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RESEARCH PAPER

AN AUDIT OF THE EGRESS SYSTEM IN MULTI-STOREY ANNEXES OF FOUR HALLS OF RESIDENCE AT KNUST, KUMASI, GHANA

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ABSTRACT
Fire safety construction and fire safety equipment installations are important systems required for occupant safety. A principal consideration in this case is the provision of an effective egress system that could be located at appropriate places to aid people to safety. The absence of these measures in multi-storey blocks leaves occupants at greater risk. This paper presents results of a study carried out in students' Halls of Residence at the Kwame Nkrumah University of Science and Technology (KNUST) in Ghana. Past and current statistics show an average of 300% increase in population of the multi-storey blocks on KNUST campus without any consideration of the capacity in the egress system. Documentation of the egress system in the halls of Residence was done by use of measured drawings and photography. A comparative analysis of the existing dimensions and standard dimensions revealed the narrow width, unequal treads and risers of steps and other inaccuracies of stair components. The results of the egress analysis showed the bottlenecks and constrictions that will be created when occupants rush out in an emergency. These lapses can be eliminated when proper circulation is introduced to the existing components and the construction of a suitable fire escape stair to aid occupants to a place of ultimate safety.

Keywords: *safety, egress, fire protection, vertical circulation*

INTRODUCTION

Apart from providing shelter, essential fire safety systems are required in buildings to ensure the safety of occupants in the event of fire and other emergencies. Buildings have to be designed such that occupants can easily travel to a place of ultimate safety in times of fire (British Standards Institution Group, 2008). To this end, there is the need to provide egress systems such as fire escape elements in the form of stairs to facilitate exiting from buildings. Fire escape stair is a continuous, unobstructed, path of escape used when traversing a building vertically in case of fire (McGraw Hill Dictionary of Architecture and Construction, 1993)

There are various students' housing on KNUST campus comprising the six traditional main Halls of Residence and other modern Halls of

Residence (Table1). Currently, the vertical circulation in the multi-storey blocks of KNUST comprises of non-functional lifts and flights of stairs serving huge numbers of occupants. This study will analyse the egress system of residential Types B (1) and C (1) as shown in Table 1.

Multiple occupation structures like the multi-storey blocks on KNUST campus have the risk of fires breaking out because of overloaded electrical circuits which is a factor created by increasing student population and occupancy (Renewals Team, 2007; Chalmers Insurance Group, 2010).

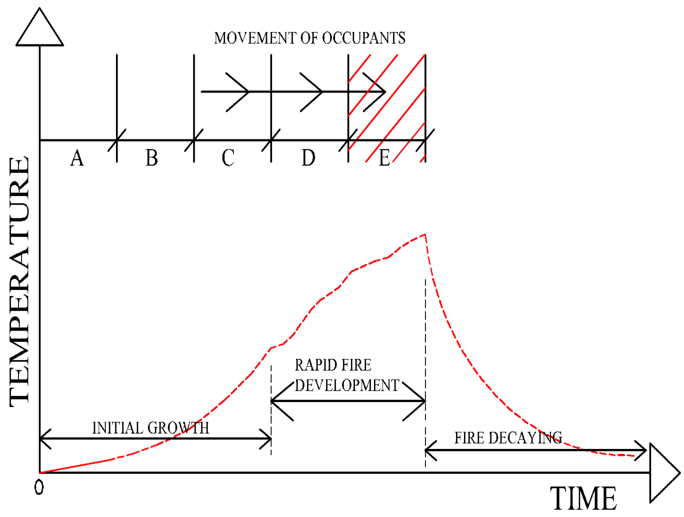
In the event of fire, evacuation as a first step is necessary as it ensures that occupants of a building reach a place of ultimate safety outside the building (British Standards Institution Group, 2008; Fire Officer, 2009; Richardson, 2009). When there is ignition and fire begins to spread, safe evacuation must be completed within the initial stages of fire growth (C and D) as indicated in Fig.1. Late evacuation (E) has to be done quickly to avoid fatalities.

Stairs - Majority of accidents occur on escape routes due to incorrect sizes and differences of stair components, especially, treads and risers. As little as 5mm difference in riser heights can be disastrous (British Standards Institution Group, 2008).

