Educational Research (ISSN: 2141-5161) Vol. 5(8) pp. 261-279, September, 2014
DOI: http:/dx.doi.org/10.14303/er.2014.121
Available online@ http://www.interesjournals.org/ER

Full Length Research Paper

Designing for safety during installation and maintenance of split air-conditioners: Case study of commercial buildings in Adum

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ABSTRACT

This research is aimed at examining the spatial requirements of split air-conditioners and how they affect the safety of technicians during installation and maintenance. Climate modification is an essential part in providing comfort for occupants of buildings. This has been aided over the years with the use of HVAC systems since the 19th century. With single unit air-conditioners going out of trend due to its effect on building aesthetics, split air-conditioners have become more popular especially in public buildings. Using a mainly qualitative method, the research focused on commercial buildings in the Central Business District of Kumasi, Adum. The research combines human anthropometrics and spatial requirements of split air-conditioners from manufacturers such as LG. An examination of design influence on safety is also done. This culminates in a design response to better understand the need to adequately provide space for outdoor units of split air-conditioners. The paper highlights the little priority given to safety in designing medium to high-rise buildings in Adum and by extension Ghana. The worry of air-condition (AC) technicians is also brought to the fore with a staggering 61.5% of respondents claiming they feel unsafe working on buildings without adequate spatial provision for outdoor units. A major limitation to this paper is the difficulty in getting the specific designers of buildings captured in the survey. Another challenge was locating AC technicians, especially those who have worked in the area under study. Obtaining current occupational safety data proved to be nearly impossible. However data from the year 2000 was obtained. This clearly does not paint the current picture. The paper concludes with a design response which factors in the anthropometric demands of AC technicians. Again the lessons learnt leads to the proposal of collecting and recycling condensate from the outdoor units. For the first time in Ghana, this paper introduces the influence of design on safety with emphasis on split air-conditioners. This is to help provide a starting point for the development of best practices in design of medium to high-rise buildings which run on split air-conditioners.

Keywords: Maintenance, Installation, Split air-conditioners, Safety, Anthropometrics.

INTRODUCTION

Ghana has seen a lot of development in terms of infrastructure and commerce in the last decade. Consequently, many of the central business districts (CBDs) have witnessed a spike in commercial developments. With the turn towards making efficient use of land coupled with high land value, vertical building development has taken centre-stage. Single-storey residential buildings are razed down and in their place huge multi-storey structures with very little sympathy to previous development are constructed (Oppong and Brown, 2012). These redevelopments sadly have come with a lot of challenges and prime among them is the

Figure 1. Outdoor units of split air-conditioners splattered on wall.

(Source: Authors field survey)

provision of thermal comfort within the buildings (Nkrumah and Koranteng, 2012). The conditions have further been complicated with the issue of temperature rise due to climate change and the huge taste for glazing.

Humans have sought to modify climate since the time of ancient Egyptian civilization. Major breakthroughs came in the 1900s with the development of refrigeration systems which over the years have matured into HVAC systems. Window units which were widely used in the past two decades have been largely abandoned due to their effect on building aesthetics as well as performance (Peixoto, 2002). According to Peixoto, the numbers of window units have gradually reduced with split air-conditioners now the preferred choice due to their efficiency in cooling larger spaces, their cost-effectiveness and the reduction of noise within the cooled space.

Taking the heights of the buildings in these redevelopments, it appears there is disregard for safety of workmen who install these units in most of commercial buildings at Adum. The risks of sustaining injuries or possible fatalities working at such high elevations stares us straight in the face due to apparent design oversights. With statistics of accidents in the construction industry soaring at 11.5 injuries/1000 persons in urban areas (Ametepeh, 2011), this situation should be rectified to prevent further increments. Installation of air-conditioners has become an after-thought in most cases as shown in Figure 1 where building occupants are at liberty to splatter units all over blank walls. This, if not rectified could add to the numbers in terms of accidents in the building industry.

An immediate remedy is of much importance due to the contribution of the construction industry to Ghana's GDP, which stands at 6.1% annually (Danso *et al*., 2012).It is very important to note however that not all accidents in the construction or building industry occur during the active construction phase but even after the building has been completed and handed over for use.

The main aim of this research is to examine the spatial requirements of split air-conditioners and how they affect the safety of technicians during installation and maintenance. Safety issues are addressed with particular reference to the role of the designer in crafting suitable spaces based on anthropometric standards and air-condition equipment requirements.

Figure 2. Aseda House, Adum
(Source: Authors)

Figure 3. Unibank Building, Adum
(Source: Authors)

Literature Review

Towards glazing of facades in Adum

It has become almost a standard in Ghana for buildings in the CBDs to be designed with curtain walls. Adum, the CBD of Kumasi is no different. Adum is made up of 75% stores, 15% offices and 10% residential facilities (Fianu, 2008). In the past decade, almost 90% of the commercial buildings in Adum have been designed with curtain wall facades with a few operable windows making them highly reliant on mechanical ventilation (Quansah et al., 2012). This is illustrated in Figure 2 and Figure 3.

Safety in the construction industry

Safety is defined as being free from danger, i.e. protection from or not being exposed to the risk of harm of injury (Encarta Dictionary, 2009). Thus, a safe environment is one which can be said to provide an accident-free working space for carrying out any activity. According to Duff et al., (1993), the construction industry is considered as a high risk industry and has an unenviable safety record. It is within this industry that provision of services and for the purposes of this study, the installation and maintenance of split air-conditioners fall. The poor safety performance of the construction industry has always been a cause for concern internationally. The International Labour Organization (ILO) highlights the growing risks for workers worldwide especially in construction works where the rate of fatal accidents could be 10 or even 20 times higher than the average (Abdul Hamid *et al.,* 2008). With such alarming statistics, it is worrying that very little is being done in Ghana to enhance the safety performance of our building industry. It should be noted that accidents do not just happen but occur as a result of a combination of factors. Bird and Germain's Accident Iceberg Theory (1985) reveals the direct and indirect cost implications of accidents in the construction industry. It is worth noting that not all accidents lead to injuries-some result in damage to site equipment, and even surrounding buildings. In some cases, these accidents lead to indirect costs which often lead to huge expenses which are most of the time unexpected. According to the Accident Iceberg Theory the indirect cost of an accident ranges from five (5) to fifty (50) times more than the direct cost of the accident.

According to Danso *et al.* (2012), the Ashanti Regional capital (Kumasi), registered a staggering 160 construction fatalities from 1998 to 2008. What is most worrying is the steady increase in number of fatalities from 1998 (16 recorded cases) through 2008 (64 recorded cases).

The Case of the Window Unit Air-Conditioner

Air-conditioners come in various forms depending on the expected cooling needs of the users. In some cases, the choice of air-conditioners is informed by aesthetic considerations of architects. Over the last decade, there has been a shift from the use of window units to split air-conditioners of various kinds with the individual split system being the most common. Out of an estimated population of 368 million individual air-conditioner units as at 2001, only 131 million were of the window or through the wall type (Peixoto, 2002).

For the window or room units, the air-conditioner is fitted through an aperture to give access to the room which is to be cooled. The unit thus houses both the condensing and evaporating unit. The main problem with their use is the exposure of occupants to noise from the machine as well as the constant dropping of condensate which destroys wall finishes (Olarewaju and Cottell, 1997).

The Split Air-Conditioner

The split air-conditioner consists of two components; the outdoor (condensing) unit and the indoor (evaporating) unit. With the added advantage of elimination of noise from the space being cooled, this has become the preferred choice in most buildings in Ghana. It is common knowledge that condensing units must be mounted outside. It is therefore important that in multi-storey buildings, they must be accessible for services purposes (Olarewaju and Cottel, 1997). Olarewaju and Cottel (1997) further suggest solid balconies, flat concrete roofs and verandas as best places for locating condensing units of split air-conditioners. This assertion is given credence by manufacturers as well as regulatory bodies across the world (See Figure 4).

