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FIRE SAFETY DESIGN OF A 5 STOREY OFFICE BUILDING: FIRE SUPPRESSION

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ABSTRACT

A design of fire suppression system for Asha Office Building was conducted. It is a proposed 5 storey administrative building with a width, length and height of 65m, 47m and 17m respectively as well as a ceiling heights of 3m throughout except ground floor which is 4m. A fire risk assessment of the building was conducted and the outcome revealed a restaurant as the most hazardous component of the building and hence a worst case scenario. A detailed design of a wet sprinkler system installation and operation in the restaurant showed that 15 sprinkler heads are required in 5 range pipes. The spacing between sprinkler heads (S) and sprinkler range pipes (D) are 3.67m and 3.0m respectively. However, only 6 sprinklers will be required to operate in a fire. A total water flow rate and the total pressure required for the operation of the six sprinklers are 444.49 lit/min and 1.7723 bar. Equally, a suction pump pressure of 7.7 bar is required to provide the necessary water volume and pressure to the sprinkler system. A CFAST simulation for a restaurant that is sprinklered revealed a peak temperature of about 400^oC at 350 seconds and began to drop as a result of the effect of sprinklers. But, for an unsprinklered restaurant, a peak temperature of about 900^oC at 700 seconds was attained. Therefore, it can be deduced that flashover will not occur in a sprinklered restaurant since it is less than the recommended temperature for flashover which is about 650^oC. However, the reverse is the case for an unsprinklered restaurant i.e. flashover will occur followed by fully developed fire that will lead to life loss and property damage.

Keywords: Fire, Safety, Suppression

INTRODUCTION

Fire suppression is a form of minimizing the effect of a fire at its earliest stage by confinement to a certain area and extinguishing it (FireTrace, 2023). Fire suppression process began from the point of fire discovery to the point the fire is entirely put out. It encompasses all efforts and actions related to controlling and extinguishing the fire. The presence of fire suppression measures will enable firefighters to confine and quench the fire in controlled situations thereby reducing the chances of a fire spreading to other areas. Most fire suppression systems also comprise of fire detection systems and signalling mechanisms intended to alert building occupants to the problem and prompt responsible persons to take further suppressive actions (STVI, 2023). The detection of a fire often trigger the extinguishing component of the system automatically. However, some fire suppression systems may require manual activation.

An automatic sprinkler system is an active fire protection device which is intended to be operated by the fire itself in order to spray water in an area where it is required. This is in addition to ensuring rapid suppression of the fire with the lowest possibility of damage to property (Verisk, 2023).

Adequate water supply is the most important requirement in sprinkler systems; the water is to be pumped through a network of pipes usually at ceiling levels to a series of sensitive sprinklers which are designed to respond to the heat conditions produced by the fire (Ramachandran, 1999). According to Patterson (1993), correctly designed and installed sprinkler system has been considered by various fire reporting agencies as the most effective single device for the protection of life and property. According to BAFSA (2022) Review involving 53 fire incidents in the UK, sprinklers are 99% efficient in extinguishing or controlling a fire. Additionally, sprinklers are 94% efficient in their ability to operate. The finding of this review reinforces the fact that fire sprinklers have been proven to have a good track record in reducing the impact of fire.

Fire extinguisher is another means of fire suppression commonly used for fire protection during early stages of fire development. In most cases they are a first line of defence and often contain or extinguish a fire thereby preventing costly damage. The prominent contents of extinguishers include water, foam, carbon dioxide, halons and dry chemical powder. In approximately 80% of all fire incidents, a simple portable fire extinguisher is all that is needed to quench the fire (Fireline, 2023). Studies have also shown that 60% of fires go unnoticed and this implies that the fire is not severe and could be handled easily with a fire extinguisher.

In this paper, a design of fire suppression system (sprinklers and fire extinguishers) for Asha Office Building is conducted. The objective of the suppression system in the Building is to give more time to the occupants in the building to escape, to be rescued or evacuated. This can be achieved by lowering fire temperature, lowering the smoke concentration and lowering the rate of fire growth. BS 5306 - 2(1990) and CIBSE Guide E (2010) are to be used as the design guides for the sprinkler system in Asha Office Building.

MATERIALS AND METHODS

The Building

Asha Building is a proposed administrative block in Federal Polytechnic Kaura Namoda, Zamfara State Nigeria. It is a 5 storey building with a width, length and height of 65m, 47m and 17m respectively as well as a ceiling heights of 3m throughout except ground floor which is 4m. The building has ground floor with restaurant (kitchen, store, service and shanks), garage, stores, toilets, 39 offices and a studio. First floor has 36 offices, a council chamber, a rest room and toilets. Second to Fourth floors have 44 offices and toilets each. The length of the corridors at each floor is 46.8 m and

27 m along the width and depth of the building respectively. Also, the ground floor has 3 dead-end corridors of 10.7 m each. The offices are of different sizes depending on the number of people design to occupy such offices. The door sizes scheduled for the following areas are main entrance (3.6mx2.1m), garage (2.4mx2.1m), offices (0.9mx2.1m), stores (0.75mx2.1m) and toilets (0.75mx2.1m) respectively. Also, the windows scheduled for the offices, main entrance, restaurant, and toilets are 1.8mx1.2m, 0.9mx1.600m, 0.9mx1.2m and 0.6mx0.6m respectively. See Figure 1.