The clear width of stair stated as at least 1200mm may be subject to change according to the total number of occupants on each floor (see Fig. 2 and 3). In calculating the width for a number of people, 530mm should be the unit width for each occupant. The product of the unit width, 530mm, and the number of people should dictate the exact width of stair on each floor. However, if the population on each floor is scanty and the product is less than the standard stated above, then 1200mm should be used. On the other hand, if the product of 530mm and the population is more than the standard stated, the result which is greater than 1200mm should be used (British Standards Institution Group, 2000; 2008; Ministry of Works and Housing, 1996).

Table 1: Student housing typologies on KNUST campus

Typology	Description
Type A	Low rise modern Halls of Residence and all traditional main Halls. Number of floor levels is between 2 and 6. Comprises of SRC hostel, Tek Credit, GUSS Hostels, GRASAG Hostel, Steven Paris Hostel, Spring Hostel and Hall 7.
Type B (1)	High rise single banking blocks with one stair. Comprises of annexes of the main Halls: Republic Annex, Queens Annex and University Hall Annex. The blocks have 9 floor levels.
Type B (2)	High rise single banking block with 2 stairs. Comprises of Independence Hall Annex. The block has 9 levels.
Type C (1)	High rise single banking blocks with one stair. Consists of 2 multi-storey blocks of Africa Hall. The blocks have 9 floor levels.
Type C (2)	High rise double banking blocks with two stairs. Consists of 2 multi-storey blocks of Unity Hall. Blocks have 10 floor levels.



O = Ignition
A = Fire Detection
B = Alarm
C = Occupants aware of Fire/ Evacuation begins
D = Evacuation of Life Safety Strategies Complete
E = Escalation of Fire/ Danger Zone

Fig. 1: Stages of fire growth and evacuation of occupants

Source: British Standards Institution Group, 2008, p. 51; Patterson 1993, p11

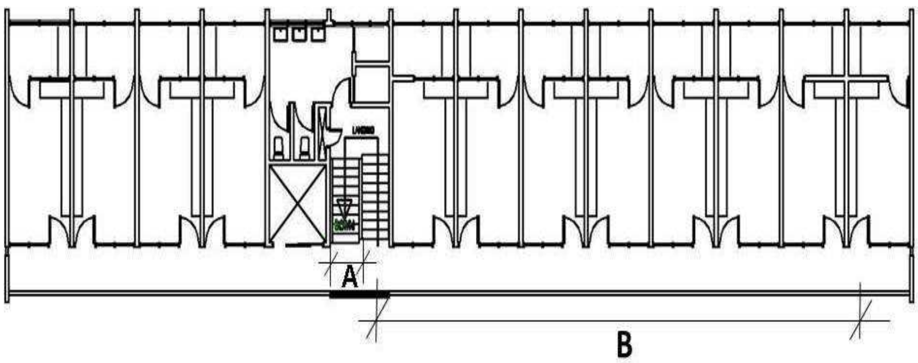


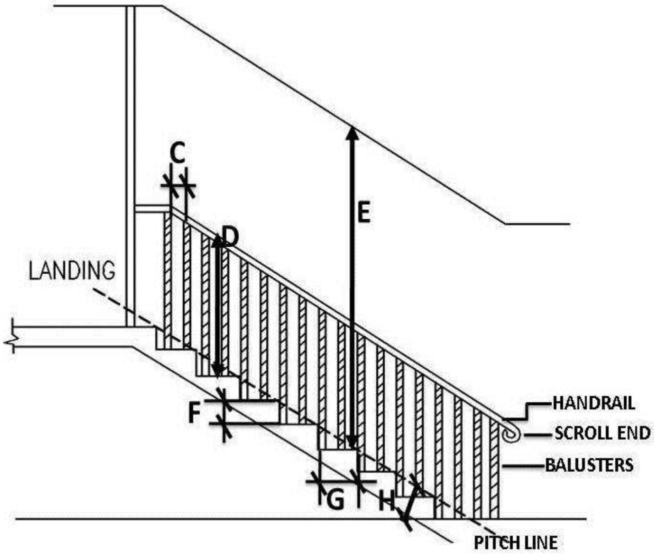
Fig. 2: Typical floor plan of Halls of Residence showing width of stair and maximum travel distance

Source: British Standards Institution Group, 2000, 2008

MATERIALS AND METHODS

This study is aimed at auditing the existing condition of the egress system of multi-storey Halls of Residence on KNUST campus for a remedy that will safeguard the safety of occupants. The approach used in this paper involved an analytical and comparative study of selected multi-storey blocks comprising Republic Hall, Independence Hall, Africa Hall Block B and Queen Elizabeth Hall Annexes.

