A STUDY ON FIRE SAFETY OF READY MADE GARMENTS (RMG) IN BANGLADESH

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DECLARATION

The work performed in this thesis for the achievement of the degree of Bachelor of Science in Civil Engineering is "A STUDY ON FIRE SAFETY OF READY MADE GARMENTS (RMG) IN BANGLADESH ".The whole work is carried out by the authors under the strict and friendly supervision of Dr. Enamur Rahim Latifee, Associate Professor, Department of Civil Engineering, Ahsanullah University of Science and Technology, Dhaka, Bangladesh.

Neither this thesis nor any part of it is submitted or is being simultaneously submitted for any degree at any other institutions.

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TO OUR

BELOVED PARENTS AND TEACHERS

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ABSTRACT

This study is specifically concerned with the industrial fire safety, especially of Ready Made Garments sector in Bangladesh. It mainly focused on fire safety conditions of our garments sector, accidents those brought havoc & indescribable damage to the victims, reasons behind these accidents, human behavior about fire accidents, various fire resisting construction materials, codes followed by the industrial (RMG) sector in Bangladesh during construction, and different extinguisher systems for fire protection.

Textile & Ready Made Garments contributes maximum currency in our economy. Along with bringing blessing for the nation, textile and RMG industry also hold the record of experiencing some worst industrial accidents in the country. Taking advantage of poor surveillance of concerned authorities, rules laws and codes are often violated in construction sector of our country and factory buildings are no exception. Each new incident of fire and related damage adversely affects the reputation of the industry abroad. These incidents raise questions about the effectiveness of existing fire prevention and fire fighting rules, regulations and practices in our RMG sector.

To reduce the fire hazard in RMG we should look into the issue in a holistic approach both from planning and design point of view. Because only a well-designed industry will be able to ensure the ultimate fire safety. Besides this, arrangement of keeping fire detection and fire extinguishers systems in all the garments must be ensured and make the garments workers concerned about fire safety by providing information and required fire drill to reduce the loss.

The empirical part of this study was conducted on a survey of human response regarding fire incidents .Data obtained from the survey gave a projection of human knowledge on fire related questionnaire. But due to having some limitations the survey was conducted among the students of our institution instead of garments workers. Finally this study illustrated a number of recommendations about fire safety in all possible ways to bring a positive change in the garments industries and round up with conclusion.

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LIST OF SYMBOLS AND ABBREVIATIONS

ACI: American Concrete Institute

ASTM: American Society for Testing and Materials; 1916 Race Street, Philadelphia, PA 19103, USA.

BGMEA: Bangladesh Garments Manufacturers and Exporters Association. BGMEA Complex, 23/1 PanthaPath, Link Road, Kawran Bazar, Dhaka-1215, Bangladesh.

BFSCD: Bangladesh Fire Service & Civil Defense.

BNBC: Bangladesh National Building Code.

BOCA: Building Officials & Code Administrators

CABO: Council Of American Building Officials

CCC: Clean Clothes Campaign

EPZ: Export Processing Zone

FDI: Foreign Direct Investment

FRI: Fire Risk index

GDP: Gross Domestic Product

ICC: International Code Council; Publications, 4051 West Flossmoor Road, Country Club Hills, IL 60478

ILRF: International Labor Rights Forum

ILO: International Labor Organization.

NAP: National Action Plan

NFPA: National Fire Protection Association; Batterymarch Park, Quincy, MA 02269, USA

NTPA: National Tripartite Plan of Action

OSHE: Occupational Safety, Health, & Environmental Foundation

RMG: Ready Made Garments.

RC: Reinforced Concrete

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

The readymade garments industry acts as the backbone of our economy and as a catalyst for the development of our country. We take pride in the sector that has been fetching billions of dollars as export earnings and creating jobs for millions of people in the country.

The “Made in Bangladesh” tag has also brought glory for Bangladesh, making it a prestigious brand across the globe. Bangladesh, which was once termed by cynics a “bottomless basket” has now become a “basket full of wonders.” The country with its limited resources has been maintaining 6% annual average GDP growth rate and has brought about remarkable social and human development.

After the independence in 1971, Bangladesh was one of poorest countries in the world. No major industries were developed in Bangladesh, when it was known as East Pakistan, due to discriminatory attitude and policies of the government of the then West Pakistan. So, rebuilding the war-ravaged country with limited resources appeared to be the biggest challenge for us.

The industry that has been making crucial contribution to rebuilding the country and its economy is none other than the readymade garment (RMG) industry which is now the single biggest export earner for Bangladesh. The sector accounts for 81% of total export earnings of the country.

When our lone export earner – the jute industry – started losing its golden days, it is the RMG sector that replaced it, and then, to overtake it.

The apparel industry of Bangladesh started its journey in the 1980s and has come to the position it is in today. The late Nurool Quader Khan was the pioneer of the readymade garment industry in Bangladesh. He had a vision of how to transform the country. In 1978, he sent 130 trainees to South Korea where they learned how to produce readymade garments.

With those trainees, he set up the first factory – Desh Garments – to produce garments for export. At the same time, the late Akhter Mohammad Musa of Bond Garments, the late Mohammad Reazuddin of Reaz Garments, Md Humayun of Paris Garments, Engineer Mohammad Fazlul Azim of Azim Group, Major (Retd) Abdul Mannan of Sunman Group, M Shamsur Rahman of Style craft Limited, the first President of BGMEA, AM Subid Ali of Aristocrat Limited also came forward and established some of the first garment factories in Bangladesh.

Following their footsteps, other prudent and hard-working entrepreneurs started RMG factories in the country. Since then up to 2015-2016 , According to BGMEA In Bangladesh there are 4328garments factories and about 4 million employees engaged in RMG sector, 85 percent of which is women.(Source: BGMEA).

CONTRIBUTION TO GDP:

According to the IMF, Bangladesh's economy is the second fastest growing major economy of 2016 (Dec), with 7.11 percent Gross Domestic Product (GDP) growth rate where the growth rate was 6.12 percent in 2015. Contribution of industry to the GDP was 28.1%, where RMG sector donate the biggest part. Since 2004, Bangladesh averaged a GDP growth of 6.5%, which has been importantly driven by its exports of readymade garments.

Bangladesh's textile and clothing sector secured a growth in achieving Foreign Direct Investment (FDI) in the FY 2015-2016. According to the Bangladesh Bank statistics, in this sector FDI successfully stood up at $396 million which is 11 percent higher than previous fiscal year when it was $351.62 million.

Export scenario:

Table 1.1: Value of total apparel export- calendar year basis. (Source- BGMEA)

Year	USD (million)	Yearly Growth (%)
2007	9350.33	4.67
2008	11878.92	27.04
2009	11890.49	0.10
2010	14854.6	24.93
2011	19214.47	29.35
2012	19788.14	2.99
2013	23500.98	18.76
2014	24583.96	4.61
2015	26602.7	8.21
2016	28668.29	7.76

Table 1.1 and the following graph shows that Bangladesh RMG have been securing a consistent growth through the decade. From 2007 to 2016 average yearly growth was 12.84% which shows strong potential of the sector. The data also shows that growth has been slowed down through last five years which was 8.47 percent average. And this was even greatly contributed by the

spectacular growth of the year 2013. As Bangladesh RMG is moving towards achieving a target of reaching USD 50 billion by 2021 the country requires more growth than it has been getting for last three years in particular. 2017 is to be a very crucial year in that path. If the country can secure a growth around of 15% in this year, it may proceed well achieving the goal.

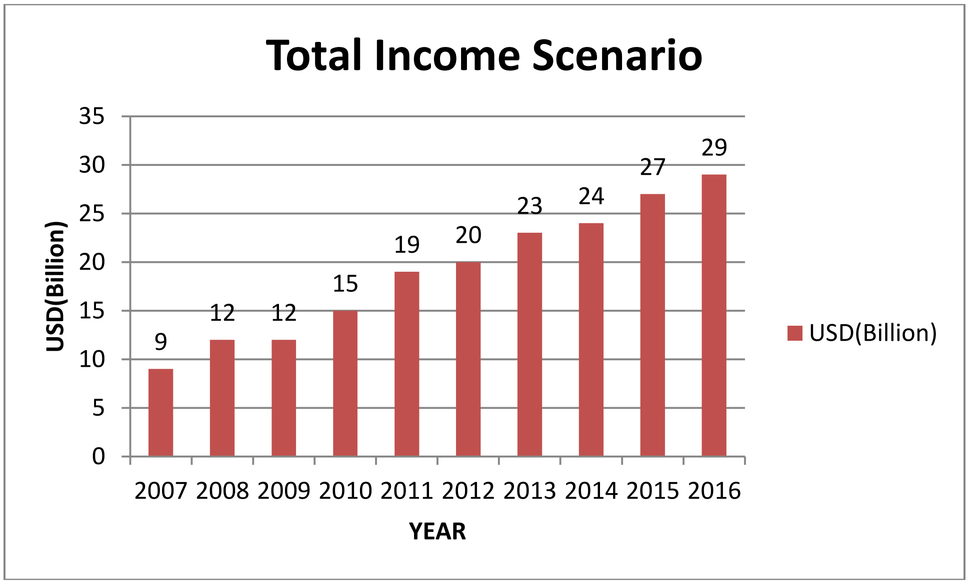


Fig1.1: Export Earning by RMG sector from year (2007-2016) USD (Billion)

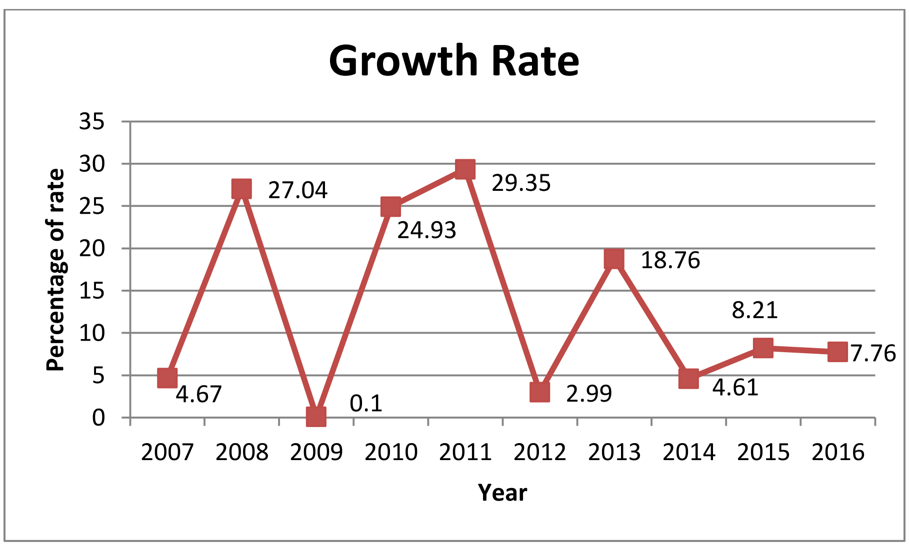


Fig 1.2: RMG growth rate from year(2007-2016)

