 1 in this study) for the required capacity of the component (Section 7.9.2), but the width computed from this table shall not be less than the minimum width as prescribed by Sections 7.17.2, 7.17.3 and 7.17.3.1 of code for such component.

Section 7.17.15 of the code specified that the minimum width of every exit door to or from a stairway shall not be less than 813 mm and shall comply with sections 7.17.14, 10.17.15 through to section 10.17.17.

Table 1. Egress Width per Occupant

Without Fire Suppression System (Millimetre per Person)			With Fire Suppression System (Millimetre per Person)	
Use Group	**Stairways**	**Doors, Ramps and Corridors**	**Stairways**	**Doors, Ramps and Corridors**
A B C D	-	-	-	-
G H I	7.62	5.08	5.08	3.31
E			7.62	5.08
F1	10.16	5.08	5.08	5.08
F2	25.40	17.78	15.24	12.70
F3	7.62	5.08	7.62	5.08

Note: A = Assembly, B = Business and professional, C = Education, D = Faculty and industries, E = High hazard, F = Institutional, G = Merchantile, H = Residential, I = Storage.

2.2 Width of treads, risers, platform and landing

Section 7.17.10 of the Code specified that maximum riser height shall be 180 mm and minimum riser height shall be 100 mm; minimum tread depth shall be 280 mm, measured horizontally between the vertical planes of the foremost projection of adjacent treads and at a right angle to the tread's leading edge and treads and risers of interior exit stairways shall comply with section 10.17.10 through to section 7.17.12. The minimum treads depth shall not be less than 152 mm. Section 7.17.11 stipulates that there shall not be variation exceeding 5 mm in the depth of adjacent treads or in the height of adjacent risers and the tolerance between the largest and smallest riser or between the largest and smallest tread shall not exceed 10 mm in any flight of stairs.

While Section 7.17.7 of the Code specified that the least dimensions of landings and platforms shall be not less than the required width of stairways and shall comply with sections 7.17.6, 10.17.7 and 10.17.8.

2.3 Stairway guard and handrails

Section 7.17.13 of the Code prescribed that stairways shall have continuous guards and handrails on both sides, and in addition thereto, stairways more than 2235 mm in required width shall have intermediate handrails dividing the stairways having a width of less than 1118mm. Guards and handrail shall be constructed in accordance with section 10.28 and Section 10.29 respectively..

2.4 Vertical rise and stairways headroom

Section 7.17.4 of the Code prescribed that the minimum headroom in all parts of the stair enclosure shall be not less than 2100 mm measured vertically from the tread nosing or from the floor surface of the landing or platform and the stairway shall not have a height of vertical rise of more than 3000 mm between landings and intermediate platforms (section 7.17.8). According to Section 7.17.5, stairways shall not reduce in width in the direction of exit travel. Projections into a stairway width are prohibited, except for handrails as indicated in section 10.29.3, stairway stringers which shall project not more than 38 mm at each side.

2.5 Capacity of egress components, number and distribution exits and final exits

Often too few and too narrow exit doors for the number of occupants served prevent or severely delay occupants' exit from the building during fire outbreak [Gairson, 2013]**.** Therefore, Sections 7.9.1 and7.17.1 prescribed that the capacity of egress for a floor, balcony, tier and other occupied space shall be sufficient for the occupant load thereof and the capacity of stairways and doors shall be computed in accordance with section 10.9 of the code. Even if all stair dimensions are met, Sections 7.7.4 and 7.7.5 noted that a stairway shall also satisfy the requirement of occupancy loads.

Section 7.10.2 of the Code prescribed that every floor area shall be provided with the minimum number of approved independent exits as required by Table 10.10.2 (labelled Table 2 in this study) based on the occupant load except as modified in section 10.9.3.

Table 2. Minimum number of exits for occupant load

Occupant Load	Minimum Number of Exits
500 or less	2
501 – 1000	3
Over 1000	4

Source: Adapted from National Building Code of Nigeria [2006]

2.6 Maximum distance occupants must travel to reach a place of relative or ultimate safety

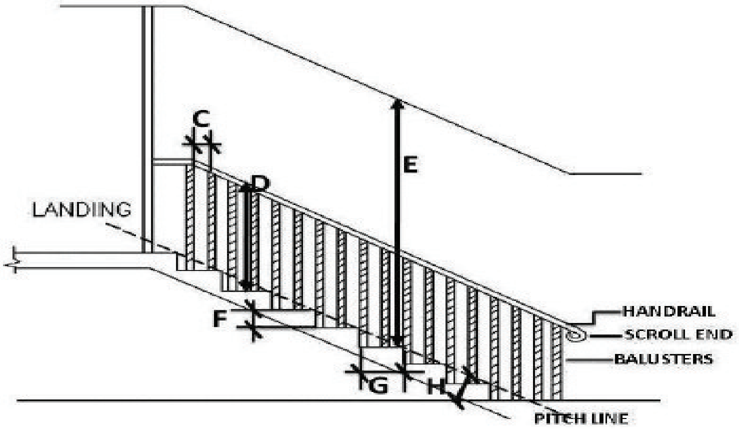
According to the code, except as modified by provision of section 10.10.3 for buildings with one exit, section 8.14 specified that all exits shall be so located that the maximum length of exit access travel, measured from the most remote point to an approved exit along the natural and unobstructed line of travel, shall not exceed the distances given in Table 10.8 (labelled Table 3 in this study). In single exit building covered by section 10.10.3 where the area is subdivided into rooms or compartments, the egress travel in the room or compartment shall not be greater than 15.22 m or 30.48 m in buildings equipped throughout with an approved automatic fire suppression system.

Table 3. Length of Exit Access Travel (m)

User Groups	Without Fire Suppression System	With Fire Suppression System
A B C D1	-	-
G H I-1	60	75
D-2 J2	90	120
E	-	22.5
F2 F3	45	60

Note: A = Assembly, B = Business and professional, C = Education, D = Faculty and industries, E = High hazard, F = Institutional, G = Merchantile, H = Residential, I = Storage
Source: Adopted from Nigeria National Building Code [2006]

On the other hand, The British Standard Institution Group [2000] stipulates some basic considerations for quality fire escape stair intended to provide safety for occupants from fire (Figure 1).