Standard egress data were gathered from the British Standard Codes. Data on the egress system was recorded through measured drawings



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. 3: Typical elevation showing components of stairs

Source: British Standards Institution Group, 2000, p.3

conducted at each Hall of Residence to obtain the floor plans and stair components' dimensions. Type B (1) and C (1) Residences studied have similar configurations thus, similar floor plan and section (Fig. 4 and Fig. 5). On a typical floor of each block, there are twelve (12) rooms, each with four (4) occupants (Fig. 4). The existing stair on the floor serves all the occupants on the floor and will also double as an escape stair in times of fire.

Apart from (Fig. 4 and Fig. 5), the following stair components' dimensions were also recorded for further discussion; width of stair, maximum travel distance to stair, space between balusters, height of handrail, headroom, riser height, tread length and pitch of stair. The recorded stair data were documented and each component's dimension compared with standard measurements (see Fig. 2 and 3).

RESULTS AND DISCUSSIONS

The chosen study areas comprise the following Halls of Residence and data about their past and current population (Table 2). Before the analysis, the occupancy growth of the study areas was computed to determine whether the existing stair qualities are appropriate for the current population as shown in Table 2.

From Table 2, the number of rooms has not increased since their establishment but there has been a 300% increase in mean occupancy. This would put the circulation and egress system of the Halls in a critical condition.

From Table 3, each Hall of Residence has one (1) stair on which all occupants commute and also doubles as an escape stair implying that there is basically one stair case provided for the entire block. The dangers associated with this condition have to be critically considered.

Documentation and Analysis of Stairs of Study Areas

The Annex blocks of the Main Halls have similar designs and spatial arrangements but different egress qualities. The auditing of the blocks is based on standard requirements for fire escape stairs which have been detailed in Fig. 2

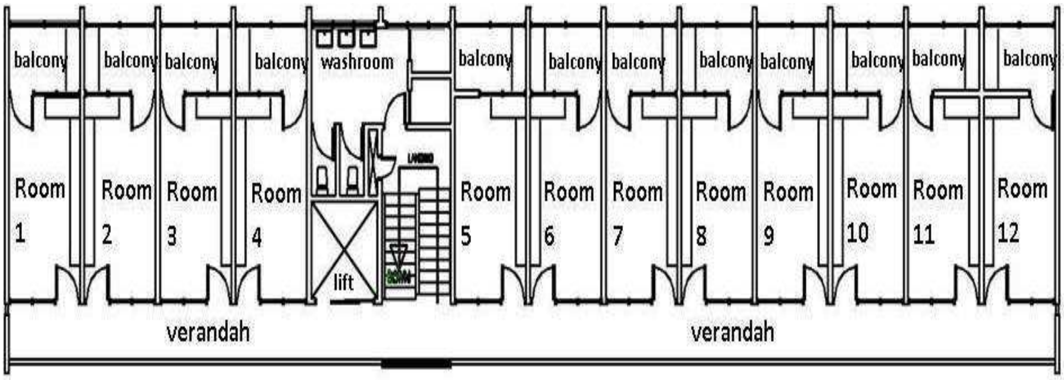


Fig. 4 Typical floor plan of type B (1) and Type C (1) annex blocks

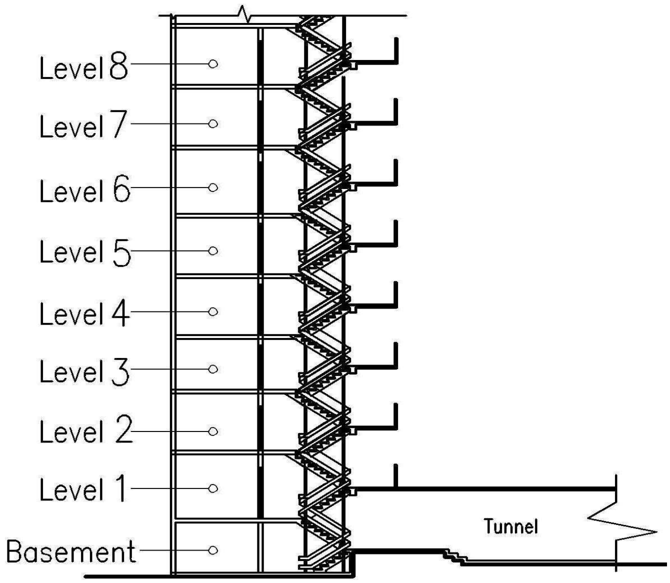


Fig. 5: Typical cross-section of Type B(1) and Type C(1) annex blocks

and 3. Each floor has 12 rooms housing 48 occupants. The resulting dimensions of the existing stair components have been recorded in Tables 4 to 11.