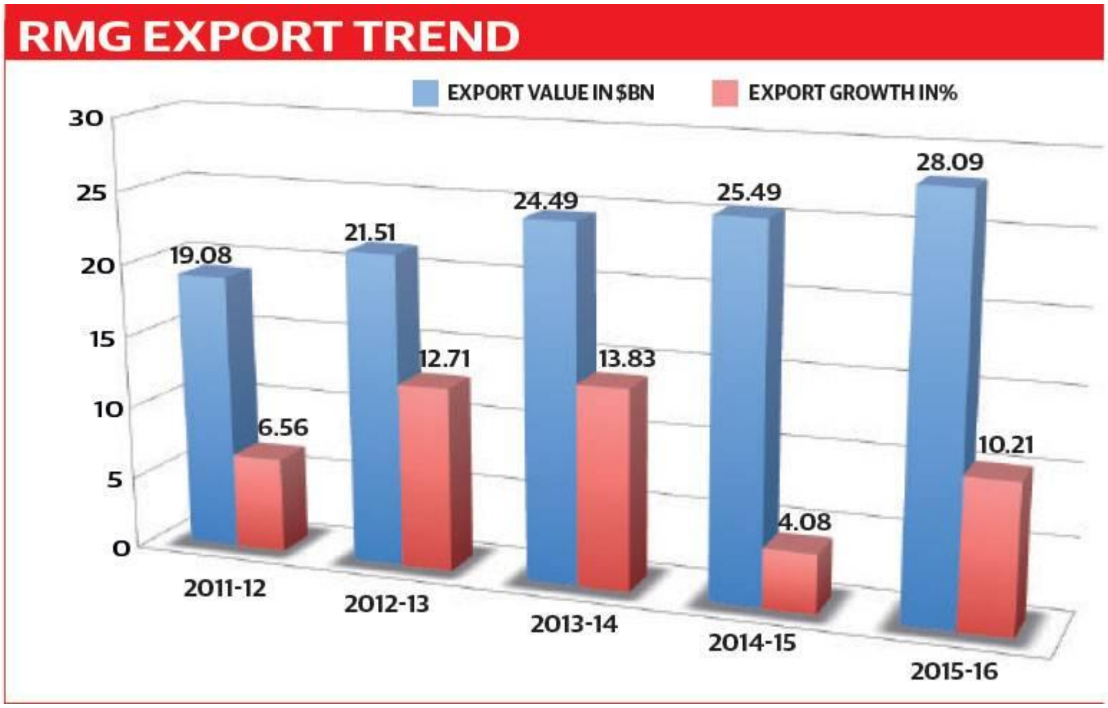


Fig 1.3: Garment exports post over 10% growth in FY2016 (July 14, 2016 Dhaka tribune)

1.2. STATEMENT OF THE PROBLEM:

The light of prosperity in RMG sector in Bangladesh is darkened when we cannot guarantee our workers' safety and security. In most cases their lives are endangered by risk of fire. They lack the safety, especially, safety from fire. Low salary and fewer benefits will affect these workers' daily life but fire incidents threaten their lives .Also every new accident of fire and related damage adversely affects the reputation of RMG industry in Bangladesh.

Bangladesh's garment industry has a long history of industrial accidents, but the fi re at Tazreen Fashions in November 2012 which killed 112 workers was the first time that the national stakeholders and the international community paid serious attention. It is popularly believed that improper design, high population load and mismanagement of floors and circulation systems in the factories are major contributors to such incidences.

These incidents raise questions about the effectiveness of existing fire prevention and fire fighting rules, regulations and practices and whether more could be done to limit fire occurrences and fire induced losses of lives and injuries. . Regretfully, almost all the accidents that have happened over the years or at least the loss of lives could have been avoided if only a few cautionary measures were taken by the concerned and relevant authorities.

The rapid and unregulated growth has also created serious problems. In the rush to meet export demands, many factories have been set up in buildings unsuitable for industrial purposes such as apartment blocks and office buildings. Many factory buildings struggle to cope with the heavy load of sewing machines, fabric and large numbers of workers, with exit and entry points not designed.

So we can say that Bangladesh is very prone to fire hazards and the capacity of preventing casualties and damage is not well-controlled. So Fire safety has become a major issue in Bangladesh in the recent few years and is raising critical concerns.

According to the analysis of Fire Risk Index (FRI) in Bangladesh, it was found that the mean FRI are 2.8 on a scale of 5.0 for the fire hazard condition, which indicates an extremely alarming condition.

1.3. Objective of the Study

The objective of the study is to evaluate the vulnerability of fire damage in RMG sector in Bangladesh at first through literature review and also

- To know the facilities available for the prevention of fire accidents in the factories in Bangladesh.
- To find out the causes of the accident.
- To suggest for better management of the fire accidents.
- To know the human response and behavior during fire incident through human survey.

The outcome of the comparative analysis will help us to draw a guideline to ensure fire safety in RGM industry in Bangladesh. This study will review all the scopes for fire hazard risk reduction in RMG as well as high rise building with a holistic approach from planning and design points of view.

CHAPTER 2

REVIEW OF LITERATURE

2.1. FIRE SAFETY

Fire safety includes measures those that are intended to prevent ignition of an uncontrolled fire, and those that are used to limit the development and effects of a fire after it starts. The most crucial aspect of a building's safety in the face of fire is the possibility of safe escape. Consequently, understanding how individuals behave in the case of fire and fire evacuation and to bring fire safety measures into line with occupants' needs during an incident.

The keys to fire safety are:

• fire prevention
• early warning of the fire
• containment of the fire
• safe exits.

Early warning of fire: It is achieved through automatic fire alarm systems. Automatic fire alarm systems are required in all types of buildings. Fire alarms can be initiated automatically by smoke detectors or heat detectors, or manually by pull stations. The alarm then sounds by means of bells or horns in order to notify the occupants to evacuate the building.

Containing the fire: It is achieved by creating fire compartments using fire resistant walls and floors. Fire barriers are required from floor to floor in multi-story buildings, around certain rooms within the building, and to enclose exit stairwells. Sprinkler systems serve two functions: detecting the fire for immediate evacuation; and containing the fire at its source.

Safe and efficient exiting: It is accomplished by providing necessary exits, and ensuring that the exits remain free of smoke and fire by requiring fire barriers around the exit stairs. Locks are not permitted on exits.

A means of egress: It is a continuous and unobstructed way of exit travel from any point in a building to a public way. A means of egress consists of three parts: exit access, exit, and exit discharge. Exit access is the path from any location within a building to an exit. An exit is typically a door leading to the outside or, in a multi-story building, an enclosed exit stairway. Exit discharge is the path from the exit to the public way. A public way is a space that is permanently deeded and dedicated to public use, most often a street or lane.

2.2. HISTORY OF FIRE SAFETY IN BANGLADESH:

The Accord for Fire and Building Safety in Bangladesh is a response by international and Bangladeshi trade union and labor rights organizations to bitter experience with a series of factory fires and two building collapses in Bangladesh and the failure of voluntary efforts by international brands and retailers to prevent further disasters. It first began to take form in February 2010 in the wake of a fire at the Garib&Garib Sweater Factory in Dhaka, which killed 21 workers. The International Textile, Garment and Leatherworkers Federation (ITGLWF – now a part of Industrial) worked with Bangladeshi unions on a set of proposals to improve fire and building safety. These were codified into a set of Health and Safety Action Points for Buyers by the Clean Clothes Campaign (CCC), the International Labor Rights Forum (ILRF), the Maquila Solidarity Network (MSN) and the Worker Rights Consortium (WRC), which was released in April 2010, on the fifth anniversary of the collapse of the Spectrum Fact.
The disaster – followed closely by more deaths at other factories – prompted another meeting between Bangladeshi and international unions and NGOs, international brands and retailers, and the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) in Dhaka, April 2011. The government was represented by officials from the Fire Safety Department and the Building and Factories Department. Participants discussed the signing of a Memorandum of Understanding (MOU) that would establish a program of work aimed to prevent future tragedies. On November 24, 2012, a catastrophic fire at the nine-story Tazreen Fashion garment factory in Dhaka took the lives of over 112 workers. What was reportedly an electrical malfunction appears to have been compounded by the factory's lack of basic safety measures like unobstructed exits, external emergency exits, functioning fire extinguishers, and worker training. Rather than recognizing the Tazreen disaster as a wake-up call to coalesce around the BFBSA's clear program of work on fire and building safety, in December 2012 a separate and vague proposal was floated by Wal-Mart, Tesco, Carrefour and Migros under the auspices of the Global Social Compliance Program (GSCP), an industry-led organization. The proposal called for a collective approach to fire and building safety and the development of a program that would include some of the same components as those of the BFBSA, including (according to the proposal):

• Better regulation and stronger enforcement
• Investment in safer facilities and infrastructure
• Closure of unsafe premises
• Engagement of workers and their representatives in promoting safe working practices with management and reporting of issues to competent authorities
• Effective training and emergency preparedness of all staff
• Assessment of buyers' responsibilities and necessary improvement of practices

At the national level in Bangladesh, the BGMEA, trade unions and the Government of Bangladesh agreed to develop a tripartite National Action Plan on January 15th, 2013. The NAP,

as it became known, set out a plan of work including a review of national safety standards, improvements to inspection capacities, fire safety training for managers and workers, and establishment of a fire safety hotline, amongst other things. The NAP was welcomed by Industrial and others as a means toward strengthening national-level actions on fire safety.
On April 24, the Rana Plaza factory building collapsed, killing over 1,100 workers and injuring approximately 2,500 more. The urgency of the need to develop a unitary and comprehensive fire and building safety program was clear to all. The April 29, 2013 GIZ-sponsored meeting brought together representatives from Industrial, GIZ, many major European and North American apparel brands and retailers, the International Labor Organization (ILO), Ethical Trading Initiative (ETI), CCC, WRC, and others. The participants reviewed two program proposals – the key principles of the BFBSA and the GIZ proposal – and established a committee to draft a new, joint agreement by May 5th, which would be circulated for final approval by May 15, 2013.