Where the outdoor unit is mounted on the balcony (as in Figure 4) of a building or other location where the discharge of condensate is likely to cause a nuisance, a safe tray to collect the removed water build-up on the outdoor coil must be provided or alternate arrangements must be made. An additional condition is in relation to the installation of outdoor units installed on ledges, decking, or roofs as illustrated in Figure 6. All these installations require suitable drainage. A specific concern is the installation of external units on balconies in multi-storey buildings. It is not acceptable to discharge the drain over the edge of the balcony where it will cause a nuisance; it must be run to the sanitary or storm water system (Plumbing Industry Commission of Australia, 2008) (See Figures 7 and 8).

Anthropometric relationship

Anthropometric relationship is shown in Figure 8-13

Using Design to Ensure Safety

Weinstein, Gambatese and Hecker (2005) emphasize on the need for designers to factor the issue of safety into the design process. Gambatese, Behm and Hinze (2005), agree by saying that design aspect of projects is a significant contributing factor to construction site accidents. Whittington *et al.* (1992) as well as *Suraji et al.* (2001) have blamed a significant proportion of construction accidents on processes such as planning, scheduling and design. Designing for construction safety as an intervention is supported by the hierarchy of controls common to the safety and health professions which identifies designing to eliminate or avoid hazards as the preferable means for reducing risk (Manuele, 1997).

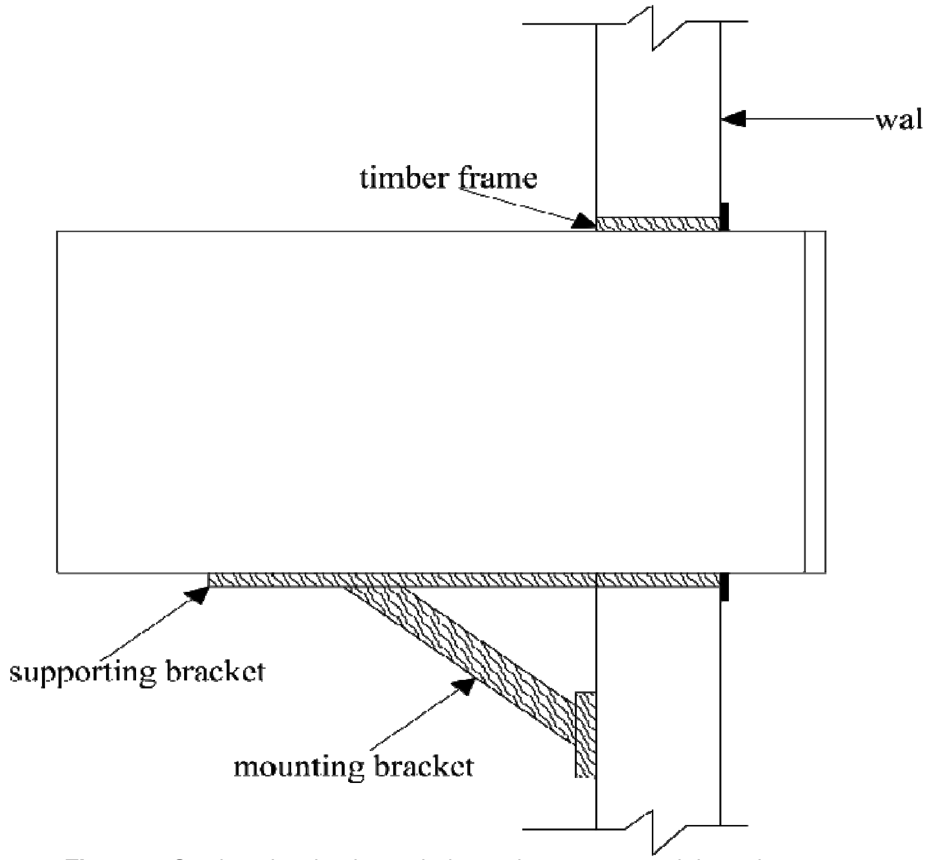


Figure 4. Section showing how window units are mounted through apertures
(Source: Olarewaju and Cottell, 1997)

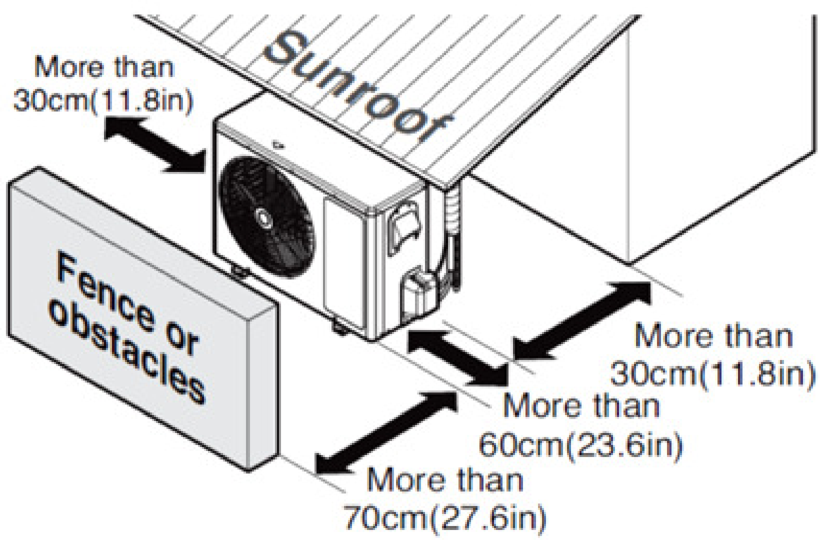


Figure 5. Spatial requirements for safe installation and maintenance of outdoor units of split air-conditioners
(Source: LG Manual for installing wall mounted split air-conditioner P/NO: MFL59506828, LG (2009)

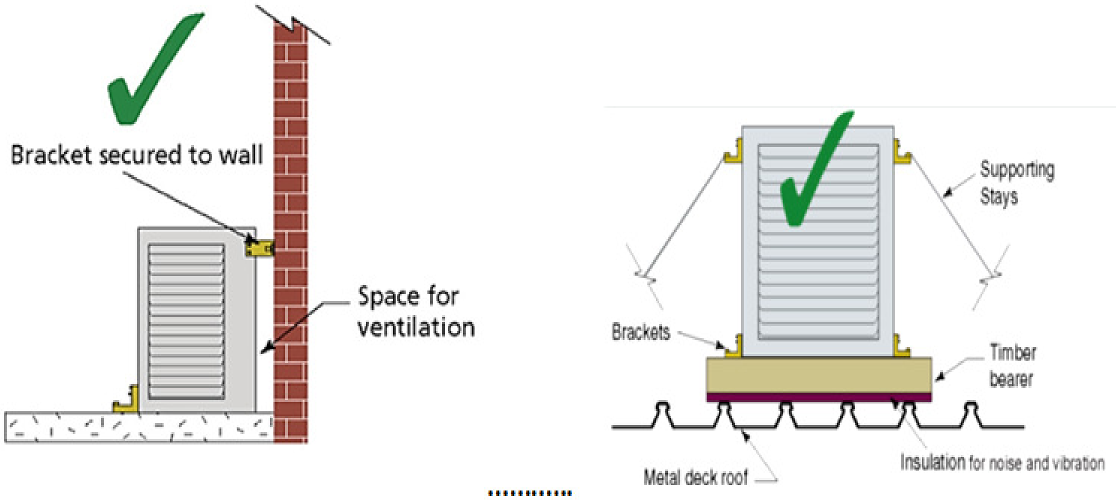


Figure 6. Solid platforms are the best support for outdoor units of split air-conditioners and also a good way of providing access for servicing