Analysis of stair components

Using a comparative analysis approach, each stair component recorded was compared with the standard value as seen from Table 4 to Table 11. Any existing dimension that was not consistent with the standard was then classified inadequate or unacceptable indicating that the particular component is not safe enough to guard occupants to safety. However, measured values that corresponded with the standard values are safe components for egress thus acceptable.

Clear Width of Stair - From Table 4, the

Table 2: Occupancy growth of multi-storey blocks of Study Areas [Type B (1) and C (1)]

Typology	Residential Block	Number of Rooms	Year Occupied by Students	Initial Occupancy	Current Occupancy (2012)	Aver-age% Increase Over the Years
Type B (1)	Queens Hall Annex	96	1959	96	384	300
	Republic Hall Annex	96	1961	96	384	300
	University Hall Annex	96	1961	96	384	300
Type C (1)	Africa Hall (Block B)	96	1967	96	384	300

Source: (KNUST Estate Office, 2012)

Table 3: Standard required escape routes versus existing stairs in the Halls of Residence (For population between 200 and 400)

Standard No. of Escape Routes	Typology	Residence	Existing Population (2012)	Existing Number of Stairs	Comment
at least 2	B (1)	Queens Hall Annex	384	1	Inadequate
		Republic Hall Annex	384	1	Inadequate
		University Hall Annex	384	1	Inadequate
at least 2	C (1)	Africa Hall Block B	384	1	Inadequate

Source: British Standards Institution Group, 2008, p.70; Patterson, 1999, p.195

Table 4: Clear Width of Stair (mm)

Standard clear width (≥ 1200mm)		
Hall	**Existing width of stair**	**Comments**
Queens	946.8	Inadequate
Republic	918.8	Inadequate
University	954.6	Inadequate
Africa (Block B)	934.2	Inadequate

Table 5: Maximum travel distance from remote area (Dimensions in millimetres)

Standard distance (≤ 14000mm)		
Hall	**Travel Distance (mm)**	**Comments**
Queens	21783	Unacceptable
Republic	19720	Unacceptable
University	19720	Unacceptable
Africa (Block B)	14420	Unacceptable

Table 6: Space between Rails (mm)

Standard space between rails (≤ 200mm)		
Hall	**Existing space between rails**	**Comments**
Queens	465.8	Unacceptable
Republic	445.8	Unacceptable
University	390.6	Unacceptable
Africa (Block B)	480	Unacceptable

Table 7: Height of handrail (mm)

Standard height of handrail (≥ 1100mm)		
Hall	**Existing handrail height**	**Comments**
Queens	978	Inadequate
Republic	831.2	Inadequate
University	923.8	Inadequate
Africa (Block B)	954.8	Inadequate

Table 8: Headroom (mm)

Standard headroom (≥ 2000mm)		
Hall	**Existing space between rails**	**Comments**
Queens	2286.5	Acceptable
Republic	2363	Acceptable
University	2288.3	Acceptable
Africa (Block B)	2346.7	Acceptable

Table 9: Existing riser heights on fifth flight in each Hall (mm)

Standard size (100 to 190 mm uniform risers)									
Hall	**Riser 1**	**Riser 2**	**Riser 3**	**Riser 4**	**Riser 5**	**Riser 6**	**Riser 7**	**Riser 8**	**Comments**
Queens	203	174	170	176	168	168	177	167	Unacceptable
Republic	168	159	180	168	168	177	169	177	Unacceptable
University	169	168	174	173	174	174	169	160	Unacceptable
Africa (Block B)	178	166	173	175	173	172	172	125	Unacceptable

Table 10: Existing treads dimensions on fifth flight in each Hall (mm)