Although the drafting committee began its work shortly after the meeting, it quickly became clear that agreement on the key principles put forward by Industrial was not going to be possible. On May 5th, Industrial and the global union UNI, jointly with NGO partners issued a new version of the BFBSA – now called the Accord on Fire and Building Safety in Bangladesh – and asked major brands and retailers to endorse the Accord by May 15th. The key provisions of the Accord were closely based on those in the earlier BFBSA, but some of the language and structure was modified to take into account concerns and suggestions for improvement expressed by companies with whom the Global Unions had consulted. It also explicitly endorsed the NAP (which had not existed when the earlier BFBSA was signed) and pledged to dovetail its efforts with the actions being undertaken under the NAP

2.3. Current State of Fire Safety Measures in the RMG Sector of Bangladesh

All factories including those in the RMG sector in Bangladesh have to obtain certification from Bangladesh Fire Service and Civil Defense Authority (BFSCDA) for their compliance with fire regulations. Newly constructed purpose-built factories have to comply with Bangladesh National Building Code of 1993 (BNBC-93) and have to obtain the certification of local authorities assigned from the Ministry of Housing and Public Works, Government of the People's Republic of Bangladesh. Factories operating in old buildings (buildings those were built before the code was formulated but was in practice), have to collect another fitness certificate from the BFSCDA, which allows them to get a second certificate from the Ministry of Housing and Public Works. According to BFSCDA regulations, garment factories have to take an operational certificate at the very beginning of operation from them and this certificate have to be renewed in every month by the respective zone officials.

BFSCDA uses a checklist for the fire certification of the garment factories. Most of the parameters on the checklist are 'hard' in nature, by which we mean that the safety parameter is ‘passed’ through construction or buying of equipment. ‘hard’ factors as those whose conditions cannot be changed very quickly. For example, in order to ensure ease of egress during an emergency, BNBC-93 stipulates a minimum corridor width of 1.1 m for a factory building with more than 50 occupants.

Fig2.1: Clear width of an exit corridor reduced by piled up boxes (Color figure online).

Figure 2.1 shows an example where the ‘hard’ parameter for corridor width is met during design and construction, but due to deficient management practices the corridor is occupied by piled up boxes which reduces the effective width of the corridor and makes the passing of hard parameter useless in practice. We call these management practice related parameters the ‘soft’ parameters, which can often have critical impact during a fire incident.

An excellent example of 'hard' parameters is the number and specification of fire exit requirements in the building codes, while the relevant ‘soft’ factor can be whether the exits are locked or blocked or fully operational at the time of survey. Similarly, the number of fire extinguishers is checked by the BFSCDA officials during their survey of the factories, yet whether the extinguishers are in working condition is not. The number and presence of fire extinguishers is a hard parameter because they may not be procured overnight, while the workability at a specific period of time is a soft parameter as it reflects the management practices of inspection and maintenance. Since the buildings are expected to have been built following the building code, our initial expectation is that the ‘hard’ parameters would be in a better condition as compared to the ‘soft’ parameters, the performance in which can change from day-to-day due to management practices. Figs. 2.2-2.3 show examples of hard parameters, where the safety regulations have not been met.

Figure-2.2: Hard factors: Stairway does not
Meet regulations.

Figure-2.3: Hard factors: Exit door
does not meet regulations.

A comparison of BFSCDA checklist and BNBC-93 shows that some major precautionary steps of 'hard' parameters as per BNBC-93, e.g. existence of central command center, existence of announcement system, presence of fire damper, maximum length of travel distances toward nearest exit, widths of stairways and corridors, etc. are missing from the BFSCDA checklist**.**

2.4. Fire safety monitoring organization in Bangladesh:

ACCORD:

The Accord on Fire and Building Safety in Bangladesh (the Accord) was signed on 15 May 2013. It is a five-year independent, legally binding agreement between global brands and retailers and trade unions designed to build a safe and healthy Bangladeshi Ready Made Garment(RMG) Industry and to oversee safety inspections into more than 1600 garment factories in Bangladesh. The agreement was created in the immediate aftermath of the Rana Plazabuilding collapse that led to the death of more than 1100 people and injured more than 2000. Fire protection is a fundamental Accord goal. The Accord is primarily concerned with the life safety aspects of fire protection. There has been especially good progress on electrical remediation which is positive as most factory fires are caused by electrical hazards**.** These Accord inspections are so important because they will ensure factories are carefully checked for fire and structural safety.

ALLIANCE:

The Alliance for Bangladesh Worker Safety**,** also known as "the Alliance" or **AFBWS**, is a group of 28 major global retailers formed to develop and launch the Bangladesh Worker Safety Initiative, a binding, five-year undertaking with the intent of improving safety in Bangladeshi ready-made garment (RMG) factories after the 2013 Rana Plaza Building collapse. Collectively, Alliance members represent the majority of North American imports of ready-made garments from Bangladesh, produced in more than 700 factories. On July 10, 2013, the group announced the Bangladesh Worker Safety Initiative. The Initiative is a binding, five-year plan focused on fire and building safety inspections, worker training, and worker empowerment.

2.5. **Rules & regulations of fire safety for the Garments Industry In Bangladesh:**

As the ready-made garment industry flourished, many factories were vertically expanded or converted from residential or retail occupancy to create additional production capacity. At the same time, few buildings had proper occupancy permits or structural documentation that evidenced design and construction compliance with the building code, the Bangladesh National Building Code (BNBC).

'Bangladesh National Building Code' (BNBC) prescribes regulations for safeguarding life and property in the use or occupancy of buildings or premises from the hazards of smoke and fire, and explosions in garments industry. All buildings are classified according to their use or by considering the character of their occupancy.

According to BNBC-

Occupancy G: Industrial Buildings. This occupancy shall include structures or portions used where materials are fabricated, assembled, or processed. The G2, Moderate Hazard Industrial Occupancy will be the predominant occupancy type in most RMG factories. [See BNBC Part 3 Section 2.1.7]

Occupancy G

1. Apparatus are not capable to igniting flammable vapor shall be permitted within a control area of a building using or processing or storing volatile flammable liquid. Control Areas of a building using or processing or storing such flammable liquid shall be covered by exhaust ventilation system.
2. Boiler rooms and areas containing heating plants shall be separated from the rest of the occupancy as per provisions of this Code.
3. Adequate protective measures shall be taken against hazards associated with distribution and use of electricity and gas in accordance with the provisions of Chapters 2 and 8 of Part 8.
4. The machine layout shall be congenial to safe fire practice.

Occupancy G1: Low Hazard Industries

Manually operated electric fire alarm system shall be installed with portable fire extinguishers or hydrants when occupant loads are not more than 150.

Where occupant loads are more than 150 active fire protections shall be performance based.

Occupancy G2: Moderate Hazard Industries

Among the moderate hazard industries where large number of occupants are densely populated in a building, the active fire protections shall be performance based. Fire safety requirement for such type industry is elaborated as follows

(a) Where occupancy load is more than 150 per production area shall have minimum 9.5 m3 air volume per occupant.
(b) There shall have direct exits from the ground floor. This exit doors shall be used by only the occupant of the ground floor.
(c) Buildings less than 33 m height shall have open stair and the interior stairs shall be protected by fire rated enclosures. Occupants located 33 m or above, all stair shall have smoke proof enclosures constructed as per provision of the Code.
(d) The floor shall be constructed such that the travel path of the occupant shall not be exceeded as per Code.
(e) All raw materials, finished good and accessories shall be stored in control areas as per provision of Code
(f) Density of storage materials per control area shall not be exceeded the provision of this Code.
(g) During production that is feeding, checking for quality control rejects, waiting area for finishing cartooning etc. in every case dedicated area shall be defined as on process storages. The total volume of materials on process shall be such that in every four hour the material shall be used up and the finished goods shall be transferred to controlled area as finished goods store.
(h) If there any change of fire classification due to the working condition or raw materials than appropriate extinguishing system shall be installed as per provision of this Code.
(i) Up to 750 m^2 single effective undivided space in a floor shall be installed with manual fire alarm system with portable fire extinguishers or as an alternate hydrants system shall be installed as per provisions of this Code.
(j) Above 750 m^2 single effective undivided space in a floor shall be fitted with manual fire alarms system with hydrants shall be installed.

Capacity of Exit Components:

The capacity of egress components shall be complied with the occupant load of the area served. The required width of each component shall be computed on the basis of the allotted width per occupant .For Occupancy G as per BNBC

Table 2.1: Required exit width per occupant

Occupancy		Buildings without Sprinkler System (mm per person)			Buildings thoroughly Sprinkled (mm per person)		
		Stairways	Ramps & Corridors	Doors	Stairways	Ramps & Corridors	Doors
G	industrial	8	5	4	5	4	4

Table 2.2 :Fire resisting rating of common construction elements

Fire Resistance Rating of Common Construction Elements (From BNBC):

Batteries	Fire Resistance Rating
1. Solid Walls	
A. 75 mm thick walls of clay bricks	0.75 hour
B. 125 mm thick walls of clay bricks	1.5 hours
C. 250 mm thick walls	5.0 hours
2. RC Walls	
a. 150 mm thick RC wall	3.0 hours
b. 200 mm thick RC wall	4.0 hours
c. 250 mm thick RC walls	5.0 hours
d. 300 mm thick RC walls	6.0 hours
3. RC Slabs	
a. 100 mm RC slabs with 13 mm cover over reinforcement	1.0 hour
b. 150 mm RC slabs with 19 mm cover over reinforcement	2.5 hours
c. 200 mm RC slabs with 19 mm cover over reinforcement	3.75 hours
d. 250 mm RC slabs with 25 mm cover over reinforcement	5.0 hours
4. RC Columns (1:2:4)	
a. 250 mm x 250 mm with 25 mm cover over reinforcement	3.0 hours
b. 300 mm x 300 mm with 25 mm cover over reinforcement	4.0 hours
c. 400 mm x 400 mm with 25 mm cover over reinforcement	6.0 hours
d. 400 mm x 400 mm with 50 mm cover over reinforcement	8.0 hours

Doorways

One surface of a door leaf which is exposed to a fire incident is the terminal point of exit access and other surface of that said door which is unexposed to that fire incident is the starting point of an exit.

Each occupant of a room or space shall have access to at least one exit door or exit access assembly. The width of a door shall not be less than 1 m and the height shall be not less than 2 m. No sliding or hanging door shall be used as a means of exit.