(Source: Plumbing Commission of Australia; www.pic.vic.gov.au*)*

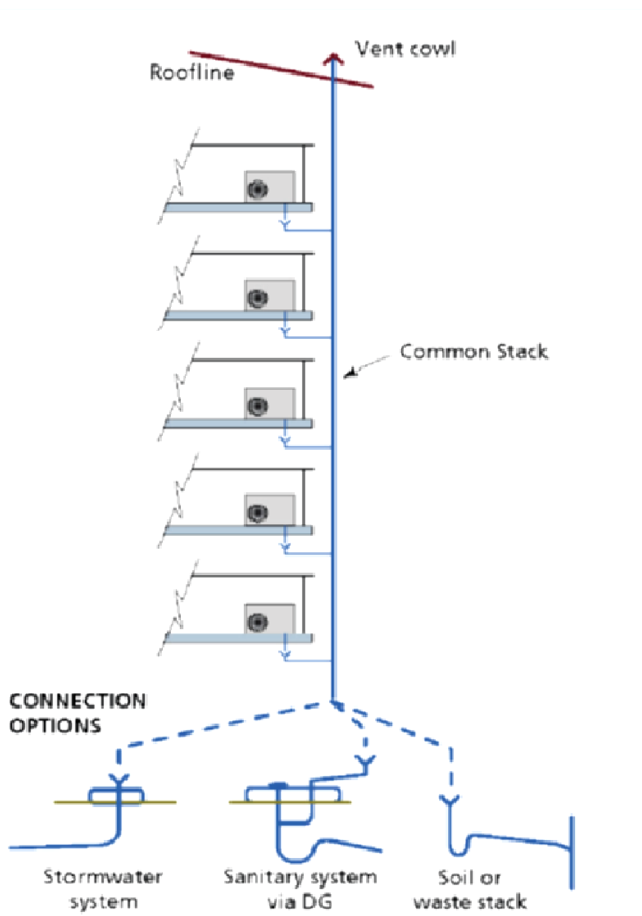


Figure 7. Drainage of outdoor units installed on balconies

(Source: Plumbing Industry Commission of Australia; www.pic.vic.gov.au*)*

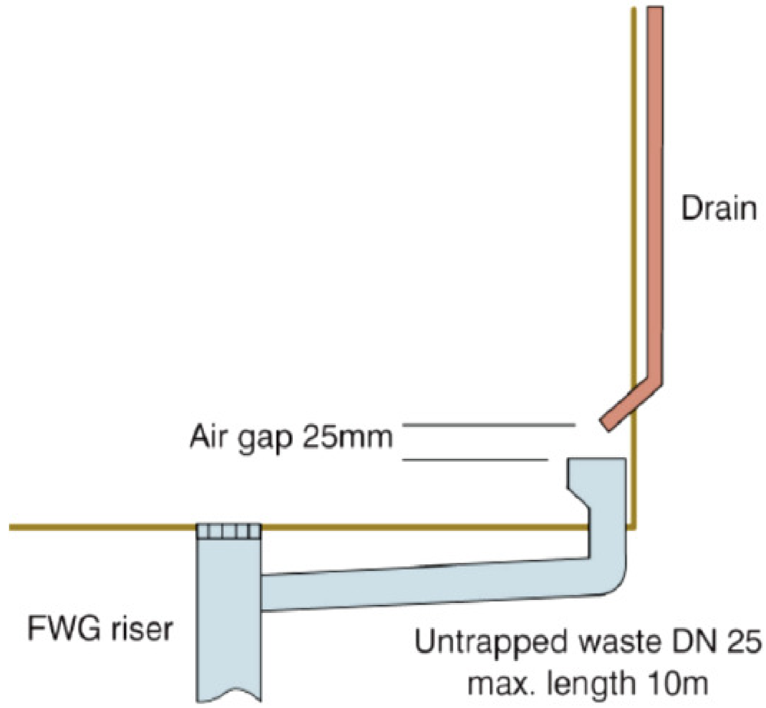


Figure 8. Detail of drainage at ground level
(Source: Plumbing Industry Commission of Australia; www.pic.vic.gov.au*)*

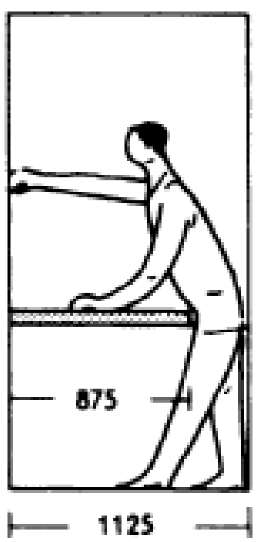


Figure 8. Dimensional requirements for an average sized human in standing position with arm outstretched

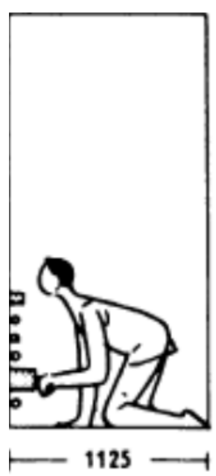


Figure 9. Dimensional requirements for an average sized human in kneeling position

Figure 10. Dimensional requirements for an average sized human in squatting position

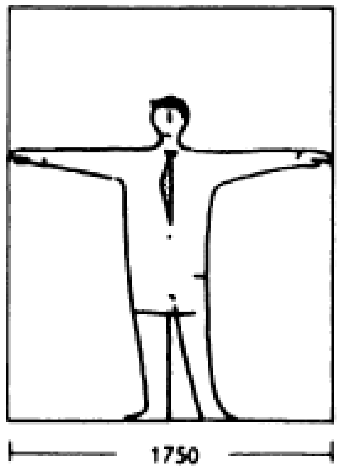


Figure 11. Dimensional requirements for an average sized human in standing position with both arms outstretched

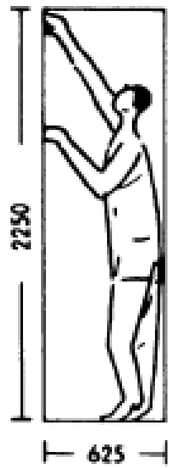


Figure 12. Dimensional requirements for an average sized human in standing position with arm stretched over the head.

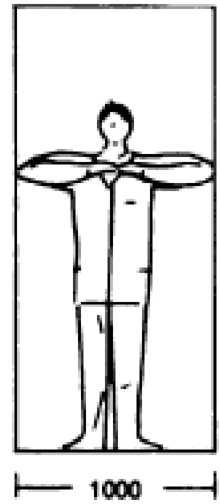


Figure 13. Dimensional requirements for an average sized human in standing position with arm bent at elbow level