A = Clear width of stair (at least 1200mm)
B = Maximum travel distance from remote area (Maximum 14000mm)
C = Space between balusters/ rails (Maximum 200mm)
D = Height of handrail (1100mm)
E = Headroom (At least 2000mm)
F= Riser height (100 to 190 mm uniform risers)
G= Tread length (250 to 350 mm uniform treads)
H= Angle of stair (Pitch) in degrees (Maximum 38 degrees)

Fig. 1: Typical elevation showing components of stairs (Source: British Standard Institution Group, 2000)

2.7 Inspection and Maintenance

Apart from provisions, fire safety practice also identifies the need for inspection and maintenance. Section 7.6 of the NBC [2006] recommends that the building owners inspect and maintain the fire protection system in an operational state while also safeguarding entry from unauthorized persons. It shall be unlawful to obstruct or reduce in any manner, the clear width of any doorways, hallways, passageway or other means of egress required by the provisions of this code [section 7.6.1] and Section 7.6.2 of the code prescribes that all exterior stairways and fire escapes shall be kept free of slippery materials. Exterior stairways and fire escapes shall be painted in an approved manner before and after erection and shall be scraped and painted as often as necessary to maintain them in safe condition.

3. Methodology

This study aimed at examining the level of fire safety preparedness of means of egress provided in low rise students' halls of residence: within Obafemi Awolowo University campus, Ile-Ife. The study adopted case study approach and field measurement to assess their compliance with fire safety practice code.

3.1. Description of the selected halls and buildings

The study areas comprised the following students' halls of residence: block A-L (PG Hall), Block A-H (Moremi Hall), Block 1-5 (Fajuyi Hall), Block 1-8 (Awolowo Hall), Block 1-4 (Akintola Hall) and Block 1-2 (Alumni Hall). The selected buildings were further categorized into types 3 based on the number of stairs and configuration. On a typical floor of each block, there are ten (10) rooms, each with 3 to 6 occupants depending on whether it is postgraduate hall or undergraduate hall. The existing stair on each floor serves all the occupants on the floor and also doubles as an escape stair in times of fire. Table 4 shows the buildings and the types of stairways studied while Figures 2 to 7 the sections through the stairways.

Table 4. Student housing typologies on OAU campus based on stairways specification

Typology	Description
Type A	PG Hall (Block A – L), Awolowo Hall (Block 5 & 6), Moremi Hall (Block A – H) and Akintola Hall (1 – 4)
Type B	Awolowo Hall (Block 1 – 4; 7 & 8) and Fajuyi Hall (Block 1 – 5)
Type C	Alumni (1 – 2)

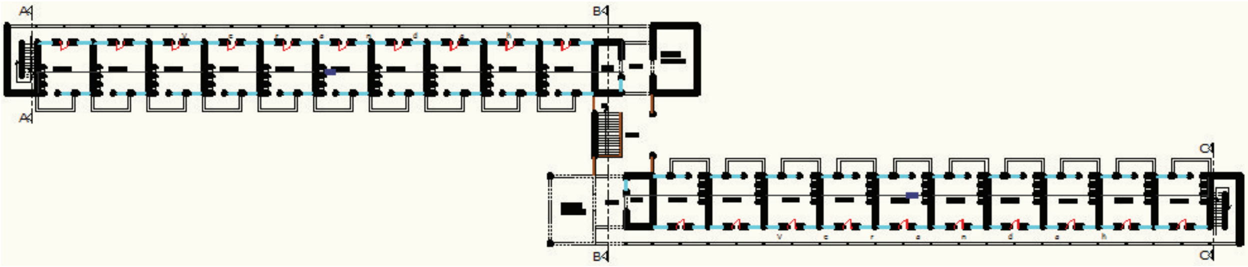
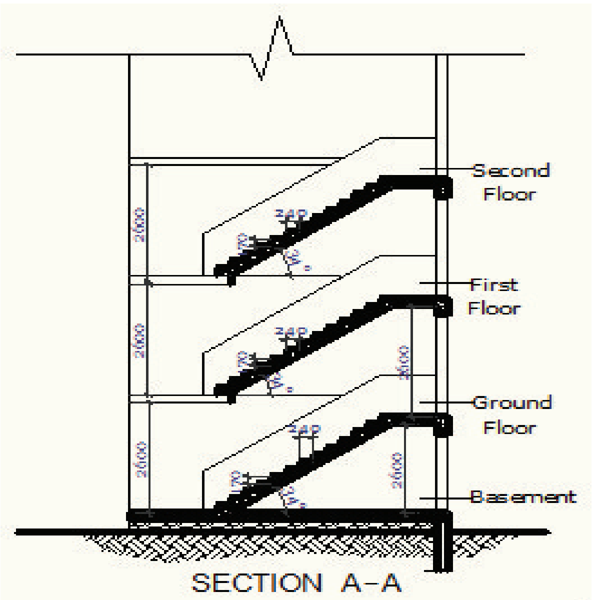
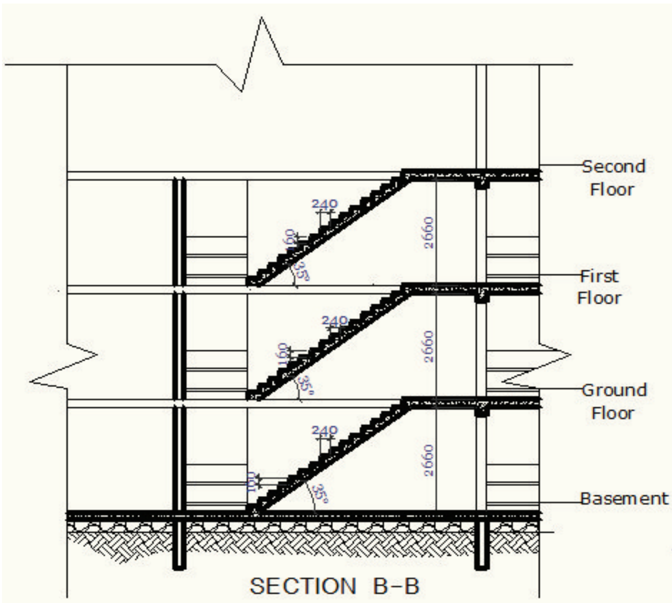