Exit Signs

All required means of exit or exit access in buildings or areas requiring more than one exit shall be signposted. The signs shall be clearly visible at all times, where necessary supplemented by directional signs. Exit signs shall be installed at stair enclosure doors, horizontal exits and other required exits from the story. Where required by the fire code official, a sign shall be permanently displayed on or near each fire door in letters not less than 1 inch (25 mm) high to read as follows:

1. For doors designed to be kept normally open: FIRE DOOR—DO NOT BLOCK.
2. For doors designed to be kept normally closed: FIRE DOOR—KEEP CLOSED.

Table 2.3: Determination of Exit and Access Requirements.

Occupancy Group/ Classification	Maximum Travel Path (meter)		Capacity Number of Occupancy per unit width of the component				Ramp, Passage , Corridors	
			Door openings					
	Unsprinklered	Fullfire resistive or sprinklered	Toout doors at Grade	Allother Exit and corridor doors	Stairs,Escalators	Ramp,Corridors,Exit passageways, Horizontalexit	Minimum width (mm)	Maximum DeadEnd (mm)
Industrial(G)	60	120	100	80	60	100	1120	15240

Signs & Floor Plans:

Arrows and other symbols of exit signs shall be written with vernacular alphabets high contrast background as per NFPA. Words on the signs shall be at least 150 mm high with a stroke of not less than 20 mm. The top of the sign shall not be more than 2 m above floor level.

Also the government of Bangladesh drafted a law in 2008 and passed it in the parliament in 2009, titled as “MahanagarImaratNirmanBidhimala – 2008” (mentioned as bidhimala -2008 in the later parts of the dissertation). This set of law is mandatory to be followed in Dhaka and

Chittagong city corporations. For construction of factories within the "Export Promotion zones‟ a separate set of laws is in practice titled as "Bangladesh Export Promotion Zone - Requirement for Self Constructed Buildings (mentioned as EPZ building rules in later parts of the dissertation)

Table2.4 : Comparison Imarat Nirman Bidhimala – 2008 and EPZ building code.

Mahanagar Imarat Nirman Bidhimala – 2008	Requirement for Self Constructed Buildings in EPZ
Maximum distance from fire exit is 23 m (for factory buildings).	The distance from any point to the nearest stair shall not exit 100ft. (30.50m).
Provides a formula to calculate size and dimension of an emergency exit and proper specifications	Provides a slab-base chart to calculate the width of the stair. Especially for buildings which will have more than 150 people

Table 2.5: Chart for determining stair dimension, EPZ building rules

Persons	1st stair width (m)	2nd stair width (m)
Up to 350	1.50	1.25
450	1.70	1.25
550	1.80	1.40
650	2.00	1.40

According to the Alliance Fire Safety and Structural Integrity Standard.

Note: For existing RMG factory buildings the number of steps in a single flight of RCC stair may exceed15. For Existing RMG factory buildings the stair treads shall be of nominal uniformity. The difference between the largest and the smallest riser shall not exceed 25mm. Any riser height or tread depth not at the top or bottom step in a stair run exceeding more than 12.5 mm difference from the adjacent step shall be modified to be within this tolerance . For existing stairs that do not meet these tread and riser dimensions and will require extensive rework of the stairway, a full detailed analysis of the tread and riser dimensions can be submitted to the Authority for review and approval of an alternate corrective action plan.

TRAVEL DISTANCE (Accord Manual fire safety for existing RMG building October 2014)

The maximum travel distance to reach an exit from any point in the building shall not exceed 45 meters unless the following requirements can be met:

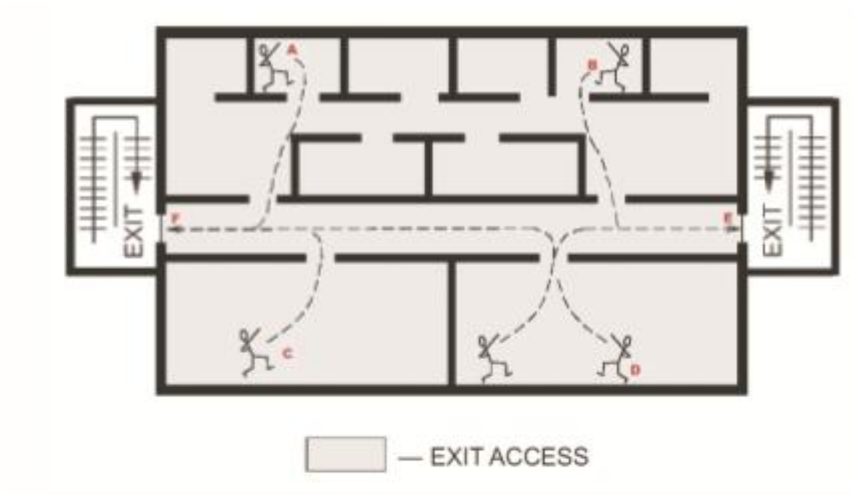


Fig 2.4: Travel distance (A-B-C-D-E) from different locations.

Travel distance limitations for G2 (RMG factories) shall be increased to 60 m (200 ft.) where a complete automatic fire detection system, portable fire extinguishers, and standpipe system are provided in accordance with this Standard.
Travel distance limitations for G2 (RMG factories) shall be increased to 122 m (400 ft.) where a complete automatic sprinkler system, automatic fire alarm system, and portable fire extinguishers are provided in accordance with this Standard.

Standard: Accord Standard Part 6 Section 6 .13

PORTABLE FIRE EXTINGUISHERS:

Portable fi re extinguishers shall be installed throughout all new and existing facilities in accordance with BNBC Part 4 Section 4.10 and NFPA 10.
Spacing: Extinguishers shall be placed so that maximum travel distance to the nearest unit shall not exceed 30 m (100 ft.)
Mounting height: a. Fire extinguishers having a gross weight not exceeding 18.14 kg (40 lb.) shall be installed so that the top of the fi re extinguisher is not more than 1.53 m (5 ft.) above the floor (NFPA 10 6.1.3.8). b. Fire extinguishers having a gross weight greater than 18.14 kg (40 lb.) (except wheeled types) shall be installed so that the top of the fi re extinguisher is not more than 1.07 m (3 ft) above the floor (NFPA 10 6.1.3.8).

According to Bangladesh FACTORY RULES 1979

Means of Escape in Case of Fire:

- Each room of a factory building shall be provided with not less than two exits for use in case of fire, so positioned that each person will have a reasonably free and unobstructed passage from his work place to an exit.

- No such exit shall be less than 3'-0" in width and less than 6'-6" in height.

- In the case of a factory building or part of a factory building of more than one story and in which not less than 20 persons work at any one time, there shall be provided at least one substantial stairway permanently constructed either inside or outside the building and which affords direct and unimpeded access to ground level.

- In the case of a factory building or part of a factory building in which 20 or more persons work at any one time above the level of the ground floor, or wherein explosive or highly inflammable materials are used or stored, or two separate and substantial stairways permanently constructed either inside or outside the building and which afford direct and unimpeded access to ground level.

- Every stairway in a factory which affords means of escape in case of fire shall be provided with a substantial handrail which if the stairway has open side shall be on that side, and if the stairway has two open sides, such handrail shall be provided on both sides

- In the case of a building constructed or converted for use a factory, after coming into force of these rules, the following additional requirements shall apply:

- at least one of the stairways shall be of fire resisting materials;

- every hoist way or lift-way inside a factory building shall be completely enclosed with fire-resisting materials and all means of access to the hoist or lift shall be fitted with doors of fire-resisting materials;

- no fire escape stair shall be constructed at an angle greater than 45° from the horizontal;

- no part of a factory building shall be at a distance (along the line of travel) of 150' or more from any fire escape stair; and

- no stairway shall be less than 45" in width.

Forms of Occupancy Separations: Portions of a building having different occupancies shall be separated with horizontal or vertical or of any other form of separation as may be required to achieve a complete separation.

Types of Occupancy Separation: The occupancy separations shall be classified as follows:

a. Four Hour Fire Resistive: The four hour fire resistive separation shall have no openings therein and shall provide a fire resistance of at least four hours.

b. Three Hour Fire Resistive: The three hour fire resistive separation shall provide a fire resistance of not less than three hours. The total width of all openings in any one storey shall not exceed 25 percent of the length of the wall in that storey and no single opening shall have an area greater than 12m2. The openings shall be protected with a fire resistance assembly providing a fire resistance of at least three hours.

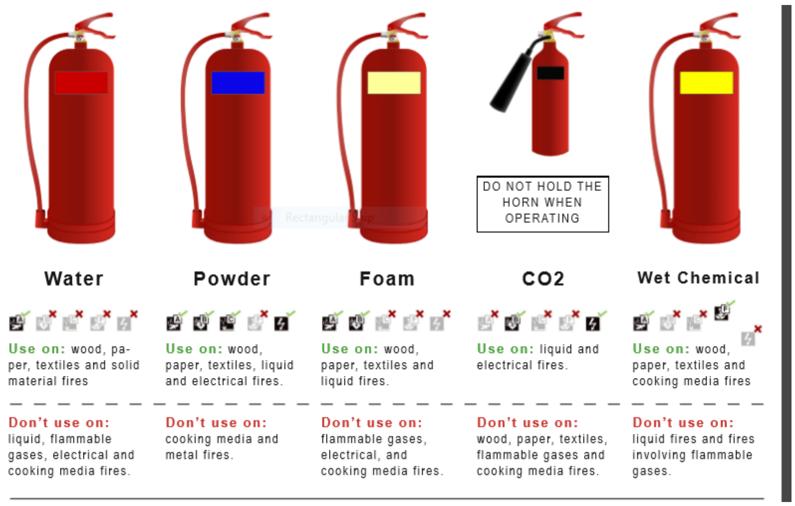
In case of a floor having a three hour fire resistance rating, the openings shall be protected by vertical enclosures extending above and below such openings. The walls of such vertical enclosures shall be of a construction offering at least two hours of fire resistance. All openings in the walls of these vertical enclosures shall be protected with fire assembly having a fire resistance rating of at least one and one-half hour.

c. Two Hour Fire Resistive: The two hour fire resistive separation shall be of a construction having a fire resistance rating of not less than two hours. All openings in such separations shall be protected with a fire assembly of a fire protection rating of at least one and one-half hour.

d. One Hour Fire Resistive: The one hour fire resistive separation shall be of at least one hour fire protection construction. All openings in such separations shall be protected with a fire protection assembly of at least one-half hour fire resistance.