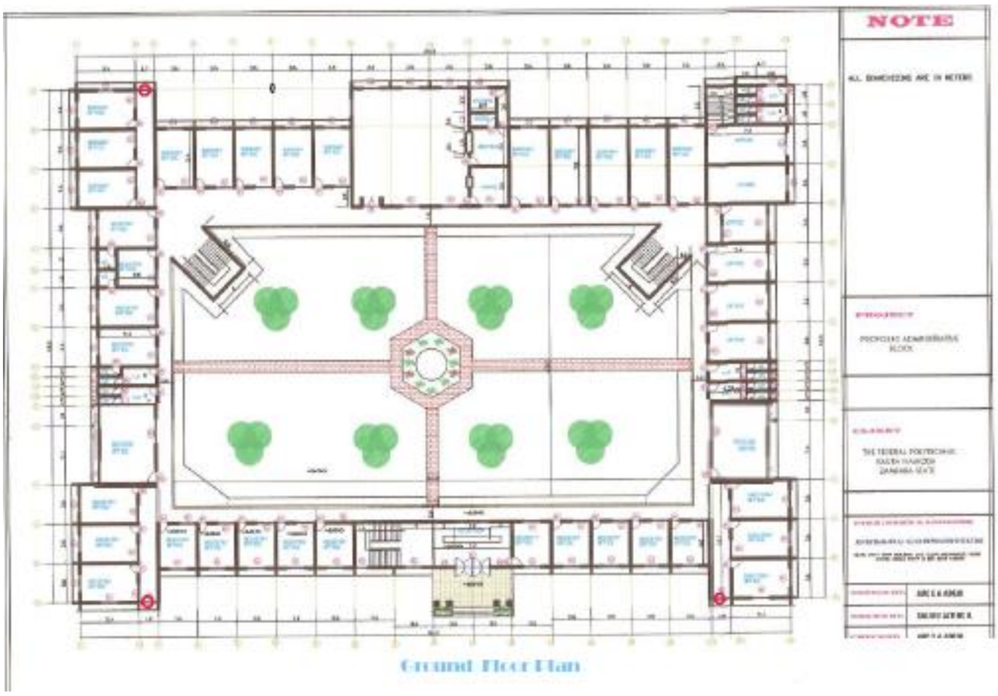


Figure 1: Overview of a layout of a ground floor of Asha Office Building

Key features of the building will be put under consideration. These include the presence of high number of people especially visitors who are not familiar with the building and the possibility of high fire growth from restaurant. With respect to these features, risk assessment was conducted in accordance with Regulatory Fire Reforms (2005). The first step carried out was the identification of fire hazards, people at risk, followed by the identification of source of ignition, thereafter, subsequent steps were followed. The outcome of the risk assessment revealed certain challenges on the design building which include insufficient number of escape routes and exits, absence of fire resistance structure in the architectural building plan and lack of early warning and detection systems. Others are kitchen as an inner room passes through more than one room via a corridor with a longer travel distance as well restaurant as an ancillary to the main building has only one escape route. The restaurant is considered to be the worst case scenario and a Consolidated Model of Fire and Smoke Transport (CFAST) simulation would be used to determine the level of safety and consequential damages as well.

Sprinkler System Design

As a result of the cost implications of sprinkler system (cost of sprinkler heads, cost of water supply, maintenance cost and installation cost), sprinklers are to be only installed in the restaurant (area of possible high fire hazard) while the remaining parts of the building are to be provided with other fire protection measures. The type of sprinkler system to be used in Asha office building is the wet-pipe system in which the pipes are to be filled with water under a certain pressure so that it would be discharged and continue to flow immediately until the system is shut off. Glass bulb is to be used as the sprinklers sensing element designed to operate at 700^oC and colour-coded orange or red so as to be recognized from a distance. In order to enhance life safety, a quick response sprinkler of Response Time Index (RTI) of about 25 and a 'C' value below 0.7 is to be used.

Hazard classification of occupancies has to be known before a sprinkler system can be designed so as to determine the risk to which it must respond to. The restaurant in Asha office building falls into an ordinary Hazard Group I (see Table 3 BS 5306 – 2:1990). This hazard classification would be used to indicate the minimum amount of water (design density mm/litre) which must be provided at the fire in the form of a spray. Also, hazard classification is used to determine the maximum area of the sprinkler system that will be activated by the fire (Assumed Maximum Area of Operation, AMAO in m^2). According to CIBSE Guide E Table 8.1, the minimum design density and AMAO for ordinary Hazard Group I are 5 mm/min and $72m^2$ respectively.

Town mains water supply would serve as the source of water for the sprinkler system in Asha Office Building. The water must be supplied to the facility being protected at the appropriate pressure and volume. In order to achieve this, a booster pump must be connected to the town mains to boost the sprinkler system's pressure to the required level. A tank (a static suction source) would require the booster pump to provide the required volume of water and pressure needed. Water would reach the sprinkler system through a series of underground pipes known as yard mains. A lead-in pipe would deliver water from the yard mains to a vertical pipe (a riser) that brings water from the below ground to ceiling level. Main distribution pipes and distribution pipes distribute the water further into the building (restaurant).