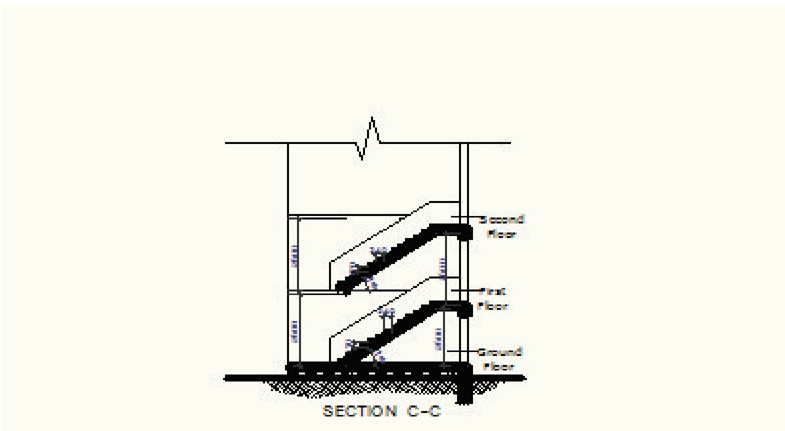
Fig. 2: Typical floor plan of type A stairway



(a) Escape route 1



(b) Escape route 2



(c) Escape route 3

Fig. 3: Typical section of type A stairway

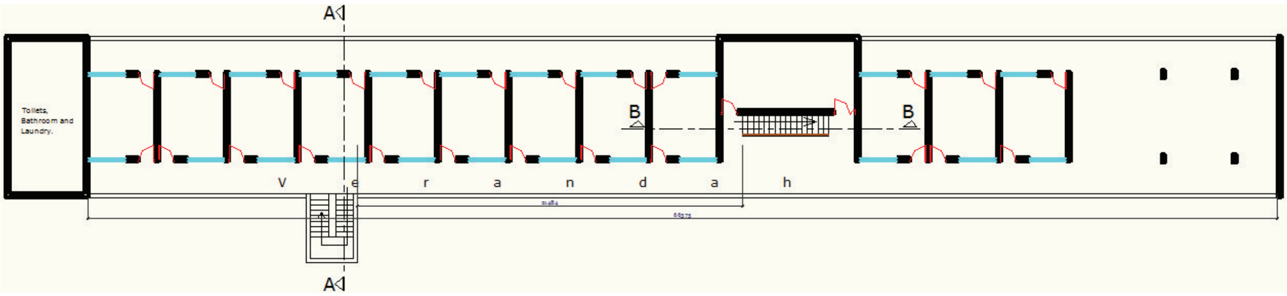


Fig. 4: Typical floor plan of type B stairway

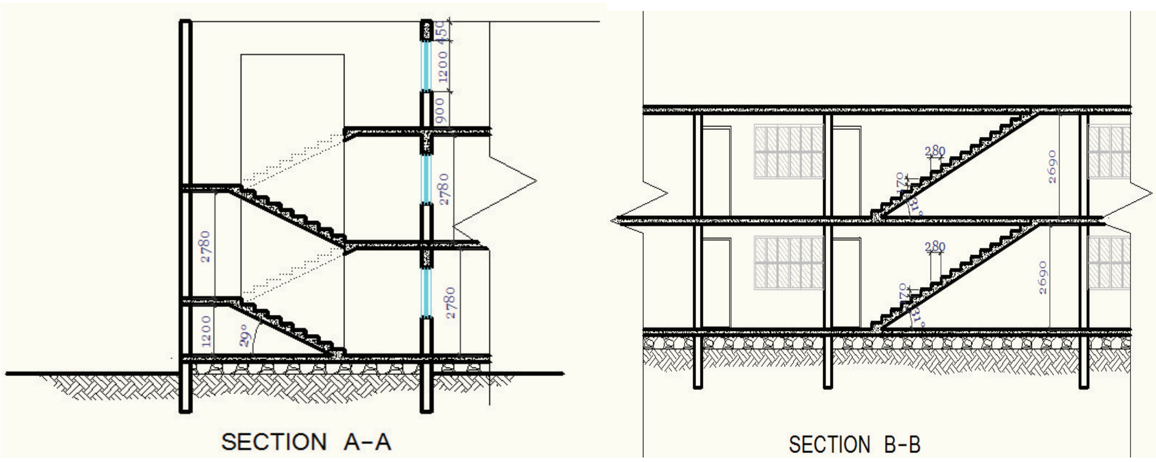


Fig. 5: Typical section of type B stairway

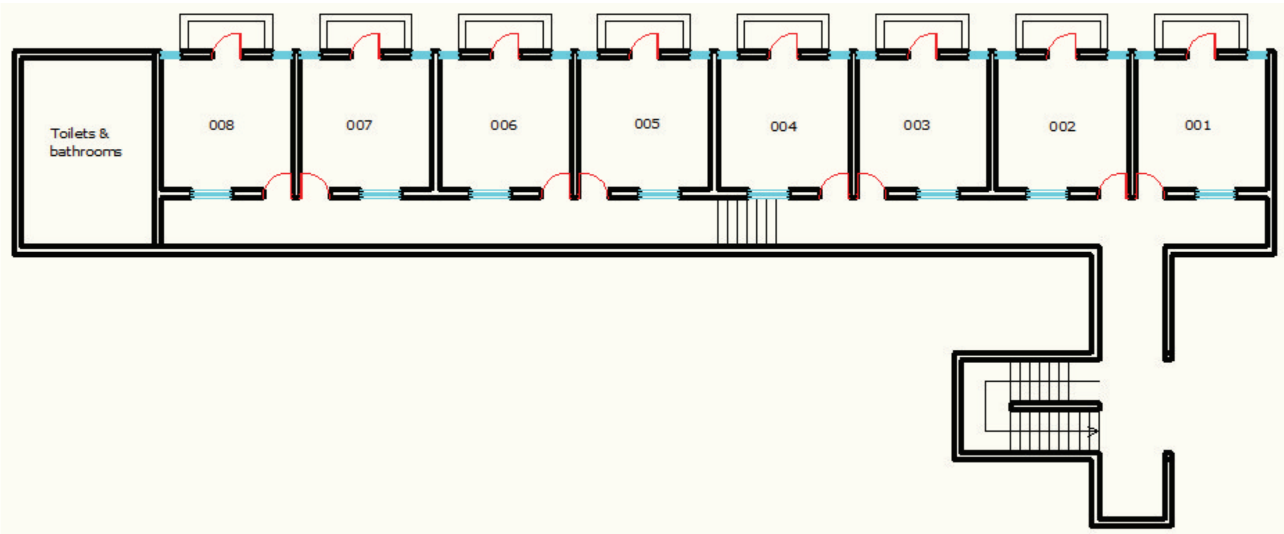


Fig. 6: Typical floor plan of type C stairway

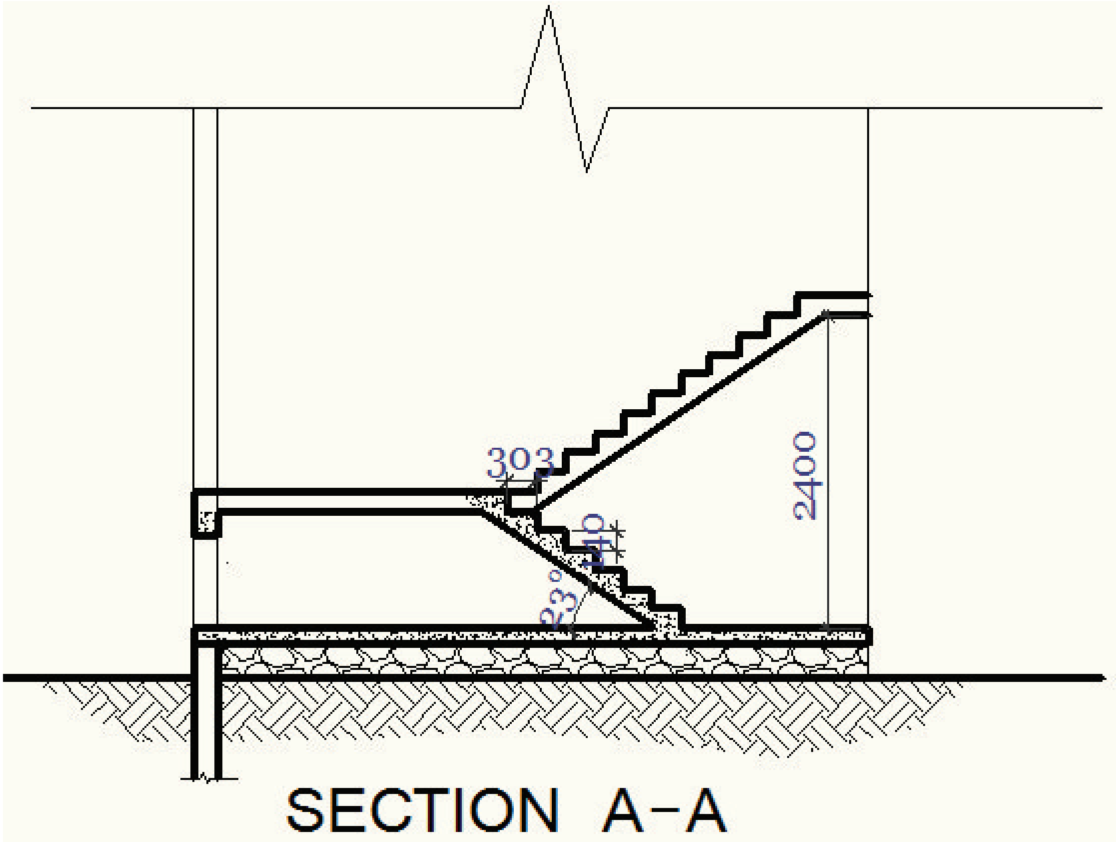


Fig. 7: Typical section of type C stairway

3.2 Data Required and Methods of Collection

Data required are the means of egress components' dimensions. The following components` dimensions were recorded: width of stair, maximum travel distance to stair, space between balusters, height of handrails, headroom, riser height, tread length and pitch of stair. Apart from these, past and current students' population in these halls of residence were collected to enable computation of occupancy growth rate. This was with a view to ascertaining the appropriateness of the existing to cope with current population in the event of fire.

3.3. Data analysis

Using a comparative analysis, each component of the means of egress system measured was compared with the standard value. For comparative analysis, the NBC [2006] shall be consulted. However, where this code does not specify or prescribe other relevant codes of fire safety practice such as Code of Practice for Fire Safety in Buildings of Hong Kong [2011], British Standard Institution Group (2008) and Stair Manufacturer Association [SMA, 2009] as well as others specified in the literature shall be our guide.

4. Results and Discussion

In this study unless otherwise stated any measured values not in consistent with the provisions prescribed in the above stated codes of fire safety practice was classified inadequate or unacceptable indicating that such particular component was not safe enough to guard occupants to safety. However, measured values that corresponded with or fall within the range of values specified by the codes were safe components for escape thus acceptable.