2.6. Colour code of fire safety:

This fire extinguisher colour- coding system enables the user to quickly identify a fire extinguishers extinguishing medium by a colour code that is carried on a band that is positioned above or below the operating instructions on the front of the extinguisher so that it is visible from a 180 degree horizontal arc when the extinguisher is wall mounted. This band should be greater than 10% of the surface area and not less than 3%.Each extinguishing medium is assigned its own colour code: red for water, cream for foam, blue for dry powder, and black for carbon dioxide. A fifth color, yellow is added for the new wet chemical type of fire extinguisher.



. Fig 2.5: Various Fire Extinguisher

National Fire Protection Association:

The National Fire Association (NFPA) has developed a color-coded number system called NFPA 704. The system uses a color-coded diamond with four quadrants in which numbers are used in the upper three quadrants to signal the degree of
health hazard =blue,
flammability hazard= red, reactivity hazard= yellow, special hazards= white

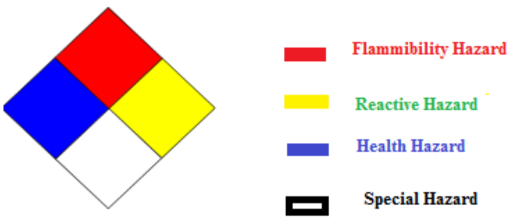


Fig 2.6: NFPA color code

Flammability hazards are displayed with the red color code. As different materials have different flash points, it is important to rate them and alert responders to this information. Natural gas, for instance, is highly flammable under normal temperatures and pressures and is one material with the highest rating for this color code.

Warning Lights and Alarms:

Warning devices such as lights and audible alarms must be installed where they are needed to warn personnel against remaining in or entering hazardous areas. Personnel must receive instructions from their supervisor, about the meaning and the response required when an alarm sounds. Lights alone do not suffice as adequate warning, a sign describing the hazard and action to take must be posted near the warning light.

Table 2.6: Color code for warning lights and alarm

Warning	Meaning	Action
Red light	Danger	Do not enter; Do not enter without permission, Evacuate the area.
Yellow light	Caution	Limited access; Warn personnel of potential hazard.
Green light	Safe	No hazard; No entry restrictions
Sirens, horns, bells, buzzers, etc.	Warning; Hazardous condition exists	Be on alert; Follow directions

OSHA (Occupational Safety and Health Association) and Safety Colors:
OSHA outlines two broad requirements for safety colors in its standard for safety color codes. The standard maintains that red and yellow must be used for marking physical hazards.

- **Red** must be used for fire-related hazards, as well as emergency switches, bars, and buttons on hazardous machines. ("Fire-related hazards" may include identifying fire protection equipment and containers of flammable liquids.)
- **Yellow** indicates caution and is used for physical hazards, including striking against, stumbling, falling, tripping, and "caught in between."

In OSHA standard 1910.145, specific colors are not mandated for use on accident prevention tags, but these colors are recommended:

- Red: for danger tags.
- Yellow: for caution tags.
- Orange: for warning tags.
- Fluorescent orange or red-orange: biological hazards.

ANSI (American National Standard institute) and Safety Colors:
ANSI has outlined 10 safety colors for visual communication—and specific applications for each—in the ANSI Z535 safety sign standard. The standard dictates every aspect of sign design, including standard colors and signal words (such as "Danger" and "Caution").
Here's a quick look at the most common colors, what each communicates, and where it should be used.

ANSI Safety Color: Red

Red is universally recognized for identifying the most serious hazards, as well as fire hazards and fire equipment. Safety signs that comply with the ANSI Z535 standard use red for "Danger" signs and labels that warn when death or serious injury is almost certain to occur if the hazard is not avoided.

In addition to "Danger" signs, here are other scenarios where red should be used:

- Fire safety items, including fire extinguishers and fire alarms
- Emergency stop switches, buttons, and bars on machinery
- Containers carrying flammable liquid
- Confined space hazards
- Construction hazards and PPE requirements

ANSI Safety Color: Orange

Orange identifies dangerous machines or equipment that may crush, cut, shock, or injure workers in other ways. Orange is used on "Warning" signs and labels when a hazard may result in death or serious injury, but when the overall risk isn't severe enough for a "Danger" sign.

The following scenarios may call for orange signs and labels:

- Exposed and moving machine parts
- Low clearance levels
- Electrical hazards (such as high voltage or potential static)
- Most work zone markings (including safety cones and barrels)

- Road construction signs

ANSI Safety Color: Yellow

Much like the OSHA standard for safety colors, ANSI recognizes yellow as a color for communicating hazards that may lead to worker injuries if not avoided. Most commonly, these signs warn against unsafe practices.

Here are a few situations where yellow signs and labels should be used:

- Instruct workers to wear PPE while working on certain machines or when in a specific area
- Point out common hazards, such as wet floors
- Inform employees when entering a construction area, or where only authorized employees are allowed
- Alert employees to exposed edges of loading docks, platforms, and curbs
- Warn workers of moving equipment, overhead hazards, and other physical hazards

ANSI Safety Color: Green

Green is reserved for general safety signs, which offer safety-related messages that don’t touch on specific workplace hazards.

Green signs should:

- Point out first aid kids, emergency eye wash fountains, and other medical equipment
- Offer general sanitation guidelines and reminders
- Encourage employees to report accidents, unsafe conditions, and other incidents
- Motivate employees to be mindful of general hazards
- Suggest best practices and other safety measures

ANSI Safety Color: Blue

Blue communicates information unrelated to personal injuries and other hazards (most commonly on "Notice" signs). It is most commonly associated with maintenance work and other safety precautions.

Blue signs may:

- Alert employees to designated smoking and non-smoking areas
- Remind employees of best work practices
- Communicate procedures, information, instructions, and rules for maintenance
- Share the overhead clearance in a given area.

Table2.7: Color codes of both ANSI/NEMA Z535.1-2006 (R2011) and OSHA:

COLOR	**MEANING**	**APPLICATION**
Red	Danger	Safety cans and signs.
	Stop	Emergency stop bar or button on machinery. Identification of fire equipment.
Fluorescent Orange, Orange-Red	Biosafety	Labels and containers for blood and infectious waste. (Warning labels must be fluorescent orange or orange-red with the biosafety symbol in a contrasting color.)
Yellow	Caution	Tripping, falling and striking hazards. "Flammable, Keep Fire Away" labels on cabinets. Safety cans and containers for explosives, corrosives or unstable materials.
Orange	Warning	Parts of machinery or energized equipment that may cut, crush or otherwise injure. Inside of transmission guards for pulleys, gears, etc.
Green	Safety	Location of first aid equipment. Location of safety equipment, respirators, safety showers, etc.
Blue	Information	Signs and bulletin boards. Specific railroad warnings against starting, using or moving equipment being repaired.
Black, White, Yellow or Combination of Black with White or Yellow	Boundaries	Traffic or housekeeping markings. Stairways, directions and borders.
Magenta or Purple on Yellow	Radiation Caution	X-ray, alpha, beta, gamma, neutron and proton radiation.

2.7. FIRE RESISTING PROPERTIES OF MATERIALS

The fire resisting material is having the following characters:
(a) It should not disintegrate under the effect of heat
(b) It should not expand under heat so as to introduce unnecessary stresses in the building
(c) The material should not catch fire easily
(d) It should not lose its strength when subjected to fire

Fire resisting characteristics of some of the commonly used building materials are:

2.7.1. Concrete:

The influence of fire on concrete varies with the nature of its coarse aggregate and its density .It has been found that aggregates obtained from igneous rocks containing higher calcareous content, tend to crack when subjected to fire. It has been noticed that in an average fire, the concrete surface gets disintegrated for a depth of about 25 mm. This is due to the dehydration of mortar in concrete by the fire. **.** In case of reinforced concrete and pre-stressed concrete, it also depends upon the position of steel. Larger the concrete cover, better is the fire resistance of the member. Concrete does not burn – it cannot be set on fire and it does not emit any toxic fumes when affected by fire. Concrete has slow rate of conductivity (heat transfer) that enables concrete to act as an effective fire shield not only between adjacent spaces, but also to protect itself from fire damage.

Physical behavior of concrete elements

For a column exposed to fire on four sides, for example, the concrete heats up rapidly on the surface and wants to expand. Its expansion is prevented by the core of the column, which remains cold.
Tensile stress is appiedto the core and compressive stress to the outside of the column.
As the thermal stresses superimpose themselves on the stresses resulting from the loads applied, the outer concrete, whose resistance drops as the temperature rises, is subjected to extremely high stresses close to the ultimate resistance. These stresses, combined with the effects resulting from the dehydration front and the expansion of the bars, explain the concrete blowouts observed during tests. These blowouts chiefly concern concrete covering corner reinforcements, followed by concretes o the faces of columns.
They reduce the section of the column and increase the flexure because the eccentricity of the load increases locally.
Furthermore, the exposed reinforcements heat up more quickly than at points where they remain protected by the concrete. This behavior is taken into account in the verification of structural elements by the Euro codes.

Table 2.8: Reactions of concrete to a thermal attack:

Temperature in the concrete (°C) Reaction of concrete	Reaction of concrete
< 100	As a general rule this temperature is inoffensive to concrete. Simple expansion.
> 100	The concrete loses its free water. The water which is not chemically bonded evaporates from the capillary pores.
100 to 800	The concrete loses its chemically bonded water from CHS.
> 300	The paste in fact contracts while the granulates expand. Long-term heating at this temperature significantly reduces resistance to traction. The concrete begins to disintegrate
400 to 600	600 Calcium hydroxide (Ca(OH)2) is broken down into calcium oxide (CaO) and water (H2O). The water vapour may bring about a phenomenon of local flaking.
+575 or -575	Spontaneous transformation of quartz α into quartz β which goes hand in hand with an increase in the volume of the concrete.
>700	The transformation of limestone (CaCO3) into calcium oxide (CaO) or .quicklime. and carbon monoxide (CO2) begins.
1150 to 1200	The concrete begins to melt. First the cement paste, then the aggregates.
1300 to 1400	Bonding of the lime with SiO2 and Al2O3. The concrete appears as a molten mass

Concrete can sustain various degrees of damage depending on the severity of the fire and the high temperature levels reached. The effects on concrete components of high temperature fire includes:

- reduction in compressive strength;
- micro-cracking within the concrete microstructure;
- color changes consistent with strength reductions;
- reduction in the modulus of elasticity;
- various degrees of spalling;
- loss of bond between concrete and steel;

The more severe fire damage would also involve the total exposure of main bars, significant exposure of pre-stressing tendons, significant cracking and spalling, buckling of steel reinforcement and even significant fracture and deflection of concrete components.