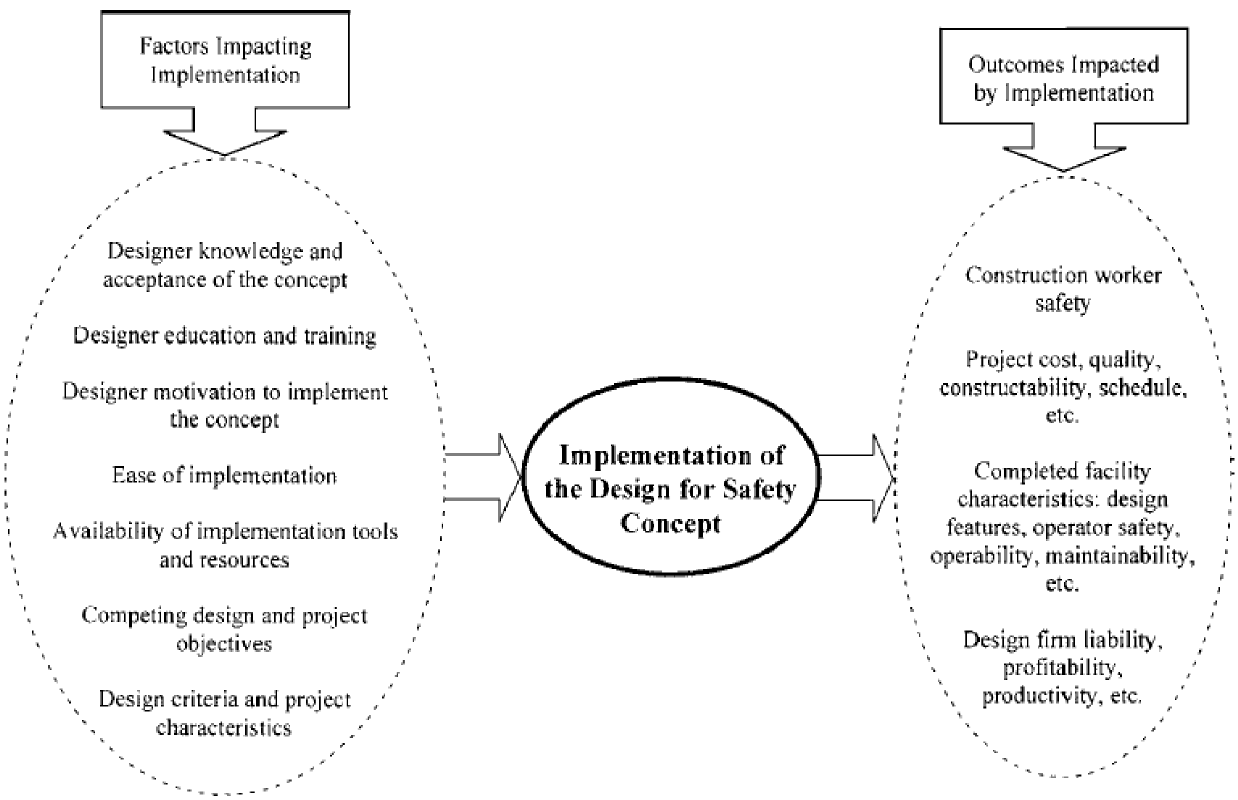


Figure 14. Design for safety concept implementation factors and impact

(Source: Gambatese et al., 2005)

The European foundation in 1991 mentioned that 60% of construction accidents could have been eliminated, reduced or avoided with more thought at the design stage (Weinstein et al., 2005). In response to a survey as stated by Smallwood (1996), 50% of the general contractors in South Africa identified design as a factor that negatively affects health and safety within the construction community. This goes to say that, designers i.e. architects, engineers etc. can have an impact on a significant number of injuries and fatalities by considering safety in their designs.

Addressing safety in the conceptual or early design stages, rather than reshuffling the design to meet those needs yields measurable benefits (Christensen and Manuele, 1999; ISTD 2003). According to Weinstein *et al.* (2005), health and safety can be addressed at design level by looking at access, material handling, fall protection, material substitution or construction process. Gambatese*et al.* (2005), admonish designers to address safety of construction workers by carefully designing permanent features of a project. The designer's knowledge and acceptance of the concept are two key factors to the implementation of designing for safety (Gambatese *et al.,* 2005).

Weinstein *et al.* (2005) however, outlined that the effectiveness of safety-in-design processes in positively impacting a design depends on many factors associated with the project team members, the scope of the project being designed and built and the nature of the project itself. The major problem so far, according to Gambatese *et al.* (2005), has been designers' responses to safety on informal bases as part of other design processes rather than being part of a formal design-for-safety process.

It can be factually concluded that, consideration of safety in designs will lead to fewer worker injuries and fatalities.

METHODOLOGY

Architects, Air Condition (AC) technicians and building occupants were the subjects of the survey. The survey for architects was structured on three parameters. The first parameter was aimed at establishing the profile of the architects with respect to depth of experience. Experience as used during the survey hinged on the number of years in practice and or the number of buildings worked on. The second parameter was familiarity with the object of study (split air-conditioners) and how they had handled them in personal works. The third parameter brought the rationale or design considerations the architects made in housing outdoor units of split air conditioners.

The survey for AC technicians was tailored in a similar fashion to that of the architects. The only difference was in the third parameter. Here, the third parameter was an assessment of their safety in buildings where protected solid platforms for outdoor units are not provided. For building occupants, maintenance routines for their air conditioners as well as ownership of the units were investigated.

Twenty-four architects and thirteen AC technicians volunteered to participate in the study. The selection of buildings in which occupants were interviewed was restricted to the following roads; Adum Road, Ankobea Street, Church Road and Harper Road. This zone was chosen after a precedent survey revealed the prevalent use of split air conditioners. Additionally, most of the buildings along the aforementioned streets fell under the category of multi-storey buildings hence the choice.

Structured questionnaires were then prepared for each group of participants. The responses thereafter were processed using Statistical Package for Social Scientists version 16 (SPSS V16).

A photo documentation of some design provisions for outdoor units of split air conditioners was also done.

RESULTS AND DISCUSSION

Provisions made in some buildings in Adum

A catalogue of design provisions made for split air conditioners in multi-storey buildings in the study zone was created to evaluate their efficiency and appropriateness.

The three interventions shown in figures 16, 17 and 18 are functionally sound in terms of providing a solid platform for the outdoor units. From the anthropometric point of view though, only that in figure 16 satisfies the requirements. With figure 17 the unit is placed on a ledge which is accessed through a window but has very little space around the unit as well as no protection from potential falls. That shown in figure 18 poses a problem of a possible collapse of the metal platform as well as potential dropping of unit during servicing.

Designers' Responses

Integration of split air conditioners into design: at which phase?

Design comprises many stages. It is through the various stages that the architect churns out and refines his or her ideas to come up with a desirable solution. Lawson (2005) argues thatevery decision made consciously or subconsciously during design affects the resultant product. So if an architect decides or is tasked by a client to design a building that would use air-conditioners, it is certain he or she would consider it at some point in the design, This must include the type of air-conditioner and how it would be integrated into the design as a whole.

Seventy-seven per cent (77%) of the respondents claimed to have considered the integration air