CFAST Simulation

The Consolidated Model of Fire and Smoke Transport, CFAST, is a computer program that fire investigators, safety officials, engineers, architects and builders can use to simulate the impact of past or potential fires and smoke in a specific building environment (CFAST, 2023). CFAST is a two-zone fire model used to determine the evolving distribution of smoke, fire gases and temperature throughout compartments of a building during a fire. The CFAST package includes a smokeview program, which visualizes with coloured, 3-D animations the results of the CFAST simulation of a specific fire's temperatures, various gas concentrations and growth and movement of smoke layers across multi-room structures. The key features organized via tabs of the Software are simulation environment, thermal properties, compartments, wall vents and ceiling/floor vents. Others are mechanical, ventilation, fires, targets, detection /suppression and surface connections. Additionally, visualizations allows specification of one or more 2-D and 3-D visualizations to be added to the simulation for viewing with Smokeview. Finally, the CFAST generates a number of output files in a plain text spreadsheet format. These files capture a snap shot of the modelling data at an instant of time.

RESULTS AND DISCUSSION

Sprinkler Installation and Operation

Sprinkler heads are to be spaced to a certain distance in order to enhance the speed of response and effectiveness of the sprinkler protection. The maximum area coverage for an ordinary hazard is 12 m^2 per sprinkler while the maximum allowable distance between sprinkler heads for standard spacing is 4 m for ordinary hazard (CIBSE Guide E, 2010). The detailed calculations on the required number of sprinklers, sprinkler layouts, pipe sizing and tank capacity are given subsequently.

Required Number of Sprinklers

Length of the restaurant, L = 11m,
Width of the restaurant, W = 15m,
Area of the restaurant = 165m^2.
Maximum area of sprinkler heads (MACS) = 12 m^2 (BS 5306 Part 2).
Spacing between sprinklers on range pipes (S) = 4 m (BS 5306 Part 2).
Spacing between ranges on pipes (D) = 4 m (BS 5306 Part 2).
Minimum required number of sprinklers = Area of restaurant/MACS = 14 sprinklers.
The number of sprinkler heads required, N1 = L/S = 3 sprinklers per range.
The exact value of S = L/N1 = 3.67 m.
The value of D = MACS/ exact value of S = 3.27
The required number of ranges, N2 = W/3.27 = 5 ranges.
The exact value of D = W/ number of ranges = 3.0 m.
Therefore, the required numbers of sprinklers in restaurant are N1 x N2 = 3 x 5 = 15 sprinklers.
Also, the exact value of S and D are 3.67 m and 3.0 m respectively.
Figure 2 below shows the typical layout of sprinklers in the restaurant.

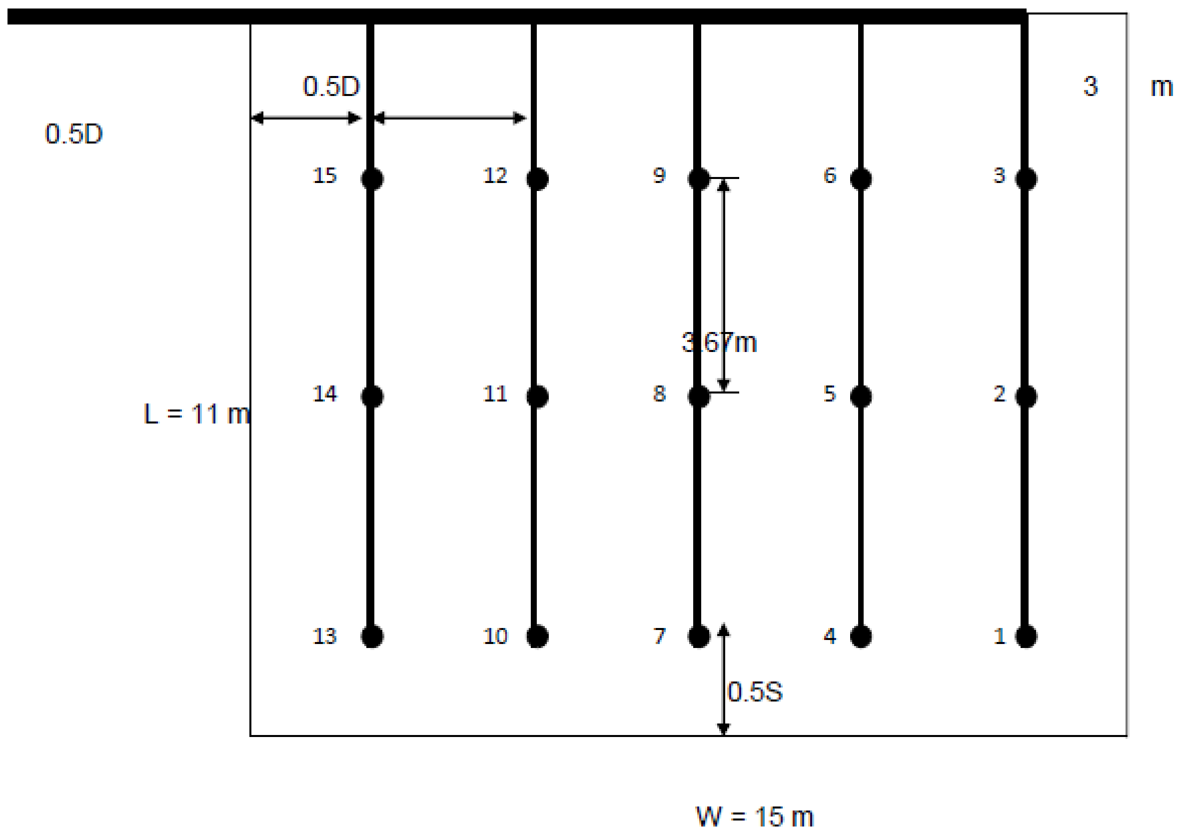


Figure 2: Sprinkler layout (three end side with an end feed) for the restaurant.