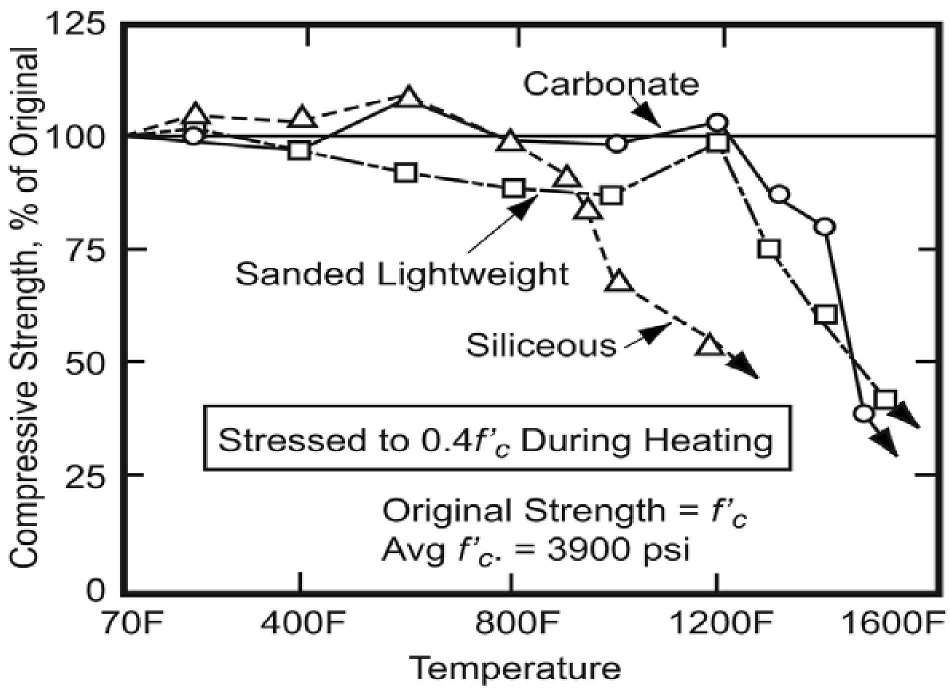


Fig2.7 Effect of high temperature on the compressive strength of concrete.

The change in concrete properties due to high temperature depends on the type of coarse aggregate used. Aggregate used in concrete can be classified into three types: carbonate, siliceous and lightweight. Carbonate aggregates include limestone and dolomite. Siliceous aggregate include materials consisting of silica and include granite and sandstone. Lightweight aggregates are usually manufactured by heating shale, slate, or clay. Figure 2.7 shows the effect of high temperature on the compressive strength of concrete. The specimens represented in the figure were stressed to 40% of their compressive strength during the heating period. After the designated test temperature was reached, the load was increased gradually until the specimen failed. The figure shows that the strength of concrete containing siliceous aggregate begins to drop off at about 800 °F and is reduced to about 55% at 1200oF. Concrete containing lightweight aggregates and carbonate aggregates retain most of their compressive strength up to about 1200F. Lightweight concrete has insulating properties, and transmits heat at a slower rate than normal weight concrete with the same thickness, and therefore generally provides increased fire resistance.

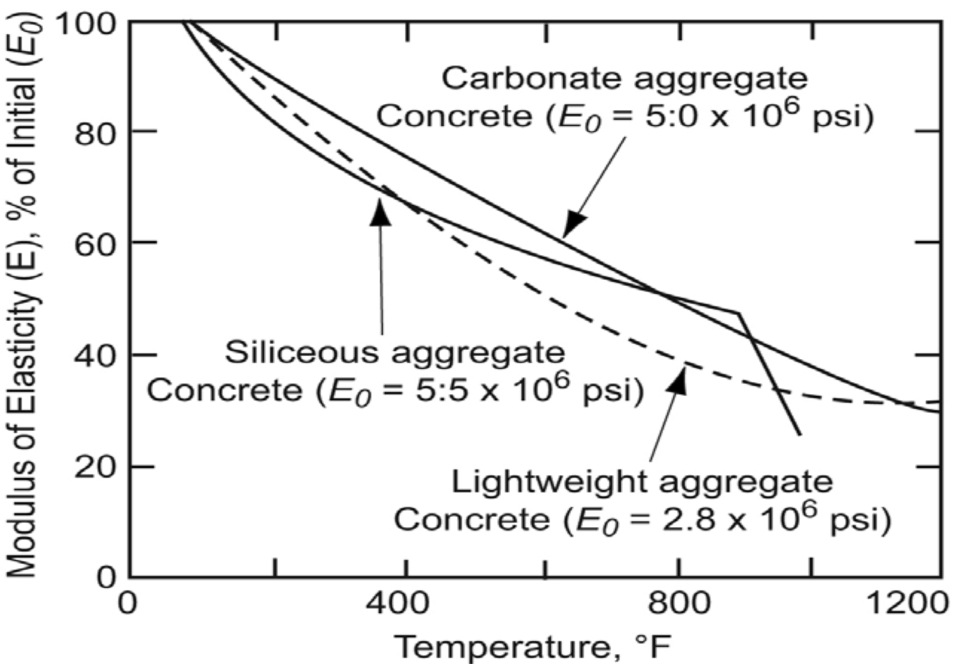


Fig 2.8: Effect of high temperature on the modulus of elasticity of concrete

Figure 2.8 shows the effect of high temperature on the modulus of elasticity of concrete. The figure shows that the modulus of elasticity for concretes manufactured of all three types of aggregates is reduced with the increase in temperature. Also, at high temperatures, creep and relaxation for concrete increase significantly.

Table -2.9: Minimum thickness for cast in place floor and roof slabs, (in)

	Fire resistance rating				
Concrete type	1 hr.	1.5 hr.	2hr	3hr	4hr
Siliceous aggregate	3.5	4.3	5.0	6.2	7.0
Carbonate aggregate	3.2	4.0	4.6	5.7	6.6
Sand-light weight	2.7	3.3	3.8	4.6	5.4
Lightweight	2.5	3.1	3.6	4.4	5.1

As noted above, carbonate refers to coarse aggregates of limestone, dolomite or lime rock – those consisting of calcium or magnesium carbonate. Siliceous refers to most other normal-weight aggregates. Sand-lightweight refers to concretes made with normal-weight sand and lightweight coarse aggregate and generally weighing between 105 and 120 pounds per cubic foot. Lightweight refers to concrete made with lightweight coarse and fine aggregates and weighing between 85 and 115 pcf.

Table- 2.10: Minimum concrete column dimensions,(in)

	Fire resistance rating				
Concrete type	1hr	1.5hr	2hr	3hr	4hr
Siliceous aggregate	8	9	10	12	14
Carbonate aggregate	8	9	10	11	12
Sand light weight	8	8.5	9	10.5	12

Table 2.11: Minimum cover for floor and roof slabs, (in)

	Fire resistance rating					
	Unrestrained					Restrained
Concrete type	1hr	1.5hr	2hr	3hr	4hr	4hr or less
Siliceous aggregate	0.75	0.75	1	1.25	1.625	0.75
Carbonate aggregate	0.75	0.75	0.75	1.25	1.25	0.75
Sand light weight	0.75	0.75	0.75	1.25	1.25	0.75

Table-2.12: Minimum cover requirements to main reinforcement in beams (All types), in

	Fire resistance rating					
Restrained or unrestrained	Beam width, in	1hr	1.5hr	2hr	3hr	4hr
Restrained	5	0.75	0.75	0.75	1	1.25
	7	0.75	0.75	0.75	0.75	0.75
	≥10	0.75	0.75	0.75	0.75	0.75
Unrestrained	5	0.75	1	1.25	-	
	7	0.75	0.75	0.75	1.75	3
	≥ 10	0.75	0.75	0.75	1	1.75

.

*** Minimum cover for reinforcement in columns, for all aggregate types, is the smaller of, 1 in. times the number of hours of required fire resistance, or 2 in.**

2.7.2. Steel:

Steel although incombustible has a very low fire resistance value. Steel bars lose tensile strength. Steel yields at 600°C. They melt at 1400°C**.** With the increase in temperature, the co-efficient of elasticity of the metal falls appreciably rendering the structural members soft and free to expand. When the members in this state come in contact with water used for extinguishing the fire, they tend to contract, twist or distort and thus the stability of the entire is endangered. Hence in a fire resistant construction, structural steel members must be suitably protected by covering them with materials like brick, terra-cotta, concrete etc. Steel grills and beams are applied with fire resistant paints.

2.7.3. Bricks:

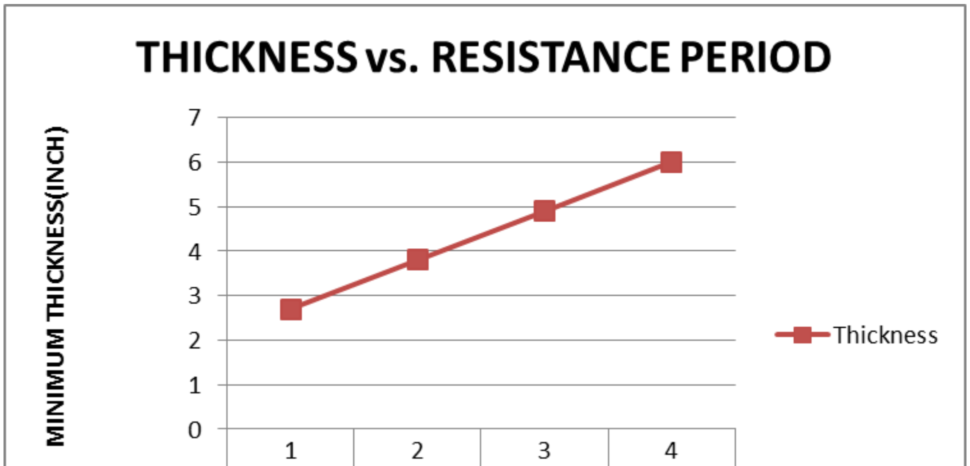
Bricks can resist heat up to 1200°C. At the time of construction, if good quality mortar is used, fire resistance is extremely good. Brick is inherent with excellent fire resistance. A 100 mm brickwork with 12.5 mm normal plastering will provide a fire-resistance of 2 hours and a 200 mm non-plastered brickwork will give a maximum rating of 6 hours for non-load bearing purposes. Brick can support considerable load even when heated to 1000^{o}C in contrast to concrete wall at only up to 450^{o}C due to loss of water of hydration. It is a fact that the non-combustibility of brick helps to promote its use in building houses against fire. The fire resistance of a building material refers to the length of time a walling element is about to resist a fully developed fire. In every case, clay brick walls obtain maximum fire ratings.