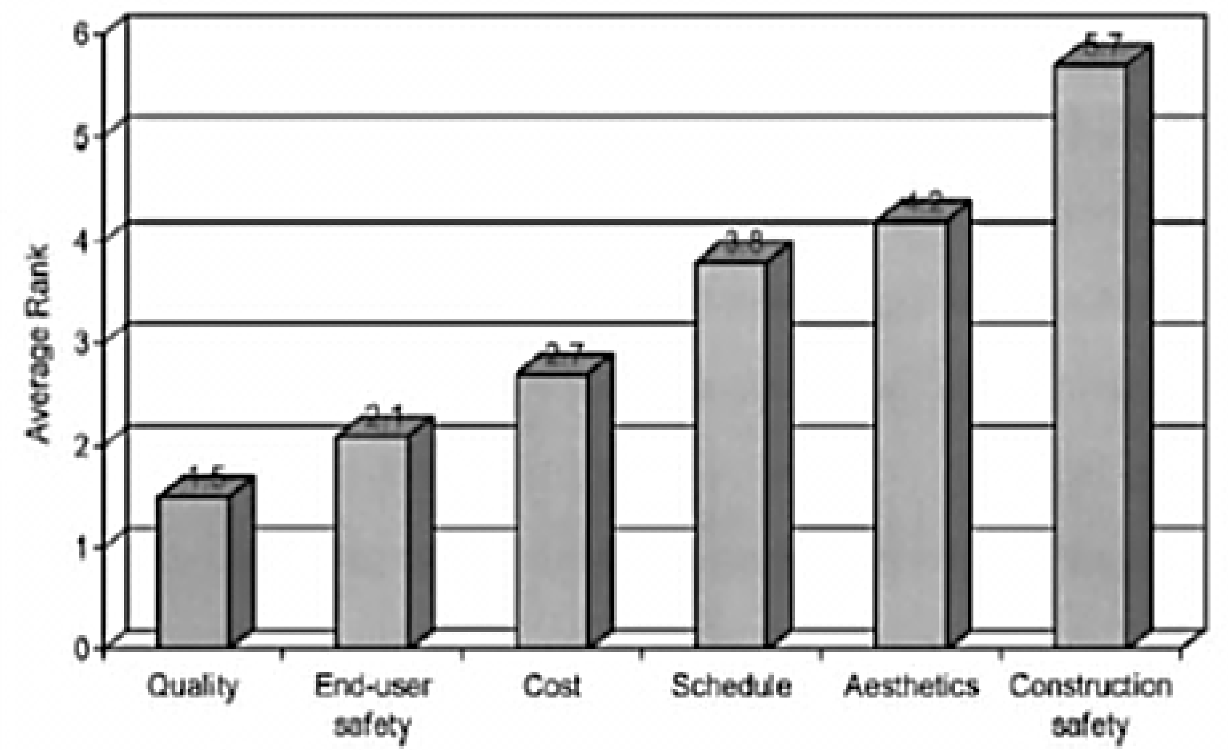


Figure 15. Rank of Priority given to project criteria

(Source: Gambatese et al., 2005)

Figure 16. Outdoor units on veranda at 3^{rd} floor level.

Figure 17. Outdoor unit on a ledge at 1st floor level.

Figure 18. Steel Bracket welded to iron gate frame.

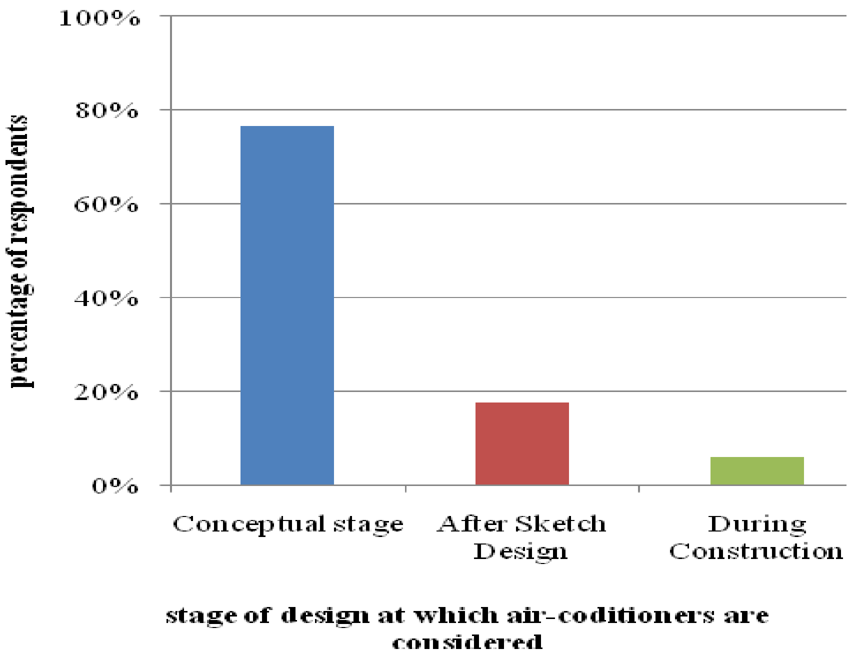


Figure 19. Chart showing the stage of design at which respondents considered ACs

conditioning at the conceptual stage; Eighteen per cent (18%) after the sketch design phase; the remaining five per cent (5%) during the construction stage. This is illustrated in Figure 19.

Design Interventions to accommodate outdoor units

Beyond the phase of design at which air condition integration is done, the kind of intervention is very vital. This in essence is the major highlight of the entire study.Balconies emerged as the most popular spatial option with thirty per cent of respondents stating that as their most used intervention. Blank walls with metal support brackets (BWMSB) according to twenty-five per cent of the designers was their most used options. Service corridors also appeared a popular option with another twenty per cent of the respondents going for them. Roof spaces with fifteen per cent and ledges with ten per cent. This is shown in figure 20.

Rationale behind choice of design intervention

Every decision is backed by intent. These tiny bits of judgements are pieced together to form an overall assessment to reach a solution (Lawson, 2005). Interrogation of a designer's mind for his or her actual intent for a particular decision is often difficult as they often embellish the truth (Lawson, 2004). Respondents were thus limited to three options as seen in figure 21. **'Accessibility for servicing'** proved to be the major factor (46%) that influenced most architects in their choice of provision with **'Aesthetics'** (33%) as the next in rank. **'Safety of technicians'** (21%) was the least considered showing architects have little regard for that particular option.

AC technician's perception of safety

It was discovered from the survey amongst AC technicians that scaffolds were the most used accessories in the absence of well-designed solid platforms to house outdoor units. Ladders emerged as the second most used accessory with ropes and harnesses as the least.

Clearly, these are high-risk high elevation access equipment. Such is what the response was from the survey on the feeling of safety by AC technicians when they work in multi-storey buildings where no proper solid platforms are provided.

Building occupants' response

A big revelation discovered from the survey among building occupants was the fact that tenants provide their own air conditioners. This further led to a bigger discovery that designers of most commercial buildings in the city centre do not factor air conditioning in the first place as it does not come within the clients demands. Thus, provisions for air conditioners are mostly after-thoughts.

Accounts given by some occupants highlighted great inconvenience to business operation when servicing of air conditioners had to be done during working hours. Issues of high cost of scaffolding were also raised by tenants who occupied floors very high from ground level.

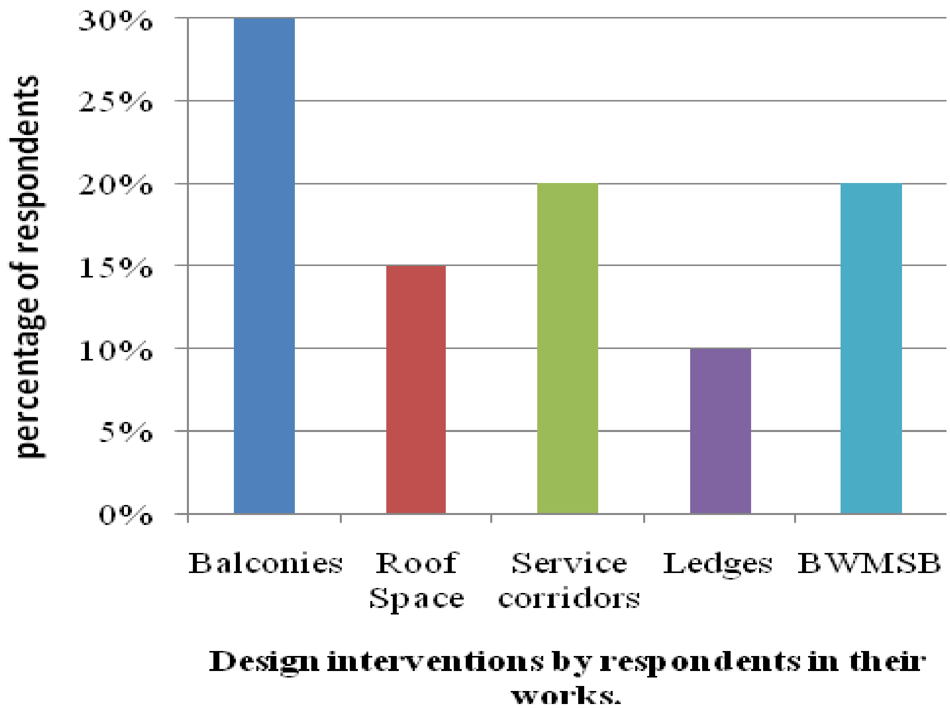


Figure 20. Chart showing Design interventions used by respondents.