4.1 Occupancy growth and appropriateness of existing stair qualities

The overcrowding of a building due to occupancy growth places impractical demands on the qualities of means of egress. As reported by Philips [2013], the death toll in Cocoanut Grove Nightclub fire incidence in USA was compounded because the occupancy load was exceeded by twice the number of occupants allowed, thus preventing or severely delaying occupants exit from the building during fire outbreak**.** Patriarch [2016] pointed out that capacity of means of egress components should be adequate for the type of workplace and should be considered based on how many people will use the escape route. Otherwise, in the event of fire outbreaks and when building occupants are attempting to escape, it may lead to bottlenecks and constriction [Botchway and Boatemaa-Oti, 2012]. The occupancy growth of the selected buildings was computed using information from past and current population. The purpose was to determine whether the existing stair qualities are appropriate for the current population. Table 5shows the results of computed occupancy growth rate while Table 6 compares the occupancy growth and the qualities of existing stairs(in terms of number) based on the provisions of NBC [2006] (see Table 2).From Table 5, the number of rooms has not increased but there has been on average a 300% increase in mean occupancy growth. In terms of required number of stairs, results in Table 6 showed that stairs provided in all the blocks in students Halls of Residence are adequate except for Alumni Hall of Residence where only one staircase is provided. Based on the requirement of the code, this would put the circulation and egress system of this hall in a critical condition in case of fire emergencies.