DESIGN OF CLAY BRICKWORK FOR FIRE		
Fire resistance period, (minutes)	Required material thickness for insulation(mm)	Maximum slenderness for structural adequacy
30	60	25.0
60	90	22.5
90	110	21.0
120	130	20.0
180	160	18.0
240	180	17.0

Fire resistance or "ratings" for masonry products are established through a testing program performed in accordance with the American Society for Testing and Materials test method ASTM E119. The results of these tests are readily accepted by all major building code authorities (ICC, ICBO, BOCA, SBCCA, & CABO) and by the National Fire Protection Association (NFPA). Testing methods and test results are discussed comprehensively in BIA Technical Note 16B as published by the Brick Institute of America. The significant data on fire resistance relating to General Shale Bricks summarized below. Minimum Equivalent Thickness1 (in.) of Loadbearing or Non-Loadbearing Clay Masonry Walls.

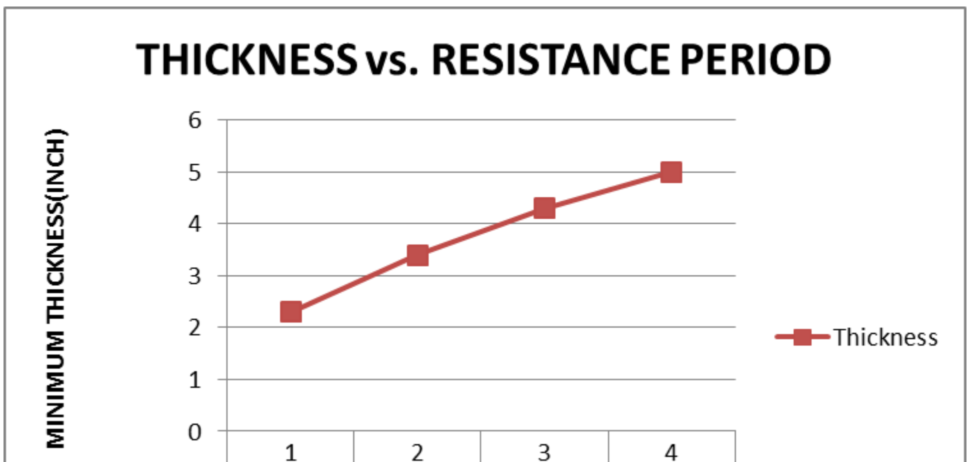
Table 2.13: Fire resisting period of various types of bricks.

Type of Material	Fire Resistance Period (minutes)			
	60	120	180	240
Solid brick of clay or shale	2.7	3.8	4.9	6.0
Hollow brick of clay or shale, unfilled	2.3	3.4	4.3	5.0
Hollow brick of clay or shale, grouted or filled with perlite, vermiculite, or expanded shale	3.0	4.4	5.5	6.6



	1	2	3	4
Thickness	2.7	3.8	4.9	6

Fig2.9: Fire resistance period of solid brick clay or shale



	1	2	3	4
Thickness	2.3	3.4	4.3	5

Fig 2.10: Fire resistance period of hollow brick clay or shale, unfilled:

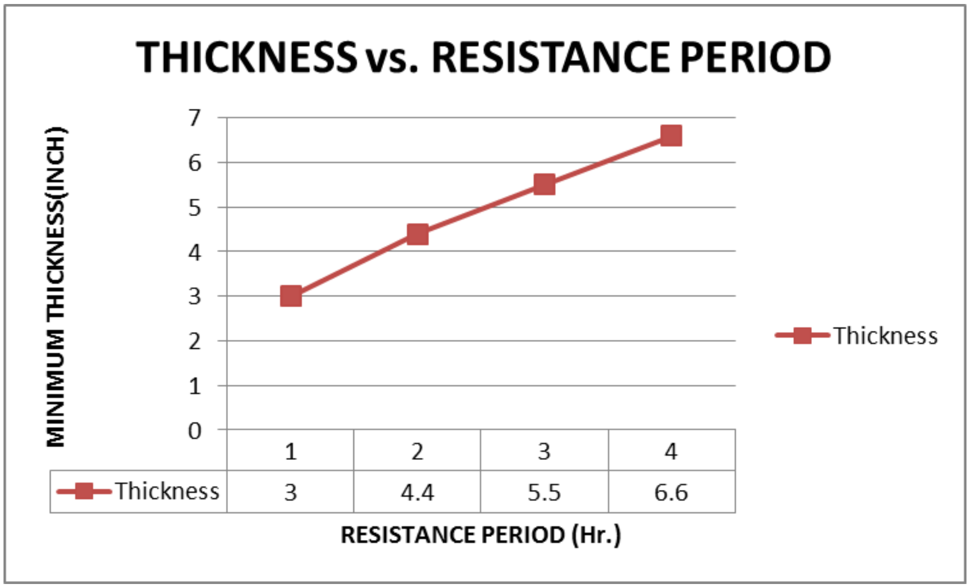


Fig: 2.11: Fire resistance period of hollow brick or clay shale ,grouted or filled with perlite vermiculite or expanded shale:

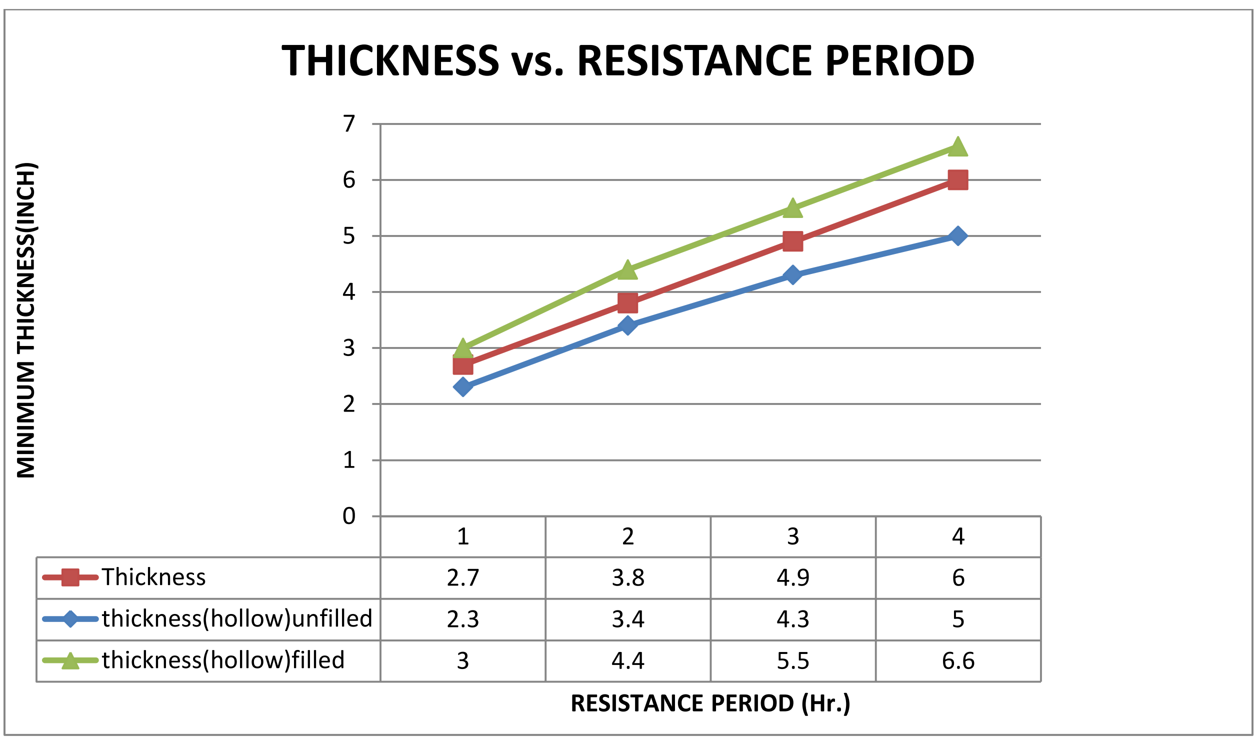


Fig 2.12: Fire resistance period of solid brick, hollow brick(unfilled) & hollow brick (filled):

Equivalent thickness is the average thickness of solid material in the wall. It is found by taking the total volume of a wall unit, subtracting the volume of core or cell space and dividing by the area of the exposed face of the unit. Where combustible members are framed in the wall, the thickness of solid material between the end of each member and the opposite face of the wall, or between members set in from opposite sides, shall not be less than 93% of the thickness shown in the table. Units shall comply with the requirements of ASTM C216 for solid brick and ASTM C652 for hollow brick. The equivalent thickness of General Shale Brick units is calculated as follows:

$$\frac{(\text{Length} \times \text{Width} \times \text{Height}) \times \%\ \text{solid volume}}{(\text{Length} \times \text{Height})\ \text{Face Area}} = \text{Equivalent Thickness (in.)}$$

2.7.4. Aluminum:

It is good conductor of heat. It has got higher resistance to fire. According to British Standard BS 476, aluminum is described as non-combustible. The same set of standards gives aluminum high marks on the fire resistance versus spreading scale. Most Aluminum alloys have a melting point between 600 and 660 degrees Celsius. Therefore when aluminum s exposed to a prolonged fire environment it will begin to melt (not burn), provided that the metal's temperature passes the melting point. Aluminum’s heat conductivity is, approximately, 4 times greater than iron's while its specific heat capacity is similar to iron. Aluminum’s extremely high reflectivity compared to iron (aluminum ranges between 80 to 90%, and 5 to 25% for iron to stainless steel) allows for better resistance to thermal radiation of fire. So when aluminum is exposed to fire, its large thermal conductivity allows it to quickly dissipate large amounts of heat from the flame and absorb even more thermal energy from the center of the fire, 'cooling' the environment and restricting 'very hot spots’. These heat levels are comparatively greater than those of iron when exposed to fire, therefore aluminum offers a comparatively higher response time to fire fighters.. In such a case, for example an aluminum roof that is melting over the fire source, the smoke and large amounts of heat are released through the opening in the atmosphere, making it easier for the fire fighters to do their job.

by increasing the thickness of the aluminum shell of the panels, the thermal capacity also increases, thus offering more time for firefighting. When aluminum melts, it begins to ‘act’ like fire-resistant or flame retardant insulation, providing even more protection time. It must be noted that the mechanical strength of structural aluminum has very safe use limits, up to 250 degrees Celsius, approximately. Subsequently, its fracture and yield point are reduced. Through appropriate alloy design, aluminum load bearing systems can reliably withstand up to 300 degrees Celsius.