Pipes Sizing and Water Supplies

Fully hydraulically method is to be used in determining pipe sizing and water supplies which is based on the design density and AMAO. The required number, N of sprinklers required to be operated in a fire can be obtained using the formula below:

N = Assumed maximum area of operation (AMAO) / maximum area coverage per sprinkler head

N = 72 m^2 (Table 7 BS 5306) / 12 m^2 (Table 70 BS 5306)

Therefore, 6 sprinkler heads are required to operate in a fire.

Also, the flow rate of water per sprinkler head, Q, can be obtained by multiplying the minimum design density (5 mm/min) and AMAO (72 m^2) and divided through by the number of sprinkler requires to operate (6).

That is (5 mm/min x 72 m^2) / 6 sprinkler head = 60 litre/minutes.

The types of pipes to be used is a galvanized steel, the details of the main distribution and distribution pipes as sourced from Table 36 of BS 5306 are:

Main distribution pipe, nominal size = 32, mean size = 35.80 mm and k value = 2.33 $x10^{-6}$

Distribution pipe: nominal size = 25, mean size = 27.14 mm and k value = 8.99 $x10^{-6}$

The pressure flow requirements in the pipes can be calculated using a formula sourced from Phylakhtou (2008) as:

$Q = k \times P^{1/2}$

Where Q = water flow through a sprinkler orifice in lit/min;

k = mean value of k factor which is 80 for a sprinkler nominal orifice size of 15mm for ordinary hazard;

P = pressure at the entry to the sprinkler shank in bar.

Also, pipe friction losses through the system can be obtained using Hazen – Williams's formula as:

$P = k \times L \times Q^{1.85}$ (Table 36 of BS 5306)

Where P = pressure loss per metre length of pipe – in bar;

k = a constant for the size, type and condition of pipe;

L = length of the pipe in metre;

Q = the flow rate through the pipe in litre/ minute.

Figure 3 below shows the number of sprinklers (1 - 6) to be operated in a fire and flow of water as well as pressure loss along pipes.

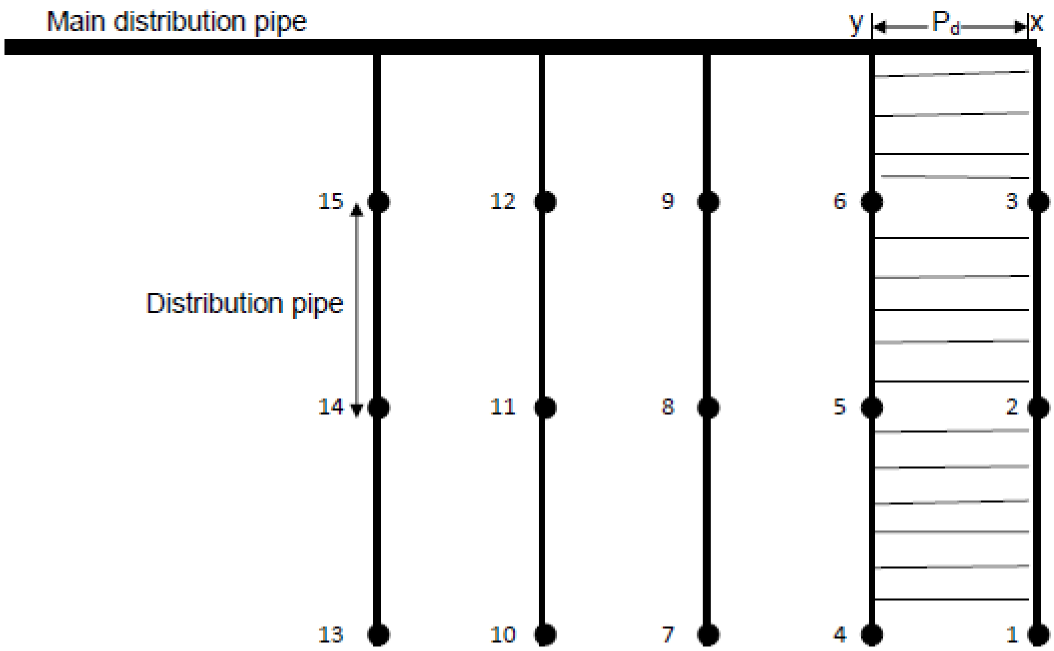


Figure 3: Number of sprinklers to be operated in a fire, flow of water and pressure losses along the pipes.

Considering the flow of water from the most remote sprinkler 1, the required pressure, pressure loss and water flow rate through the pipe for sprinklers 1 to 6 can be calculated as follows:

Sprinkler 1: (range 1)

The required pressure, P_1 can be obtained using $Q_1 = k\ P_1^{0.5}$

Where Q_1 = water flow rate in a sprinkler 1 which is 60 lit/min;

k = mean value of k factor for ordinary hazard which is 80

Therefore, P_1 = 0.5625 bar.