Table 5. Occupancy growth of the selected hostel in the study area

Typology	Residential block	Number of room	Initial occupancy	Current occupancy (2014)	Average % increase over the year
Type (A)	Postgraduate Hall (Blocks A & B)	128	128	128	0
	Postgraduate Hall (Blocks C & D)	128	128	128	0
	Postgraduate Hall (Blocks E & F)	76	228	228	0
	Postgraduate Hall (Blocks G & H)	76	228	228	0
	Postgraduate Hall (Blocks I & J)	76	228	228	0
	Postgraduate Hall (Blocks K & L)	76	228	228	0
	Moremi Hall (Block A & B)	60	120	300	300
	Moremi Hall (Block C & D)	60	120	300	300
	Moremi Hall (Block E & F)	60	120	300	300
	Moremi Hall (Block G & H)	60	180	300	300
	Awolowo Hall (Block 5 & 6)	60	120	360	300
	Akintola (Blocks W_1& W_2)	64	192	320	166.67
	Akintola (Blocks M_1& M_2)	64	192	320	166.67
Type (B)	Awolowo Hall (Block 1)	30	60	180	300
	Awolowo Hall (Block 2)	30	60	180	300
	Awolowo Hall (Block 3)	30	60	180	300
	Awolowo Hall (Block 4)	30	60	180	300
	Awolowo Hall (Block 7)	47	94	202	214.89
	Awolowo Hall (Block 8)	47	94	202	214.89
	Fajuyi Hall (Block 1)	57	114	246	215.79
	Fajuyi Hall (Block 2)	57	114	246	215.79
	Fajuyi Hall (Block 3)	57	114	246	215.79
	Fajuyi Hall (Block 4)	36	72	216	300
	Fajuyi Hall (Block 5)	36	72	216	300
Type (C)	Alumni Hall (Block 1)	12	184	200	109
	Alumni Hall (Block 2)	12	184	200	109

Source: Obafemi Awolowo University, Ile-Ife Directorate of Students Affair Office

Table 6. Standard required for stairs for population between 200 and 400

Residential block	Current occupancy (2014)	Standard no of escape routes	Existing no of stairs	Comments
Postgraduate Hall (Blocks A & B)	128	2	3	Adequate
Postgraduate Hall (Blocks C & D)	128	2	3	Adequate
Postgraduate Hall (Blocks E & F)	114	2	3	Adequate
Postgraduate Hall (Blocks G & H)	114	2	3	Adequate
Postgraduate Hall (Blocks I & J)	114	2	3	Adequate
Postgraduate Hall (Blocks K & L)	114	2	3	Adequate
Moremi Hall (Block A & B)	300	2	3	Adequate
Moremi Hall (Block C & D)	300	2	3	Adequate
Moremi Hall (Block E & F)	300	2	3	Adequate
Moremi Hall (Block G & H)	300	2	3	Adequate
Awolowo Hall (Block 5 & 6)	360	2	3	Adequate
Akintola Hall (Blocks W_1& W_2)	320	2	3	Adequate
Akintola Hall (Blocks M_1& M_2)	320	2	3	Adequate
Awolowo Hall (Block 1)	180	2	2	Adequate
Awolowo Hall (Block 2)	180	2	2	Adequate
Awolowo Hall (Block 3)	180	2	2	Adequate
Awolowo Hall (Block 4)	180	2	2	Adequate
Awolowo Hall (Block 7)	202	2	2	Adequate
Awolowo Hall (Block 8)	202	2	2	Adequate
Fajuyi Hall (Block 1)	114	2	2	Adequate
Fajuyi Hall (Block 2)	114	2	2	Adequate
Fajuyi Ha ll(Block 3)	114	2	2	Adequate
Fajuyi Hall (Block 4)	72	2	2	Adequate
Fajuyi Hall (Block 5)	72	2	2	Adequate
Alumni Hall (Block 1)	200	2	1	Inadequate

Source: Obafemi Awolowo University Students Affair Office

4.2 Analysis of stair components

Botchway and Boatemaa-Oti [2012] stated that bottlenecks and constrictions will be created with narrow width, unequal treads and risers of steps and other inaccuracies of stair components when occupants are rushing out of the building in the of fire emergencies. British Standards Institution Group [2008] also acknowledged that as little as 5mm difference in riser heights can be disastrous. Thus, the dimensions of the existing means of egress components were measured and the results are presented in Tables 7 to 14.

4.2.1 Clear width of means of egress (stairways)

The results of field measurements of clear width of stairs are presented in Table 7. The results indicated that the clear width of some escape stair types, for examples, sections A-A & C-C of escape stair Types A and B, when compared with the provisions of Sections 7.17.2, 7.17.3, 10.17.3 through to 10.17.5) of NBC [2006] are inadequate and unacceptable due to narrow width. As shown in Table 7 and Fig. 8, this indicates that the escape stairs A-A & C-C in Postgraduate and Akintola Halls Residence; the escape stairs in Blocks 7 & 8 (Awolowo Hall of Residence) and Blocks 1-5 (Fajuyi Hall of Residence) could create bottleneck on each flight. The bottlenecks that will occur due to the narrow width of the stair will also extend to the landings and could finally cause obstruction. As can be seen in Fig. 8, obstructions would be complicated on the ground floor as people moving from the sub-basement will meet the cumulative total number of occupants descending the stairs. In addition, there will be a confluence of people at the threshold of the tunnel. Therefore, there is need for extension of the narrow width of existing stair. This extension as a solution to this challenge is indicated with dotted lines in Fig. 9. On the other hand, the existing escape stair Type C in Alumni Hall of Residence and stair section B-B are adequate indicating that these escape stairs would facilitate occupants' free movement in case of fire outbreak. However, escape stair Type C in Alumni Hall of Residence would be congested on the stairway as a result of high occupancy load being the only escape stair provided in this hall. This, in a way makes it unsafe for occupants' escape.