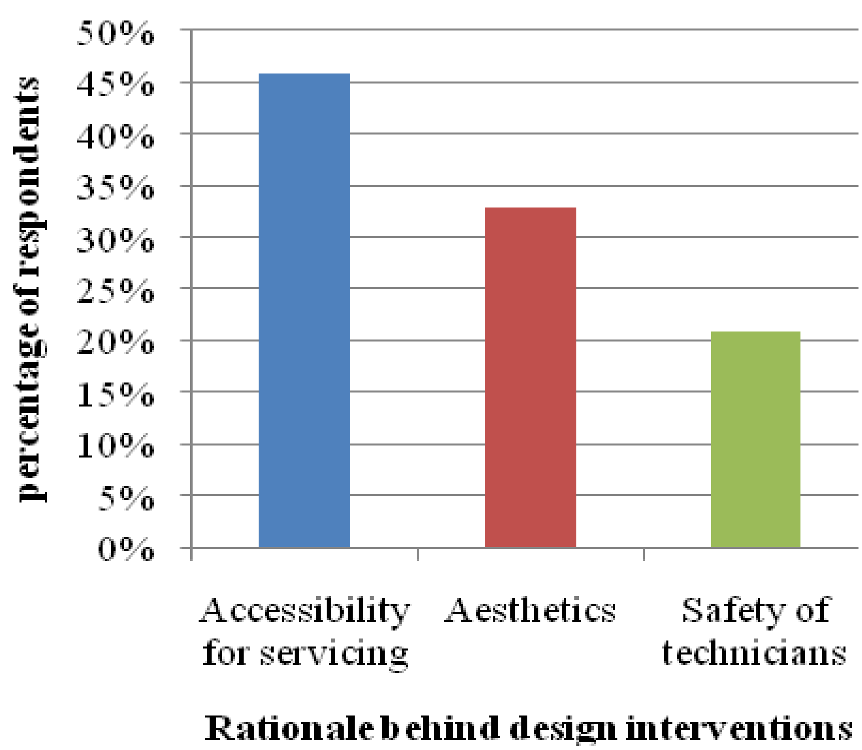


Figure 21. Chart showing rationale behind respondents' choice of intervention for ACs.

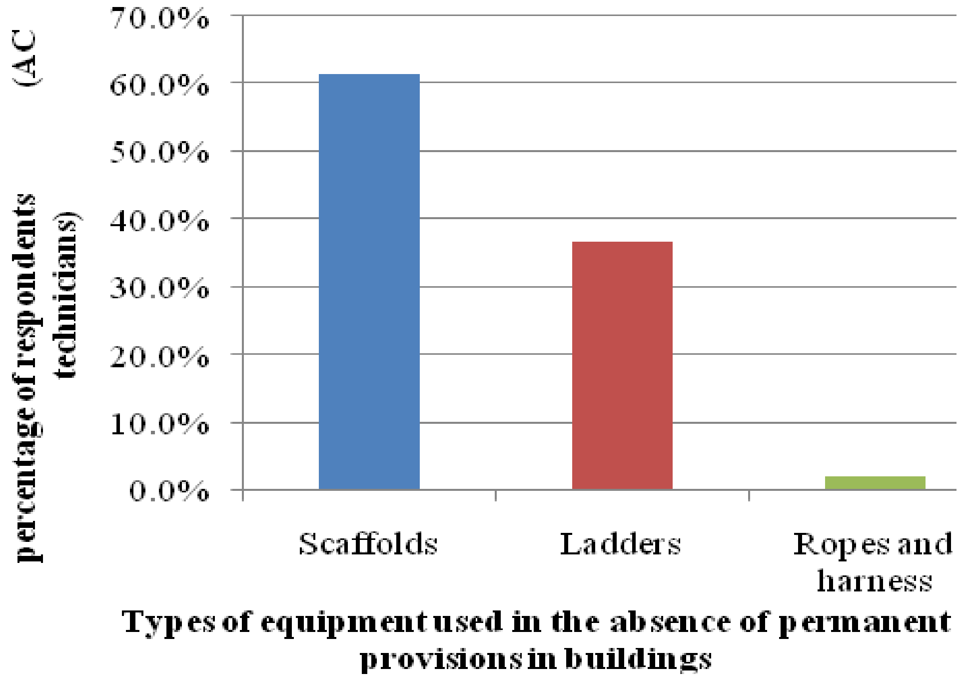


Figure 22. Chart showing improvisation done by AC technicians to reach high elevations

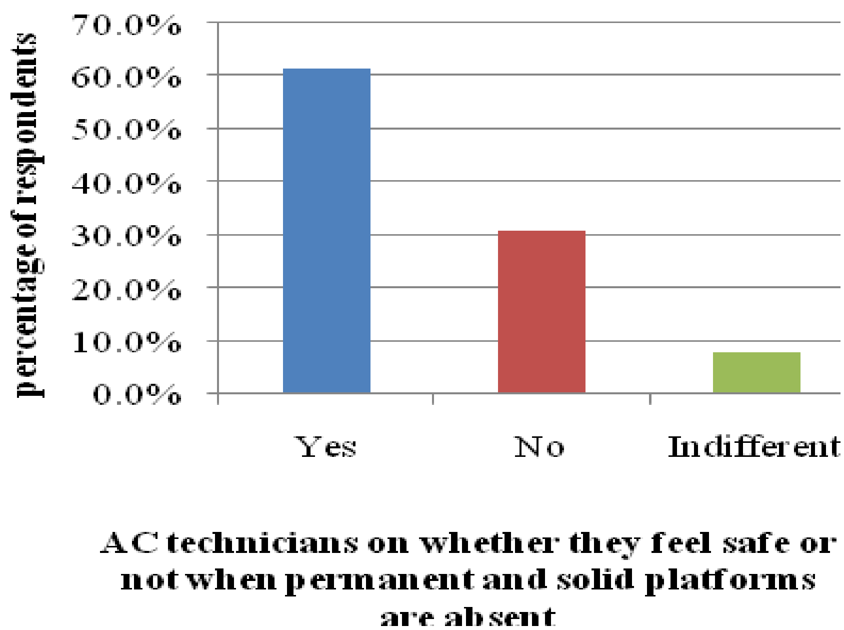


Figure 23. Feeling of safety by AC technicians in absence of solid and stable platform.

A better solution?

Christensen and Manuele (1999) suggest that addressing safety in the conceptual or early design stages, rather than reshuffling the design to meet those needs yields measurable benefits. Also, Weinstein *et al.* (2005) posit that health and safety can be addressed at design level by looking at access, material handling, fall protection, material substitution or construction process. Using these two underpinnings and tying in all the positives drawn from the results, the authors proposed a safe, solid platform for housing outdoor units without compromising on aesthetics.