Standard size (250 to 350 mm uniform tread)								
Hall	**Tread 1**	**Tread 2**	**Tread 3**	**Tread 4**	**Tread 5**	**Tread 6**	**Tread 7**	**Comments**
Queens	275	274	269	269	270	268	268	Unacceptable
Republic	270	268	270	270	274	276	277	Unacceptable
University	284	280	281	284	282	280	282	Unacceptable
Africa (Block B)	276	278	279	275	274	274	269	Unacceptable

Table 11: Pitch of stair (degrees)

Standard Pitch (≤ 38 degrees)		
Hall	**Existing pitch of stair**	**Comments**
Queens	32.7	Acceptable
Republic	31.6	Acceptable
University	30.9	Acceptable
Africa (Block B)	33.2	Acceptable

existing value of each Hall when compared to the standard clear width as seen (Fig. 2 and 3) are inadequate. This indicates the inadequate widths will be an ingredient for bottlenecks on each flight as depicted in Fig. 6 and Fig. 7 (indicated in dotted circles). The bottlenecks that will occur due to the narrow width of the stair will extend to the landings and could finally cause an obstruction. As can be seen in Fig. 6 and Fig. 7, constrictions will be complicated on the ground floor as people moving from the sub-basement will meet the cumulative total number of occupants descending the stairs. As seen in dotted circle in Fig. 6, there will be a confluence of people at the threshold of the tunnel.

Travel Distance - All the Annex blocks do not meet the standard travel distance as seen in Table 5. Occupants from remote parts of each floor will have to travel more than 14000mm to reach the stair. In Fig. 7, occupants in rooms 1 to 4 will travel beyond 14000mm to access the stair in order to evacuate. This could cause a lot of harm to occupants as they will spend a lot more time travelling to the exit point in the building with fire and smoke.

On the other hand, when an escape stair is provided at the extreme end of the block as indicated in Fig. 8 (in dotted circle), occupants will be ushered out in two directions and this will prevent bottlenecks on the stairs (Fig. 6 and 7) and reduce travel time for evacuation.

Space between Rails - From Table 6, the existing rail spacing as recorded are greater than the standard 200mm, thus unacceptable to aid occupants to safety. As depicted in Fig. 9, introducing guardrail 2 (shown as continuous line) will reduce the wide gap between the rails to prevent casualties.

Handrails and guards are very important in egress as they provide support and guide for users of the stair. Circular handrails with a diameter between 32 and 50mm are most comfortable to grasp (British Standards Institution Group, 2000).

Handrail height - All the existing handrail heights in the Halls of Residence (Table 7) are lower than the standard height (1100mm). This makes their heights inadequate to aid occupants during evacuation. The existing

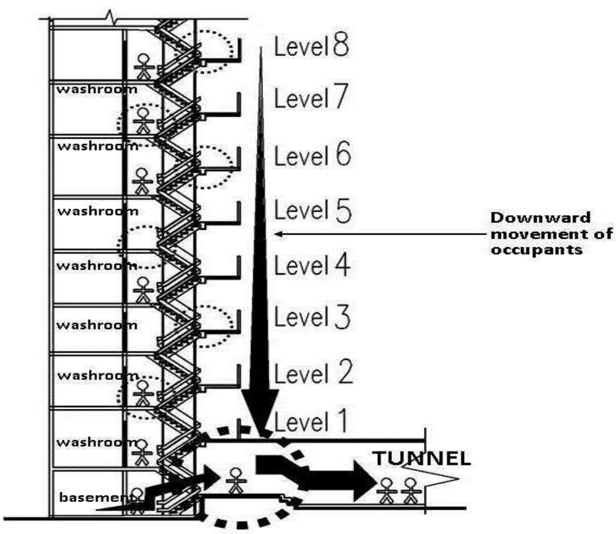


Fig 6: Typical section through multi-storey annex blocks (Section A-A)