Table 7. Clear width of stair (mm)

Standard clear width (≥1118mm)					
Stair Type	**Hall**	**Existing width (Stair A-A & C-C) (mm)**	**Comment**	**Existing width (Stair B-B) (mm)**	**Comment**
Type A	Postgraduate Hall	1070	Inadequate	2050	Adequate
	Awolowo Hall (Block 5 & 6)	1150	Inadequate	1920	Adequate
	Moremi Hall	1140	Inadequate	1850	Adequate
	Akintola Hall	1070	Inadequate	2050	Adequate
Type B	Awolowo Hall (Block 1-4)	1150	Inadequate	1920	Adequate
	Awolowo Hall (block 7 & 8)	1020	Inadequate	1350	Adequate
	Fajuyi Hall (Blocks 1 – 5)	1020	Inadequate	1350	Adequate
Type C	Alumni Hall	1290	Adequate	-	-

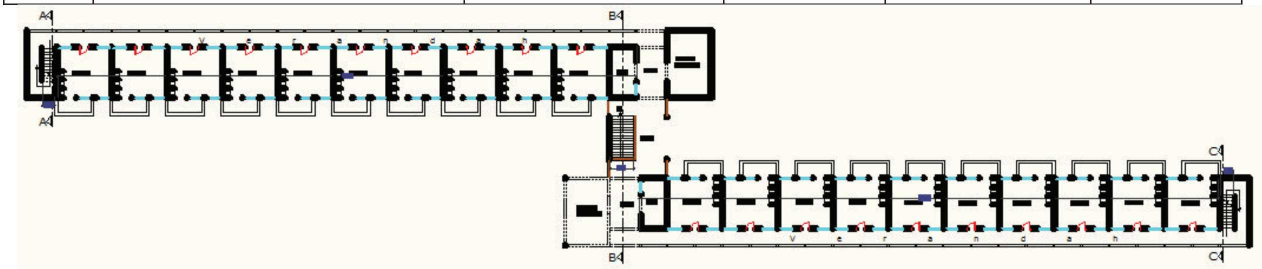


Fig. 8: Typical floor plan of type 3 blocks (PG and Moremi Halls) showing width of existing stair (mm)

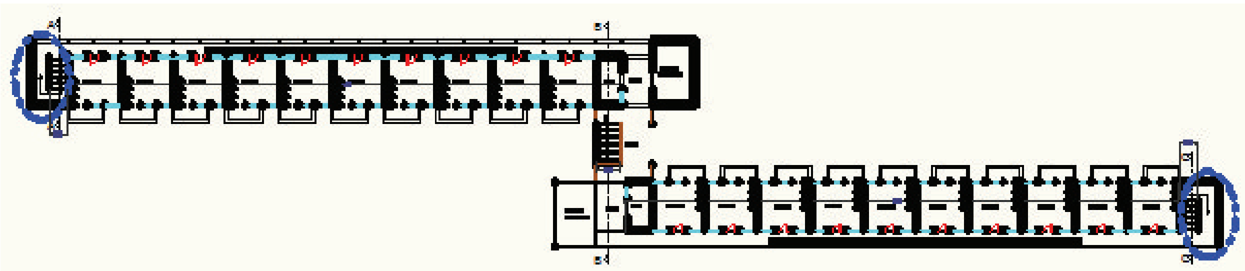


Fig. 9: Typical plan showing fire escape stair width extension recommended for existing blocks

4.2.2 Risers and treads

Botchway and Boatemaa-Oti [2012] indicated that uneven risers and treads are major causes of accidents on escape stairs. They also added that apart from risers and treads falling within the standard range, it is also important for their dimensions to be uniform throughout the flight. Comparing the results of field measurements of risers and treads dimensions presented in Tables 8 and 9 with the provisions of section 7.17.10 through to section 7.17.12 of NBC [2005], show that the heights of risers and the widths of treads of escape stairs in Postgraduate and Akintola Halls of Residence fall within the range specified in the code. However, the risers and treads are non-uniform, discrepancies more than 10 mm beyond the provisions specified in section 7.17.11 of the code was found. This could pose great danger to the occupants. Besides, escape stairs in Blocks 1-8 (Awolowo Hall of Residence), Blocks 1-8 (Moremi Hall of Residence), Blocks 1-5 (Fajuyi Hall of Residence) and Alumni Hall of Residence have some risers and treads exceeded the provisions of NBC [2006] as well as not uniform. This indicates that both risers and treads in these halls of residence are inadequate. This could have been as a result of construction inadequacies or errors but the danger to occupants is grave. Thus, the inconsistence of the treads and risers in the halls of residence makes them unacceptable.

Table 8: Existing riser height (mm)

Hall	Stair Type	Riser 1	Riser 2	Riser 3	Riser 4	Riser 5	Riser 6	Riser 7	Riser 8	Riser 9	Riser 10	Riser 11	Riser 12	Riser 13	Riser 14	Riser 15	Riser 16	Riser 17	Comments
Postgraduate Hall	A-A/C-C	165	177	172	173	175	173	171	169	170	177	168	170	169	169	165	171	N/A	Height is adequate but not uniform
	B-B	173	168	174	170	170	178	170	169	174	176	172	170	168	175	170	170	N/A	Height is adequate but not uniform
Awolowo Hall (Blocks 5 & 6)	A-A/C-C	155	175	180	179	183	177	185	183	181	185	172	180	N/A	N/A	N/A	N/A	N/A	Inadequate
	B-B	180	175	178	173	177	174	175	176	174	178	178	172	174	174	180	N/A	N/A	Height is adequate but not uniform
Moremi Hall	A-A/C-C	160	170	170	176	178	172	175	178	178	165	170	170	174	177	205	N/A	N/A	Inadequate
	B-B	165	174	180	175	173	179	178	175	174	175	175	175	175	180	210	N/A	N/A	Inadequate
Awolowo Hall (Blocks 1-4)	A-A/C-C	173	183	182	184	180	183	175	180	179	184	184	179	N/A	N/A	N/A	N/A	N/A	Inadequate
	B-B	185	173	175	179	179	180	176	173	180	175	175	170	175	175	177	N/A	N/A	Inadequate
Akintola Hall	A-A/C-C	165	177	172	173	175	173	171	169	170	177	168	170	169	169	165	171	N/A	Height is adequate but not uniform
	B-B	173	168	174	170	170	178	170	169	174	176	172	170	168	175	170	170	N/A	Height is adequate but not uniform
Awolowo Hall (Blocks 7 & 8)	A-A/C-C	153	164	165	164	162	162	162	163	165	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Height is adequate but not uniform
	B-B	170	170	170	170	170	170	170	170	175	170	170	175	175	175	175	175	175	Height is adequate but not uniform
Fajuyi Hall	A-A/C-C	153	164	165	164	162	162	162	163	165	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Height is adequate but not uniform
	B-B	170	170	170	170	170	170	170	170	175	170	170	175	175	175	175	175	175	Height is adequate but not uniform
Alumni Hall	A-A	140	140	146	150	140	140	160	163	128	145	150	150	145	153	146	130	160	Height is adequate but not uniform
	B-B	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A = Not Applicable