Sprinkler 2

The pressure loss between sprinkler 1 and 2, P_{1-2} can be obtained using a formula:

$P_{1-2} = k \times L \times Q^{1.85}$

Where k = 8.99 x 10^{-6} (a constant for a galvanized steel of 25 nominal size and d = 27.14 mm);

L = length of a pipe between sprinkler 1 and 2 which is 3.67 m

Q_1 = water flow rate in a sprinkler 1 which is 60 lit/min;

Therefore, the pressure loss between sprinkler 1 and 2, P_{1-2} = 0.064 bar

The required pressure in sprinkler 2, $P_2 = P_1 + P_{1-2}$ = 0.6265 bar.

Water flow rate in sprinkler 2, $Q_2 = k\ P_2^{0.5} + Q_1$ = 123.32 lit/min (note: k = 80).

Sprinkler 3:

The pressure loss between sprinklers 2 to 3, P_{2-3} can be obtained using the formula:

$P_{2-3} = k \times L \times Q^{1.85}$

Where k = 8.99 x 10^{-6} (a constant for a galvanized steel of 25 nominal size and d = 27.14 mm);

L = length of a pipe between sprinkler 2 and 3 which is 3.67 m

Q_2 = water flow rate in a sprinkler 2 which is 123.32 lit/min;

Therefore, the pressure loss between sprinkler 2 and 3, P_{2-3} = 0.2437 bar

The required pressure in sprinkler 3, $P_2 = P_2 + P_{2-3}$ = 0.8702 bar.

Water flow rate in sprinkler 3, $Q_3 = k P_3^{0.5} + Q_1 = 197.95$ lit/min (note: k = 80).
Pressure loss between sprinkler 3 and x, P_{3-x} can be obtained using a formula:
$P_{2-3} = k \times L \times Q^{1.85}$

Where $k = 8.99 \times 10^{-6}$ (a constant for a galvanized steel of 25 nominal size and d = 27.14 mm);
L = length of a pipe between sprinkler and x which is (3.67 m) /2 = 1.835 m
Q_3 = water flow rate in a sprinkler 3 which is 197.95 lit/min;
Therefore, the pressure loss between sprinkler 3 and x, P_{3-x} = 0.2924 bar
The required pressure at x, $P_x = P_3 + P_{3-x} = 1.1626$ bar.
Pressure loss at the 90º junction, P_{90} (assuming 90º screw elbows, length pipe L at 25 nominal size is 0.77 m Table 37 of BS 5306).
$P_{90} = k \times L \times Q_3^{1.85}$
where $k = 8.99 \times 10^{-6}$ (a constant for a galvanized steel of 25 nominal size and d = 27.14 mm);
L = length of a pipe at 90º = 0.77 m (Table 37 of BS 5306);
Q_3 = water flow rate in a sprinkler 3 which is 197.95 lit/min;
Therefore, the pressure loss at 90^0, P_{90} = 0.1227 bar.
Pressure drop within the main distribution pipe from range 1 to 2 can be obtained using a formula:
$P_d = k \times L \times Q_3^{1.85}$
Where $k = 2.33 \times 10^{-6}$ (a constant for a galvanized steel of 32 nominal size and d = 35.80 mm);
L = length of the main distribution pipe from range 1 to 2 which is 3.0 m;
Q_3 = water flow rate in a sprinkler 3 which is 197.95 lit/min;
Therefore, the pressure drop from within the main distribution pipe, P_d = 0.1239 bar.
The total pressure required from range 1 to 2 is given as $P = P_x + P_{90} + P_d = 1.4092$ bar

Sprinkler 4: (range 2)
Assuming a flow rate of water in a sprinkler head 4, Q_4, to be 75 lit/min, the required pressure can be obtained using a formula:
The required pressure, P_4 can be obtained using $Q_4 = k P_4^{0.5}$
Where Q_4 = water flow rate in a sprinkler 4 which is 75 lit/min;
k = mean value of k factor for ordinary hazard which is 80;
Therefore, P_4 = 0.8789 bar.
Sprinkler 5
The pressure loss between sprinkler 4 and 5, P_{4-5} can be obtained using a formula:
$P_{4-5} = k \times L \times Q^{1.85}$
Where $k = 8.99 \times 10^{-6}$ (a constant for a galvanized steel of 25 nominal size and d = 27.14 mm);
L = length of a pipe between sprinkler 1 and 2 which is 3.67 m;
Q_4 = water flow rate in a sprinkler 4 which is 75 lit/min;
Therefore, the pressure loss between sprinkler 4 and 5, P_{4-5} = 0.096 bar;
The required pressure in sprinkler 5, $P_5 = P_4 + P_{4-5}$ = 0.9749bar.
Water flow rate in sprinkler 5, $Q_5 = k P_5^{0.5} + Q_4 = 153.99$ lit/min (note: k = 80).
Sprinkler 6:
The pressure loss between sprinklers 5 to 6, P_{5-6} can be obtained using the formula:
$P_{5-6} = k \times L \times Q^{1.85}$
where $k = 8.99 \times 10^{-6}$ (a constant for a galvanized steel of 25 nominal size and d = 27.14 mm);
L = length of a pipe between sprinkler 5 and 6 which is 3.67 m;
Q_5 = water flow rate in a sprinkler 5 which is 153.99 lit/min;
Therefore, the pressure loss between sprinkler 5 and 6, P_{5-6} = 0.3634 bar.
The required pressure in sprinkler 6, $P_6 = P_5 + P_{5-6} = 1.3383$ bar.
Water flow rate in sprinkler 6, $Q_6 = k P_6^{0.5} + Q_5 = 246.54$ lit/min (note: k = 80).
Pressure loss between sprinkler 6 and y, P_{6-y} can be obtained using a formula:
$P_{6-y} = k \times L \times Q^{1.85}$
where $k = 8.99 \times 10^{-6}$ (a constant for a galvanized steel of 25 nominal size and d = 27.14 mm);
L = length of a pipe between sprinkler and x which is 3.67 m/2 = 1.835 m
Q_6 = water flow rate in a sprinkler 6 which is 246.54 lit/min;
Therefore, the pressure loss between sprinkler 6 and y, P_{6-y} = 0.4340 bar
The required pressure at y, $P_y = P_6 + P_{6-y} = 1.7723$ bar.
Total water flow for the six sprinklers would be = total flow of in range 1 + total flow in range 2
Q_{total}= 197.95 lit/min + 246. 54 lit/min = 444.49 lit/min
Total pressure = 1.7723 bar