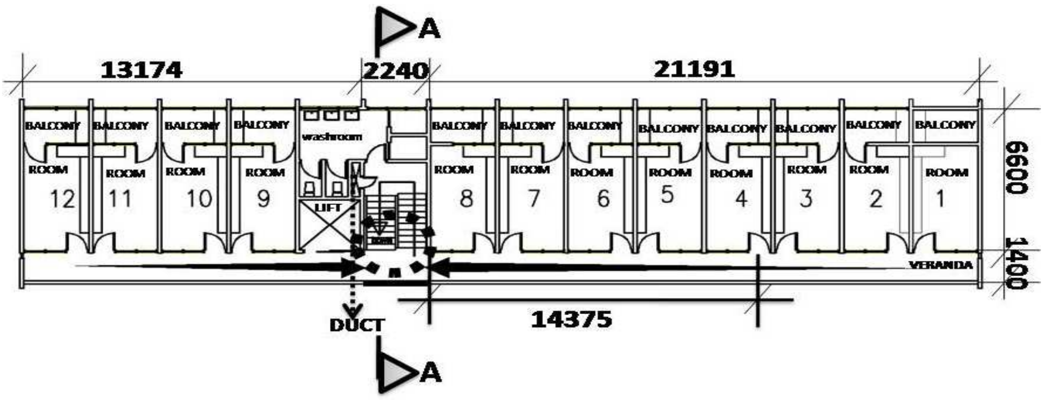


Fig. 7: Typical floor plan of type B (1) and Type C (1) blocks showing existing stair (All dimensions in millimetres)

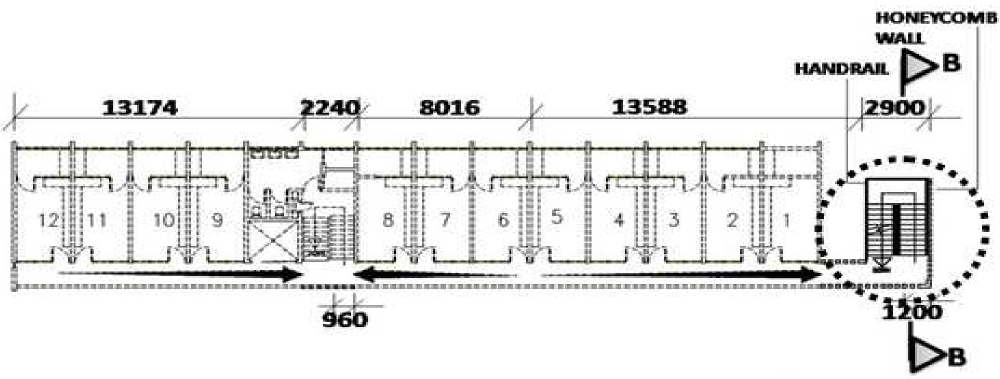


Fig. 8: Typical plan showing fire escape stair attached to existing blocks

handrail heights can be increased by a 130mm additional to provide total support for occupants as depicted in Fig. 9.

Headroom - From Table 8, 2000mm is the least height for headroom as suggested by British Standards Institution Group. The existing average headroom of each Hall is higher than the minimum value (2000 mm). This means that all existing headroom of the Annex blocks are safe for occupants as accidents will not occur from collision into the under parts of other flights of stairs.

Risers and Treads - Uneven risers and treads are major causes of accidents on stairs. Apart from risers and treads falling within the standard range as recorded in Tables 9 and 10, it is also important for their dimensions to be uniform throughout the flight as indicated in Fig. 9. The inconsistency of the treads and risers in the Halls of Residence makes them unacceptable.

Pitch - From Table 11, all recorded measured values of the pitch of each Hall of Residence is acceptable. Each of the pitch is not steep