Table 9: Existing Treads Dimension (mm)

Hall	Stair Type	Tread 1	Tread 2	Tread 3	Tread 4	Tread 5	Tread 6	Tread 7	Tread 8	Tread 9	Tread 10	Tread 11	Tread 12	Tread 13	Tread 14	Tread 15	Tread 16	Comments
Postgraduate Hall	A-A/C-C	240	239	240	246	250	252	249	250	244	245	246	245	259	261	257	N/A	Depth adequate but not uniform
	B-B	246	241	242	239	239	240	246	248	243	244	244	253	242	245	248	N/A	Depth adequate but not uniform
Awolowo Hall	A-A/C-C	260	252	257	256	257	258	235	252	250	262	250	N/A	N/A	N/A	N/A	N/A	Depth adequate but not uniform
(Block 5&6)	B-B	290	286	283	286	285	268	280	275	276	285	280	278	282	285	N/A	N/A	Inadequate
Moremi Hall	A-A/C-C	250	248	250	250	258	255	260	260	253	256	250	259	254	250	N/A	N/A	Depth adequate but not uniform
	B-B	260	255	255	255	255	255	254	254	256	257	255	258	260	260	N/A	N/A	Depth adequate but not uniform
Akintola Hall	A-A/C-C	240	239	240	246	250	252	249	250	244	245	246	245	259	261	257	N/A	Depth adequate but not uniform
	B-B	246	241	242	239	239	240	246	248	243	244	244	253	242	245	248	N/A	Depth adequate but not uniform
Awolowo Hall	A-A/C-C	245	250	240	250	255	250	250	245	245	255	250	N/A	N/A	N/A	N/A	N/A	Depth adequate but not uniform
(Blocks 1-4)	B-B	285	287	285	285	277	284	285	286	285	286	284	271	275	280	N/A	N/A	Inadequate
Awolowo Hall	A-A/C-C	280	282	282	284	283	280	280	280	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Inadequate
(Block 7&8)	B-B	275	280	278	274	280	280	280	277	280	280	277	280	280	280	278	N/A	Depth adequate but not uniform
Fajuyi Hall	A-A/C-C	280	282	282	284	283	280	280	280	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Inadequate
	B-B	275	280	278	274	280	280	280	277	280	280	277	280	280	280	278	280	Depth adequate but not uniform
Alumni Hall	A-A/C-C	307	310	292	280	327	310	303	290	315	295	300	295	307	297	285	N/A	Inadequate
	B-B	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A = Not Applicable

4.2.3 Headroom

Table 10: presents the results of measured height of escape stairs` headroom in the selected blocks. From Table 10, it is observed that the least height of escape stair headroom is 2400mm.Section 7.17.4 of NBC [2006] specified that the headroom of an escape stair shall not be less than 2100mm. On the other hand, British Standard Institution Group [2008] prescribed that the minimum value of stair headroom shall not be less than 2000mm. Since the average measured values of headroom of existing escape stair in all the blocks studied are higher than the specified minimum values, this means that the headroom of all the existing escape stairs in the halls of

residence are adequate and safe for occupants.

Table 10. Headroom (mm)

Standard Headroom (≥ 2000mm and/or 2100mm)				
Stair Type	**Hall**	**Existing Headroom (Stair A-A & C-C) (mm)**	**Existing Headroom (Stair B-B) (mm)**	**Comment**
Type A	Postgraduate Hall	2600	2660	Acceptable
	Awolowo Hall (Block 5 & 6)	2450	2450	Acceptable
	Moremi Hall	2450	2420	Acceptable
	Akintola Hall	2600	2660	Acceptable
Type B	Awolowo Hall (Block 1-4)	2480	2470	Acceptable
	Awolowo Hall (block 7 & 8)	2780	2690	Acceptable
	Fajuyi Hall (1 – 5)	2780	2690	Acceptable
Type C	Alumni Hall	2400	-	Acceptable

4.2.4 Handrail height

The NBC [2006] only specified the positioning and construction of handrail but did not prescribe the height of handrail. However, British Standard Institution Group [2008] specified the minimum height of handrail of 1100mm. Table 11 displays the results of measured height of escape stair handrails. From this table it was observed that the handrail heights of all the existing escape stairs of the blocks under consideration are lower than the provisions of the British Standard Institution Group [2008] except for the handrails height of escape stair B-B in Blocks 1-4 (Awolowo Hall of Residence). This indicated that the handrail heights of many of the escape stair are inadequate to aid occupants during evacuation. The authors advised that, the existing escape stairs handrails' heights should be increased at least to the minimum height specified by British Standard Institution Group [2008] in order to provide total support for occupants in the event of fire outbreaks.