Water Velocity and Tank Capacity
The velocity of the water flow in the main distribution pipe, V can be obtained using a formula:
$V = Q_{total}$ / Area of the main distribution pipe.
where Q_{total} = total flow water in the six sprinklers which is 444.49 lit/min = 0.00742 m^3/ s; Area of the main distribution pipe of a 35.8 mm diameter = $(3.143 \times 0.0358^2)/ 4 = 0.001\ m^2$.
V = 7.42 m/s.
This velocity is appropriate since it has not exceeded 10 m/s as stated in BS 5306 15.3.2.

The tank capacity can be obtained using a formula sourced from Table 24 of BS 5306 as:
Tank capacity (volume) = 0.03 Q_{total}.
where Q_{total} = 444.49 lit/min;
Therefore, the water tank volume required = 13.33 m^3.

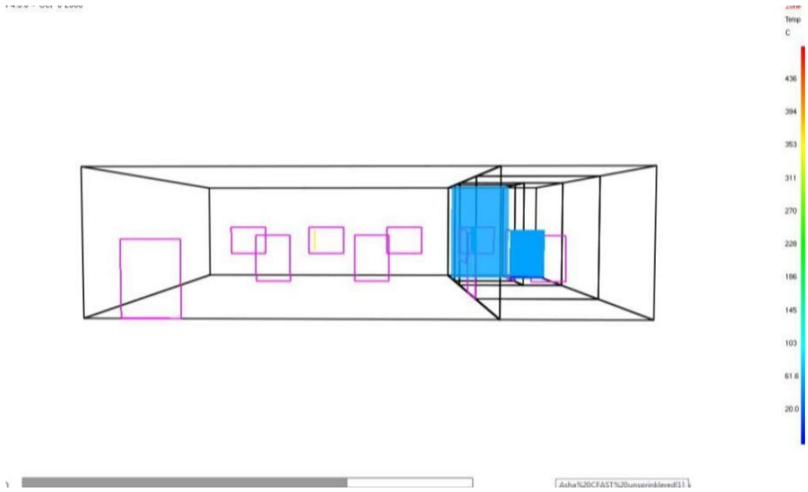
Suction Pump Pressure Requirement
A static suction pump which enables a fire pump to provide a necessary water volume and pressure to the sprinkler system must not exceed 10 bar (BS 5306 Clause 17.4.6.1). The suction pressure can be calculated by summing up:
$P_{suction} = P_{total} + P_{height} + TP_{loss}$
where: P_{total} = total required pressure within the six sprinklers which is 1.7723 bar;
P_{height} = required pressure loss for a riser of 5 m height which is 0.5 bar (since BS 5306 recommends 10 m riser to produce 1 bar);
TP_{loss} =total pressure losses in all the pipes (riser, main distribution pipe and distribution pipes), these can be obtained using Hazen William's equation:
$P = k \times L \times Q^{1.85}$
Where k = a constant for a particular pipe size;
L = pipe length in metre;
Q = total water flow rate which is 444.49 lit/min.

For a riser pipe, $k = 9.90 \times 10^{-8}$ (for a 65 nominal size and a mean size of 68.50 mm, Table 36 of BS 5306);
L = 5 m (estimated);
Q = 444.49 lit/min.
Therefore, pressure loss in a riser = 0.039 bar.