The design presented below (Figure 24- 27) is a four-storey residential facility located at Ayeduase in Kumasi near the KNUST. The design bases its provisions for the

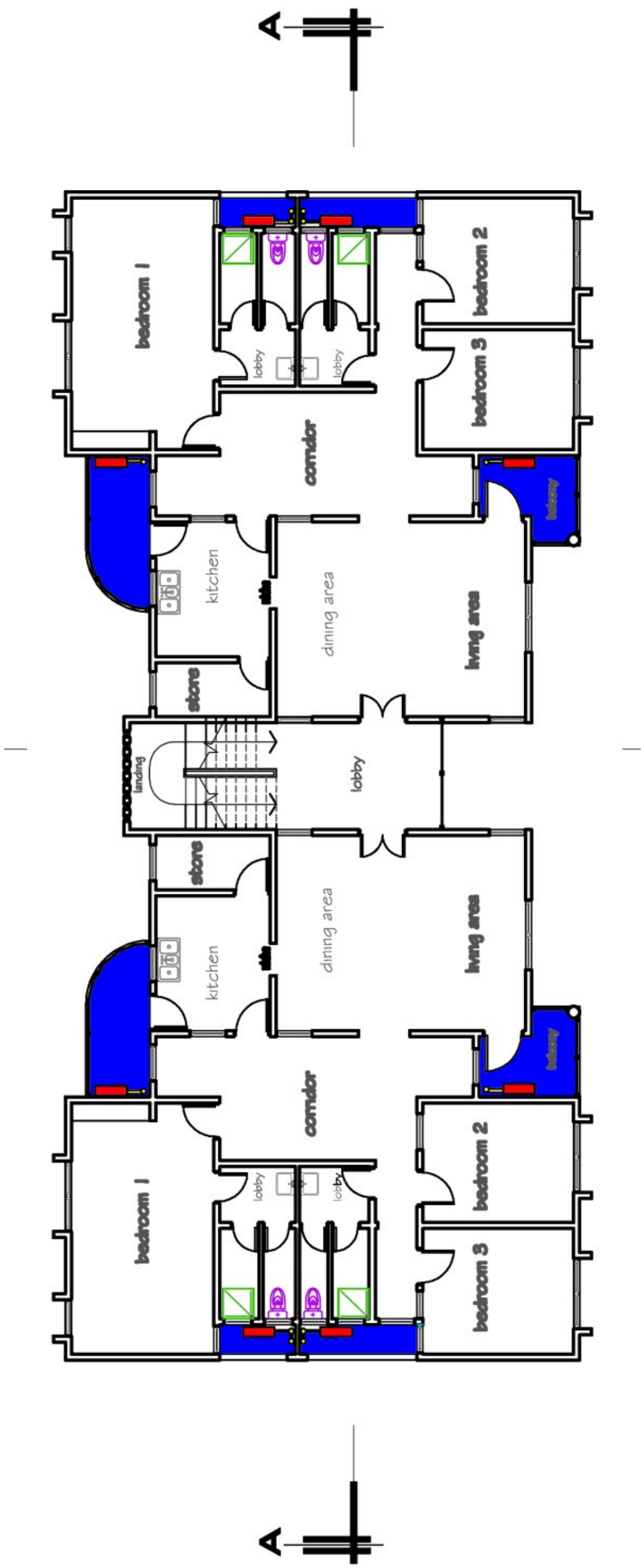


Figure 24. Typical floor plan of the building with service balconies and normal balconies shaded blue.

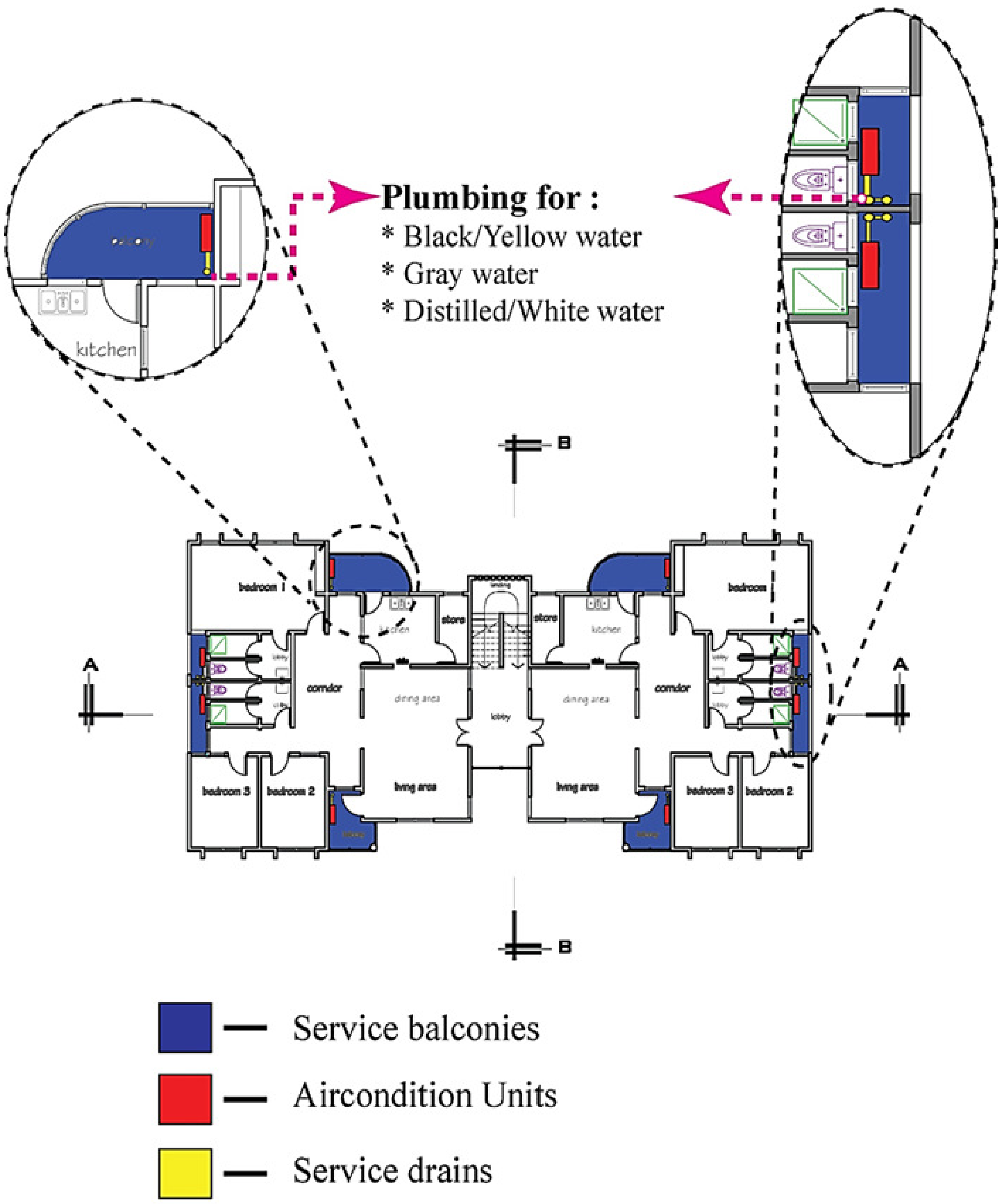


Figure 25. Blow-ups of service balconies

use of split air-conditioners on the concept of raising solid platforms which not only provide for easy access to servicing but also provide safety to technicians. Drain holes and ducts are also provided to enhance the aesthetics of the building as piping work is screened. The presence of drains also allows for easy disposal of condensate from the outdoor units without staining walls. Balconies (highlighted blue in Figure 24) are employed here to provide the kind of solid platform and the necessary screening needed to allow for servicing of outdoor units in a safe environment.