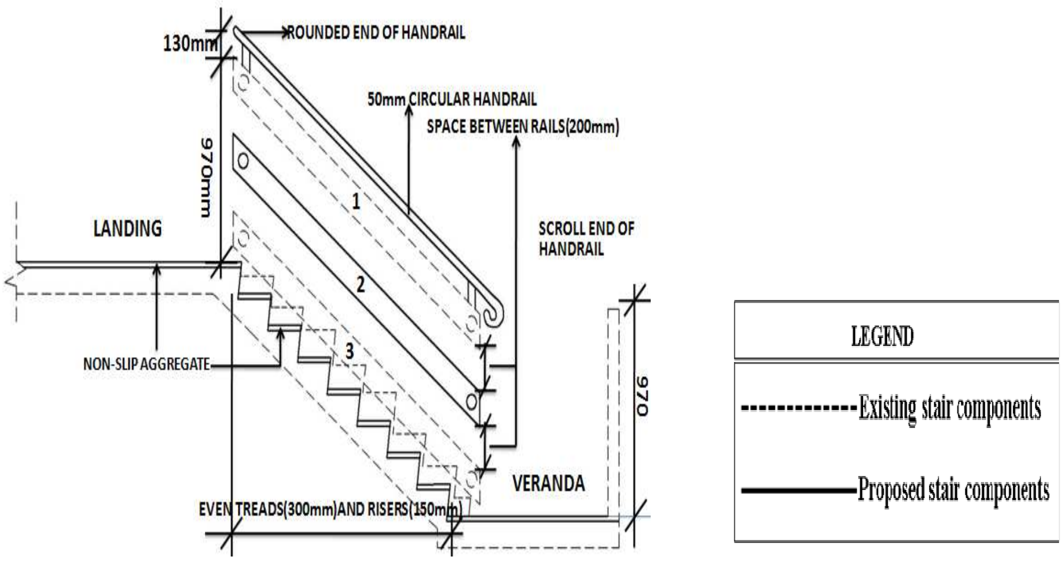


Fig. 9: Typical section B-B through stairs showing existing and proposed components

CONCLUSIONS AND RECOMMENDATIONS

Safety measures in the multi-storey blocks have been undermined looking at the inadequacy of fire preventive measures such as the absence of fire equipment and the non-provision of a fire escape stair. The only means of circulation, which is the stair, is over utilized due to the increasing number of occupants in the multi-storey Halls of Residence.

The principal remedy is the provision of a fire escape stair at the extreme end of the blocks to aid easy movement and smooth egress out in times of emergencies as has been illustrated. The addition of an extra stair will facilitate egress from the blocks and this is a prime factor that will improve the safety conditions in the multi- storey Annex blocks of all the Halls of Residence.

The construction inaccuracies of the existing stair 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. Though the stairs are made of concrete, non-slip aggregate treatment should be further introduced on the individual treads as well as the landings to prevent possible slipping.

The University in addition to this bears the responsibility of conducting periodic checks on fire safety conditions in the Halls of Residence as the occupancy situation changes. This will have to be carried out by the Fire Safety Department of the University to ensure total safety of occupants and that of properties as well.

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REFERENCES

British Standards Institution Group (2000). *British Standard codes 5395*. [E-book] London: British Standards Institution. Available at: http://www.4shared.com [Accessed 3rd July, 2010].

British Standards Institution Group (2008). *British Standard codes 9999*. [E-book] London: British Standards Institution. Available at: http://www.4shared.com [Accessed 3rd July, 2010].

Chalmers Insurance Group (2010). *A report on Electrical Current.* [pdf] Maine: MMG Insurance Available at: http://www.chalmersinsurancegroup.com/assets [Accessed 18th July, 2010].

Fire Officer (2009). *Disability Emergency Egress and Evacuation Issues or Policy, Fire Safety Technical Guide*. [pdf] London: University College of London. Available at <http://*www.ucl.ac.uk/efd/maintenance/fire/.../UCLFire_TN_008.pdf*>. *[Accessed 29th July, 2010].*

Kwame Nkrumah University of Science and Technology Estate Office (2012). *Students Halls of Residence.* [online] K.N.U.S.T., Kumasi. Available at <http://www.knust.edu.gh>. [Accessed 2nd July, 2010]

McGraw Hill Dictionary of Architecture and Construction (1993). Available at <http://www.answers.com/topic/fire-escape>. [Accessed 23rd August, 2012]

Ministry of Works and Housing (1996).*Ghana National Building Regulations (L.I.1630).* Accra, Assembly Press.

National Institute of Standards and Technology (2010) .*E-handbook of Statistical Methods. [E-book] Gaithersburg: U.S. Commerce Department. Available at http:www.itl.nist.gov/div 898/handbook>. [Accessed 11th August, 2010]*.

Patterson, J. (1993). *Simplified Design for fire safety*, New York: John Wiley and Sons Inc. *Renewals Team* (2007). *Fire precautions for houses in multiple occupation*. [pdf] Bideford: Torridge District Council. Available at <http://www.torridge.gov.uk/CHttpHandler.ashx?>. [Accessed 2nd July, 2010]

Richardson, K. (2009). *Fire Safety in High Rise Apartment Buildings.* [E-book] Atlanta: ASHRAE Publication. Available at <http://www.cmhc.ca/Fire-Safety-in-High-Rise-Apartment-Buildings*. [Accessed 2nd August, 2010]*.