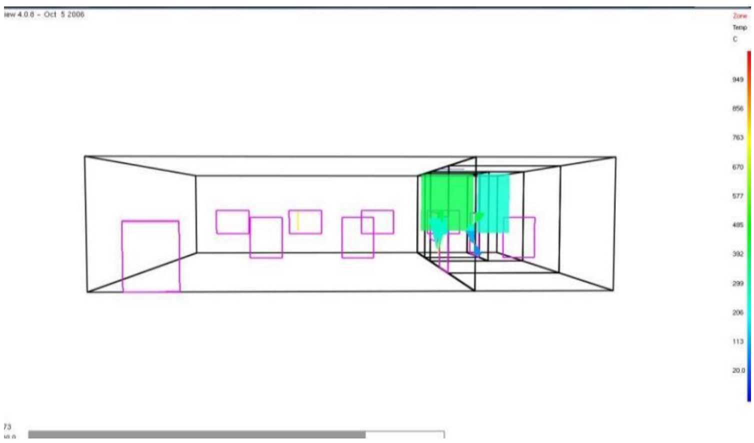
For a main distribution pipe, $k = 2.33 \times 10^{-6}$ (for a 32 nominal size and a mean size of 35.80 mm, Table 36 of BS 5306);
L = 15 m (estimated);
Q = 444.49 lit/min.
Therefore, the pressure loss in the main distribution pipe = 2.767 bar.
For the distribution pipes, $k = 8.99 \times 10^{-6}$ (for a 25 nominal size and a mean size of 27.14 mm, Table 36 of BS 5306);
L = 3.67 m;
Q = 444.49 lit/min.
Therefore, the pressure loss in the distribution pipes = 2.612 bar
The total pressure losses in all the pipes, TP_{loss} = 5.418 bar.
Finally, the suction pump pressure, $P_{suction}$ = 7.7 bar. This shows that the pump suction pressure has not exceeded 10 bar.

CFAST Modelling to Determine the Effectiveness of Sprinklers

Consolidated Fire and Smoke Transport (CFAST) model is a zone model that forecasts the effect of a compartmented fire on temperatures, smoke layer height and concentration of toxic gases in a building structure (CFAST, 2023). In Asha office building, CFAST modelling has been used to determine the effectiveness of sprinklers on fire in the restaurant. The compartments that have been modelled are the restaurant, shank, service, store, corridor and kitchen. A corner fire (in the kitchen) has been placed so as to determine the effects of fire products (heat and smoke) to the occupant (target) likely to be in the restaurant. Figure 4 shows the smoke view of the CFAST modelling for both sprinklered (4a) and unsprinklered (4b) restaurant so as to compare the suppressive effect of sprinklers on fire.



(a) Smoke view of a fire in a sprinklered simulation.



(b) Smoke view of a fire in an unsprinklered simulation

Figure 4: Smoke view of a fire for both sprinklered and unsprinklered simulations using CFAST

From the smoke view simulations above, the sprinklered simulation from (a) above has a zone temperature of about 400^{o}C while the zone temperature for an unsprinklered simulation (b) above is 900^{o}C. This sharp disparity in temperature is as a result of the presence of sprinklers in (a) above. The following data such as layer temperature, living pressure, floor target, fire size, effect of CO, O_2, HCN, HCL, gas radiation, total flux, inflow and outflow among others were generated as a result of the CFAST simulation for the two scenarios.
From the above data generated, temperature is the basic fire effect that leads to the remaining effects such as smoke toxicity, fire size etc. As a result of this, upper layer temperature out of many data has been chosen to analyse the effectiveness of sprinklers in the restaurant. Figure 5 below shows the upper layer temperature for both sprinklered and unsprinklered restaurant.

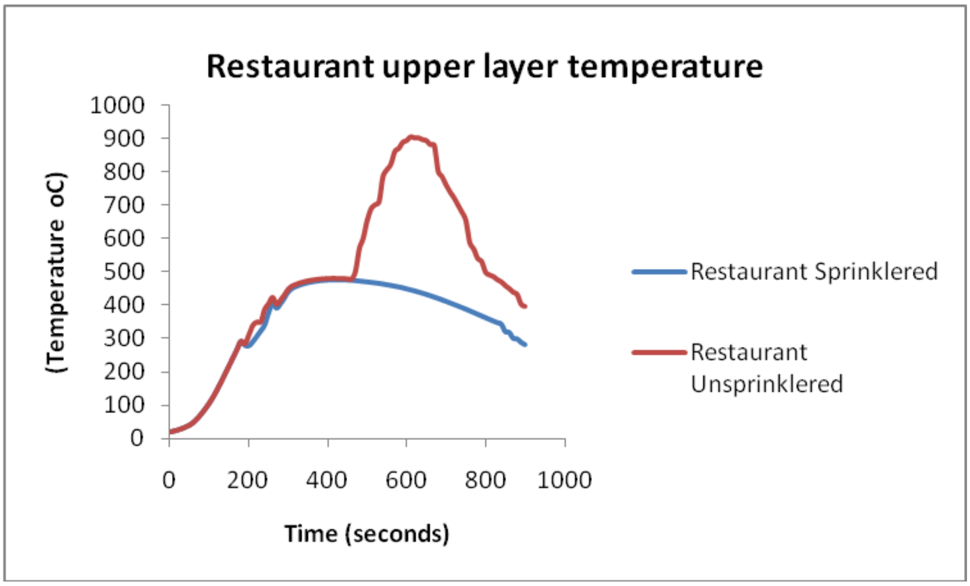


Figure 5: Comparison between sprinklered and unsprinklered restaurant with respect to upper layer temperature

From the Figure 5, it can be seen that for a restaurant that is sprinklered, the fire temperature has risen from zero second and zero temperature to about 400°C at 350 seconds and started dropping as a result of the effect of sprinklers. But, for an unsprinklered restaurant, the fire temperature begins to rise from zero level and reached its peak temperature of about 900°C at 700 seconds. Therefore, it can be deduced that flashover will not occur in a sprinklered restaurant since it is less than the recommended temperature for flashover which is about 650°C. However, the reverse is the case for an unsprinklered restaurant i.e. flashover will occur followed by fully developed fire that will lead to life loss and property damage.