Table 11. Height of handrail (mm)

Standard height of handrail (>1100mm)					
Stair Type	**Hall**	**Existing handrail height (mm) Stair A-A**	**Comment**	**Existing handrail height (mm) Stair B-B**	**Comment**
Type A	Postgraduate Hall	1000	Inadequate	1000	Inadequate
	Awolowo Hall (Block 5 & 6)	1080	Inadequate	1000	Inadequate
	Moremi Hall	950	Inadequate	990	Inadequate
	Akintola Hall	1000	Inadequate	1000	Inadequate
Type B	Awolowo Hall (Block 1-4)	1000	Inadequate	1100	Adequate
	Awolowo Hall (block 7 & 8)	1000	Inadequate	1000	Inadequate
	Fajuyi Hall	1000	Inadequate	900	Inadequate
Type C	Alumni Hall	990	Inadequate	-	-

4.2.5 Space between rails

Handrails and guards are very important in egress as they provide support and guide for users of the escape stair. Circular handrails with a diameter between 32 and 50mm are most comfortable to grasp [British Standard Institution Group, 2008]. The results of space between rails obtained from field measurement are presented in Table 12. The results indicate that the existing rail spacing are greater than the value recommended by British Standard Institution Group [2008], Stairway Manufacturers Association of Virginia [2009] and Code of Practice for Fire Safety in Buildings of Hong Kong [2011] that is200mm.Thus,unacceptable and make them unsafe to aid occupants to safety. Therefore, the authors advocated for the introduction of new guardrail spaced according to the provisions of the code to reduce the wide gap between the rails to prevent casualties.

Table 12. Space between rails (mm)

Standard space between rails (< 200mm)				
Stair Type	**Hall**	**Existing space between rail (Stair A-A & C-C) (mm)**	**Existing space between rail (Stair B-B) (mm)**	**Comment**
Type A	Postgraduate Hall	1200	1600	Unacceptable
	Awolowo Hall (Block 5 & 6)	1500	1790	Unacceptable
	Moremi Hall	1400	1400	Unacceptable
	Akintola Hall	1200	1600	Unacceptable
Type B	Awolowo Hall (Block 1-4)	1500	1800	Unacceptable
	Awolowo Hall (block 7 & 8)	No rails	1580	Unacceptable
	Fajuyi Hall	No rails	1580	Unacceptable
Type C	Alumni Hall	No rails	-	Unacceptable

4.2.6 Pitch

Results of the measured pitch angle of stairs in the study area are presented in Table 13. A typical elevation showing the required maximum pitch angle of stairs as specified by British Standard Institution Group [2000] is shown in Figure 1. As shown in Figure 1 the maximum angle of stair shall be 38 degrees. The results of field measurements on pitch angles of stairs as depicted in Table 13 reveal that the pitch angles of all the stairs are acceptable

Table 13. Pitch of stair (degree)

	Standard Pitch (< 38 degree)			
Stair Type	**Hall**	**Existing pitch of stair A-A & C-C**	**Existing pitch of stair B-B**	**Comment**
Type A	Postgraduate Hall	34^0	35^0	Acceptable
	Awolowo Hall (Block 5 & 6)	37^0	31^0	Acceptable
	Moremi Hall	36^0	36^0	Acceptable
	Akintola Hall	34^0	35^0	Acceptable
Type B	Awolowo Hall (Block 1-4)	37^0	30^0	Acceptable
	Awolowo Hall (Block 7 & 8)	29^0	31^0	Acceptable
	Fajuyi Hall	29^0	31^0	Acceptable
Type C	Alumni Hall	23^0	-	Acceptable

4.2.7 Travel distance

Amoako [2014] noted that the escape route should be as short as possible; the impact of a blocked escape route must be considered and long dead ends in which escape is only possible in one direction should be avoided if occupant should reach a place of safety. From the field measurements, it was found that the travel distance from some of the rooms to the exit (Table 14) was more than the required maximum travel distance specified by NBC [2006] (Table 3) and British Standard Institution Group [2008].Occupants of these rooms will have to cover more than 14000mm to reach the nearest escape stair in order to escape. The dangers associated with this condition have to be critically considered as this could create a lot of challenges to occupants while trying to escape as they will spend a lot more time travelling to the nearest exit point in the building.

Table 14. Maximum travel distance from remote area (mm)

Maximum travel distance from remote area ≤ 14000mm					
Stair Type	**Hall**	**Travel Distance to Escape route 1 (mm)**	**Comment**	**Travel Distance to Escape route 2 (mm)**	**Comment**
Type A	Postgraduate Hall	32730	Unacceptable	33800	Unacceptable
	Awolowo Hall (Block 5 & 6)	26900	Unacceptable	34300	Unacceptable
	Moremi Hall	24400	Unacceptable	25800	Unacceptable
	Akintola Hall	32730	Unacceptable	33800	Unacceptable
Type B	Awolowo Hall (Block 1-4)	30500	Unacceptable	33600	Unacceptable
	Awolowo Hall (blocks 7 & 8)	11100	Acceptable	24500	Unacceptable
	Fajuyi Hall (Blocks 1, 2 & 3)	11100	Acceptable	24500	Unacceptable
	Fajuyi Hall (Block 4)	16200	Unacceptable	28600	Unacceptable
	Fajuyi Hall (Block 5)	24400 15500	Unacceptable	20600	Unacceptable
Type C	Alumni Hall	46200	Unacceptable	-	-

5. Conclusions and recommendations

The study has investigated the operational readiness of egress system in students` halls of residence within Obafemi Awolowo University, Ile-Ife. Evacuation and safety of occupants might be undermined considering some inadequacies noticed during field measurements and observations such as narrow width, long travel distance, inadequate handrail height and rails spacing, inadequate width of stairways**,** non-uniformity of dimensions of risers and treads and provision of insufficient number of escape stairs especially in Alumni Hall of Residence. The only means of circulation provided in this hall of residence will be over stressed due to the number of occupants.

The construction inaccuracies of the existing stairs can be corrected by using screed. This will make the existing stair functional, acting as an alternative fire escape stair and a means of vertical circulation. Besides, non-slip aggregate treatment should be further introduced on the individual treads as well as the landings to prevent possible slipping. The authors also recommended that in addition to the existing stair in Alumni Hall of Residence, a new stairway should be provided (see Fig. 6 for optimum location). This, in our opinion, will prevent bottleneck on the existing single stair and aid easy movement as well as smooth egress in times of fire emergencies, thus, helping to improve the fire safety conditions of this hall. Finally, the University administration is advised to conduct periodic checks on fire safety conditions in the halls of residence as the occupancy situation changes.

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