Each balcony is designed with the capability to house an outdoor unit of a split air-conditioner with apt protection provided through balustrades. Section A-A in Fig. shows how units are mounted on service balconies at various levels. Fig. and Fig. further show how steel pipes are used to provide adequate protection to technicians above ground level during servicing of units.

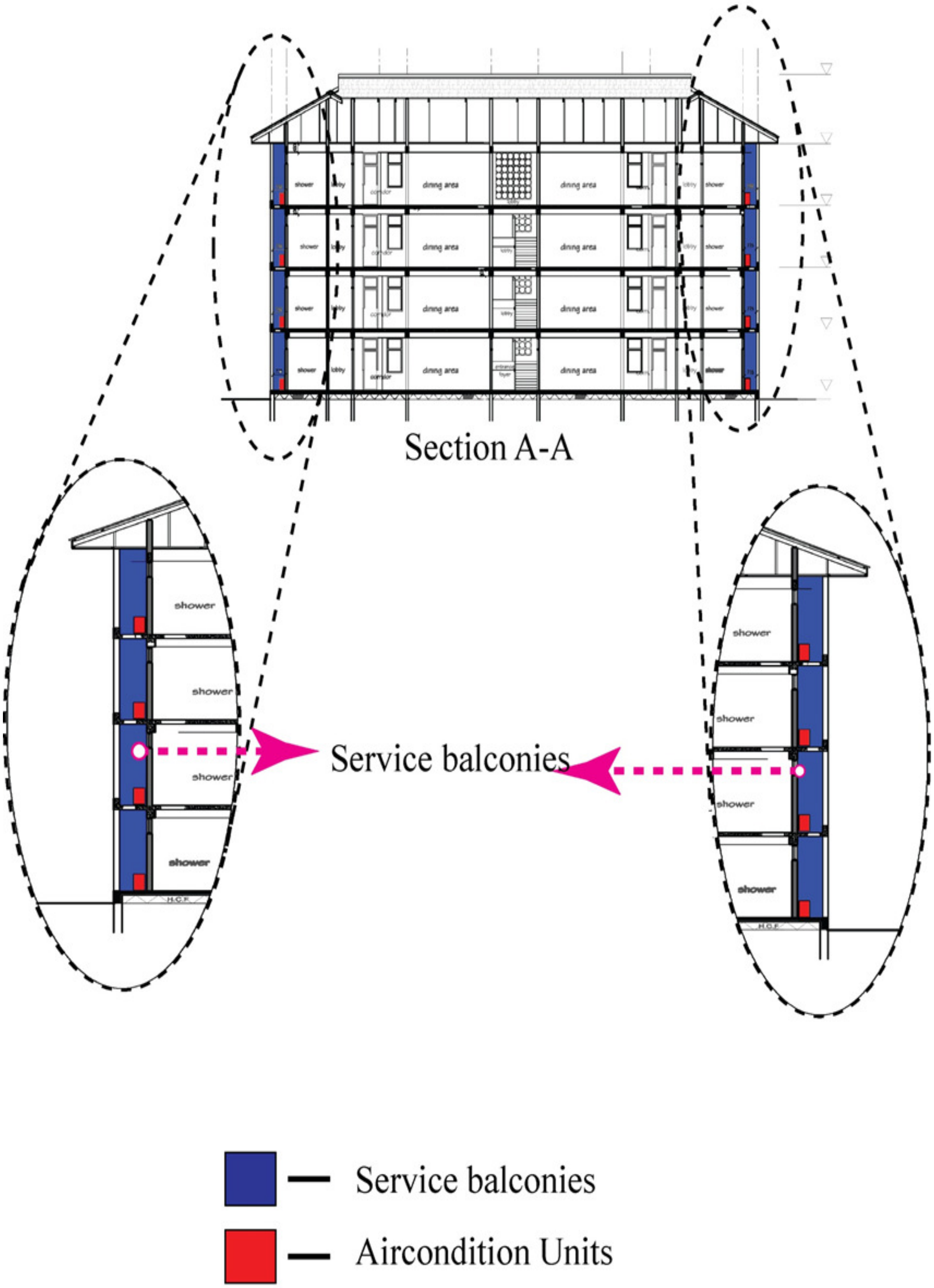
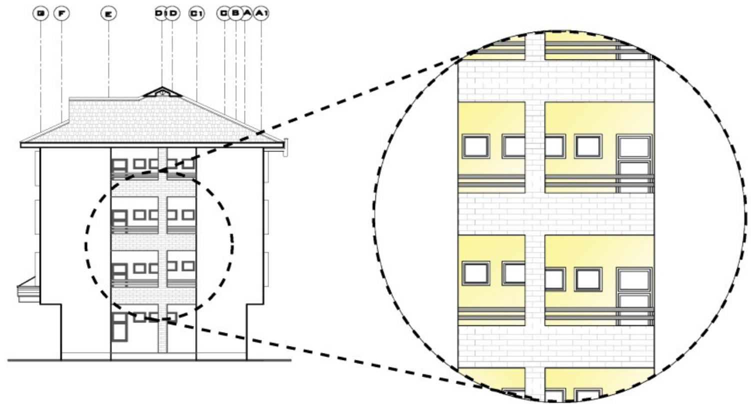
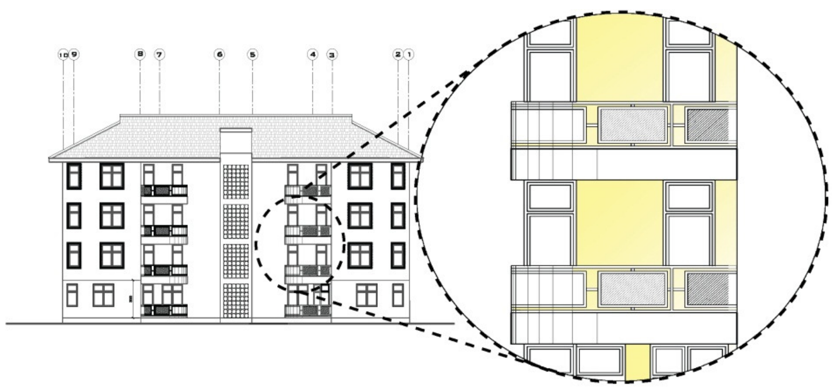


Figure 26. Section showing service balconies and how outdoor units are mounted on upper floors



Side Elevation with Service balconies



Front Elevation with Service balconies

Figure 27. Screened balconies provide safety as well as adequate room for technicians during work on outdoor units.

CONCLUSION

The progress of the study has revealed clearly the need to not only consider aesthetics and accessibility for servicing as the main factors to look at when designing high-rise buildings which would use split air-conditioners. The results vividly point to the fact that majority of AC technicians do not feel safe working on most of the high-rise buildings in Adum and Kumasi as a whole as proper provisions in the form of solid platforms have not been made. The trend is worrying as a substantial number of architects according to the results of the survey still design buildings with blank walls to receive metal support brackets even with the knowledge that individual split air-conditioners would be used. It was discovered tenants provide their own air-conditioners and as such developers may not task architects to design spaces which they see as extraneous to cut cost. Finally, it was established that the cost of maintaining or repairing outdoor units of split air- conditioners was higher in buildings where ladders and scaffolds have to be used in order to get access to outdoor units. These extra costs could have been cut out if architects had designed proper and easily accessible platforms in the building.

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How to cite this article: Essel C., Koranteng C., Asare K.B.A. (2014). Designing for safety during installation and maintenance of split air-conditioners: Case study of commercial buildings in Adum. Educ. Res. 5(8):261-279