Fire Suppressant System (Carbon dioxide - CO_2)

A carbon dioxide (CO_2) fire suppressant system operates by discharging carbon dioxide onto a fire. It works by displacing the oxygen the fire depends upon to sustain burning, and it is mainly used to extinguish fires in which the source of the fuel is a flammable liquid or gas. Carbon dioxide fire extinguishers are a very common form of fire extinguisher and are used in situations where traditional water and foam fire extinguishers or dry chemical fire extinguishers are not suitable. A carbon dioxide fire suppressant is referred to as a "clean extinguisher" and leaves no residue on the area it is applied. Hence, this extinguisher will be most suitable for use in the restaurant of Asha office building.

The basic quantity of CO_2 required in the restaurant is obtained by multiplying the volume of the restaurant with the volume factor which is 0.80 kg CO_2/m^3 (Phylakhtou, 2008).

The volume of the restaurant, V is obtained from the following parameters:

L = length of the restaurant which is 11 m;

W = width of the restaurant which is 15 m;

H = ceiling height of the restaurant which is 4 m.

$V = L \times W \times H = 660\ m^3$.

The basic quantity = 660 m^3 x 0.80 kg CO_2/m^3 = 528 kg.

Assuming that the area of the uncloseable vent = 2 m^2, an additional 5 kg of CO_2 would be required for each 1 m^2 (Phylakhtou, 2008). Thus, 10 kg of CO_2 is to be added to the basic quantity which is 528 kg + 10 kg = 538 kg.

Also, an additional requirement of CO_2 is needed due to the presence of force ventilation. The volume required to be removed per minute is 43 m^3 is calculated as

$V = (M_{smoke}\ T)/(\rho_o T_o)$ (PD 7974-2, 2002)

where V = volumetric flow rate in m^3/s,

M_{smoke} = mass flow rate of smoke which is 32 kg/s,

T = total smoke temperature which is 490 K (217°C),

ρ_o = ambient air density which is 1.2 kg/m^3,

T_o = ambient temperature which is 303 K (30°C),

Therefore, the volumetric flow rate is 43 m^3/s

This volume is to be multiplied by the volume factor 0.8 kg CO_2/m^3 i.e. 43 m^3 x 0.8 kg CO_2/m^3 = 34.4 kg. This value is to be multiplied by a material conversion factor for a paint which is 1 (Phylakhtou, 2008).

34.4 kg x 1 = 34.4 kg

Therefore, the total weight of CO_2 required in the restaurant = 538 kg + 34.4 kg = 572.4 kg

CONCLUSION

Fire suppression is a component of fire safety design of a building which is aimed at minimising the effect of a fire at its earliest stage by confinement to a certain area and subsequently quenching. The bulk of fire suppression systems involve fire detection and signalling mechanisms which are activated either automatically or manually in order to alert an occupant of the affected building to escape or prompt responsible persons for the suppression of such fire to swing into action. An automatic sprinkler system and fire extinguishers are the major active fire suppression measures put in place to extinguish fire at its infancy.

A design of fire suppression system (sprinklers and fire extinguishers) for Asha Office Building was conducted. It is a proposed 5 storey administrative building with a width, length and height of 65m, 47m and 17m respectively as well as a ceiling heights of 3m throughout except ground floor which is 4m. A fire risk assessment of the building was conducted and the outcome revealed a restaurant as the most hazardous component of the building and hence a worst case scenario. A Consolidated Model of Fire and Smoke Transport (CFAST) simulation was used to determine the level of safety and consequential damages as well in the restaurant.

A detailed design of a wet sprinkler system installation and operation in the restaurant showed that 15 sprinkler heads are required in 5 range pipes. The spacing between sprinkler heads (S) and sprinkler range pipes (D) are 3.67m and 3.0m respectively. However, using a fully hydraulically method in determining pipe sizing and water supplies which is based on the design density and AMAO, only 6 sprinklers will be required to operate in a fire. The total water flow rate and the total pressure required for the operation of the six sprinklers are 444.49 lit/min and 1.7723 bar. The velocity of the water flow in the main distribution pipe is 7.42 m/s. This velocity is appropriate since it has not exceeded 10 m/s as stated in BS 5306. Also, a water tank capacity of 13.33 m^3 by volume is required. Equally, a suction pump pressure of 7.7 bar is required to provide the necessary water volume and pressure to the sprinkler system. A CO_2 extinguisher was considered most suitable for use in the restaurant and a total of 572.4 kg is required to suppress a fire.

A CFAST simulation for a restaurant that is sprinklered revealed a peak temperature of about 400^{o}C at 350 seconds and began to drop as a result of the effect of sprinklers. But, for an unsprinklered restaurant, a peak temperature of about 900^{o}C at 700 seconds was attained. Therefore, it can be deduced that flashover will not occur in a sprinklered restaurant since it is less than the recommended temperature for flashover which is about 650^{o}C. However, the reverse is the case for an unsprinklered restaurant i.e. flashover will occur followed by fully developed fire that will lead to life loss and property damage.

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