2.7.5. Glass:

Glass conducts heat faster than metal. Because of its low thermal conductivity, the change in volume on account of expansion or contraction is very small and as such it may be considered to be a good fire resisting material. However when subjected to sudden and extreme variation of temperatures, it fractures or cracks .By the use of glass reinforced with steel wire netting, such cracks can be minimized. Even when the cracks are formed, the fractured glass remains in its original position, as the embedded wire holds the cracked portion and does not allowed it to fall. The reinforced glass has a higher melting point than the ordinary glass, and as such it is commonly used for fire resisting doors, windows, sky lights etc.

Fire-protective glass prevents the spread of fire and smoke. However, it will not prevent radiant heat transfer. That means that as the glass heats up from fire on one side, objects on the other side of the glass will feel the heat. Wired glass, specially tempered glass, and glass-ceramics are considered fire-protective glass and can generally be used where the building code calls for an opening protective. Fire-resistive glass prevents the spread of fire and smoke; in addition it also stops radiant and conductive heat transfer so that objects on the protected side do not get hot enough to spontaneously combust. This is generally achieved by creating a laminated assembly that is composed of a number of layers of glass separated by heat resistant interlayers. Fire-resistive glass is used where the building code calls for a fire-resistive assembly, which also means that the temperature-rise on the protected side must be below a threshold (usually 250 degrees in rise beyond ambient).

2.7.6. Stone:

It is a bad conductor of heat. Hot stone when subjected to sudden cooling develops cracks and can lead to failure of structures. Granite, when exposed to severe fire, explodes and disintegrates. Lime stone is least It is a bad conductor of heat recommended it crumbles and gets ruined by an ordinary fire .Only compact sand-stone having fine grains may be used as it can stand the exposure to moderate fire without serious cracks). At high temperatures of 600 to 800°C, the strength of stone is reported to be seriously affected, and disintegration is reported in the case of thermal shock. Damage at lower temperatures of 200 to 300°C is normally restricted to colour changes, including reddening in the case of stone containing iron. Colour change is considered to be non-reversible and therefore damage can be significant (Chakrabarti B., 1996)

2.7.7. Timber:

Timber has unique property of self-insulation and slow burning and offers considerable resistance to fire. Fire resistance is achieved through impregnation of timber with large quantities of fire retarding chemicals .The commonly used chemical for this purpose are ammonium phosphate and sulphate, borax and boric acid, zinc chloride etc. This treatment retards increase in temperature during fire, decreases rate of flame spread and enables easy fire control. Usually 32 to 48 kg of chemical per cubic metre of wood are used for moderate protection and 80 to 96 kg per cubic metre for high protection. Fire resistant paints of asbestos, magnesium sulphate ,ferrous-oxide etc. are also very effective.

2.7.8. Asbestos:

Asbestos is fibrous mineral which is combined with Portland cement to form a material having great fire resistive value. Asbestos cement products are largely used for the construction of fire – resistive partitions, roof etc. on account of its low co-efficient of expansion and property of incombustibility, the structural members blended with asbestos cement possess great resistance to cracking, swelling or disintegration when exposed to fire.

2.7.9. Plaster or Mortar:

Plaster or mortar is incombustible and as such, by suitable choice of the type of mortar, the walls or ceiling of a building can be made more fire resistant. Cement mortar is preferred to lime mortar as the latter is liable to calcite. The resistance of the plaster to fire hazards can be increased by using it in thicker layers or reinforcing the plaster with metal laths. Gypsum plaster when applied over structural members like steel columns etc., makes the latter have good fire resistive qualities.

2.7.10. GYPSUM:

Many structural materials will require underlying gypsum sheathing in order to achieve a good fire-resistant rating, and gypsum board is the most commonly used fire-resistant interior finish. Gypsum board, also known as drywall, consists of a layer of gypsum sandwiched between two sheets of paper. Type X gypsum board is specially treated with additives improve its fire-resistive qualities.

Fig2.13: Gypsum boards typically are treated to be even more fire-resistant

The paper on the exterior of the type X gypsum board burns slowly and doesn't contribute to fire spread. In addition, gypsum board has a noncombustible core that contains chemically combined water (in calcium sulfate). When affected by fire, the first thing that happens is that this water comes out as steam. This effectively impedes the transfer of heat through the gypsum board. And even after the water is gone, the gypsum core continues to resist fire penetration for a time. Builders often use multiple layers of gypsum board to increase the fire-resistance rating.

2.8. Fire resistant construction:

In a fire resistant construction ,the maximum use of non-combustible materials should be encouraged .All the structural elements such as beams, columns ,lintels ,arches, floors and roofs, load -bearing walls or partition wall etc. should be constructed in such a way that should continue to function as structural members at least for the period which may be sufficient for the occupants to escape .The following additional points should be kept in view while designing a fire-resistant structure---

- The load bearing walls or columns of masonry should be thicker in section so that they may successfully act as fire barrier for considerable time.
- Flooring made from materials like concrete, brick, ceramic tiles etc. is considered to be most suitable for fire resistant construction .In case , cast iron, wrought iron or combustible materials like rubber ,carpet etc. have to be used in flooring ,such materials should be protected by covering of insulating material like ceramic tiles ,terracotta ,bricks etc.
- The cover of concrete for reinforced concrete members like beams or columns should be sufficient to enable the members function satisfactorily, under fire for maximum time. The concrete cover outside the main reinforcement should be at least 5 cm for very important structural members columns, trusses etc. 38 mm for ordinary beam, or long span slabs, arches etc. and 25 mm for partition walls and short span slabs.
- The load bearing walls, as well as non -load bearing walls, should be plastered with fire resistive mortar.
- The ceiling should be directly attached or suspended from the floor joists and it should be made fire resistant by fixing asbestos cement boards, fiber board, metal lath or plaster etc. to its framework.
- The doors, windows or exposed sides should be glazed and fitted with reinforced glass panels.
- The staircase hall which acts like a vertical shaft connecting the various floors should be surrounded with the enclosure walls made up of fire –resistive materials.

2.9. Fire Detection and Alarm Systems:

A key aspect of fire protection is to identify a developing fire emergency in a timely manner, and to alert the building's occupants and fire emergency organizations and to call for assistance at the same time. Fire alarm system can be either manual or automatic.

1. Manual Fire alarm systems:

This consists of a hand bell or similar sounding device emitting distinctive sound when struck. Such devices are installed near all the main exits and passages. In the event of fire, the device is sounded by watchman and the occupants are thereby warned to have safe exist in shortest possible time.

2. Automatic alarm system:

This type of system, on detection of fire, starts sounding alarms or information to the nearest control point. Besides this, the system can also perform the function of sounding of evacuation gongs or siren and to transmit information of fire to a remote fire station.

Thermal detector:

Thermal detectors are the oldest type of automatic detection device, having origin in the mid 1800's, with several styles still in production today. The most common units are fixed temperature devices that operate when the room reaches a predetermined temperature (usually in the 135°–165°F/57°–74°C). The second most common type of thermal sensor is the rate-of-rise detector, which identifies an abnormally fast temperature climb over a short time period. Both of these units are "spot type" detectors, which means that they are periodically spaced along a ceiling or high on a wall. The third detector type is the fixed temperature line type detector, which consists of two cables and an insulated sheathing that is designed to breakdown when exposed to heat. The advantage of line type over spot detection is that thermal sensing density can be increased at lower cost. Thermal detectors are highly reliable and have good resistance to operation from nonhostile sources. They are also very easy and inexpensive to maintain. On the down side, they do not function until room temperatures have reached a substantial temperature, at which point the fire is well underway and damage is growing exponentially. Subsequently, thermal detectors are usually not permitted in life safety applications.

Smoke detector:

A smoke detector is a device that senses smoke, typically as an indicator of fire. Commercial security devices issue a signal to a fire alarm control panel as part of a fire alarm system, while household smoke detectors, also known as smoke alarms, generally issue a local audible or visual alarm from the detector itself.

The most common smoke detectors are spot type units, which are placed along ceilings or high on walls in a manner similar to spot thermal units. They operate on either an ionization or photoelectric principle, with each type having advantages in different applications. For large open spaces such as galleries and atria, a frequently used smoke detector is a projected beam unit. This detector consists of two components, a light transmitter and a receiver, that are mounted at some distance (up to 300 ft. /100m) apart. As smoke migrates between the two components, the transmitted light beam becomes obstructed and the receiver is no longer able to see the full beam intensity. This is interpreted as a smoke condition, and the alarm activation signal is transmitted to the fire alarm panel.

Fig 2.14: smoke detector

Flame detectors: Flame detector represents the third major type of automatic detection method, and imitate the human sense of sight. They are line of sight devices that operate on either an infrared, ultraviolet or combination principle. As radiant energy in the approximate 4,000 to 7,700 angstroms range occurs, as indicative of a flaming condition, their sensing equipment recognizes the fire signature and sends a signal to the fire alarm panel. The advantage of flame detection is that it is extremely reliable in a hostile environment. They are usually used in high value energy and transportation applications where other detectors would be subject to spurious activation.. A disadvantage is that they can be very expensive and labor intensive to maintain. Flame detectors must be looking directly at the fire source, unlike thermal and smoke detectors which can identify migrating fire signatures.

Photoelectric or optical smoke detector:
It contains a source of infrared, visible, or ultraviolet light (typically an incandescent light bulb or light-emitting diode), a lens, and a photoelectric receiver (typically a photodiode). According to the National Fire Protection Association (NFPA), "photoelectric smoke detection is generally more responsive to fires that begin with a long period of smoldering". Photoelectric alarms react slower to rapidly growing fires than ionization alarms, but laboratory and field tests have shown that photoelectric smoke alarms provide adequate warning for all types of fires and have been shown to be far less likely to be deactivated by occupants. Although photoelectric alarms are highly effective at detecting smoldering fires and do provide adequate protection from flaming fires, fire safety experts and the National Fire Protection Agency recommend installing what are called combination alarms, which are alarms that either detect both heat and smoke, or use both the ionization and photoelectric processes..

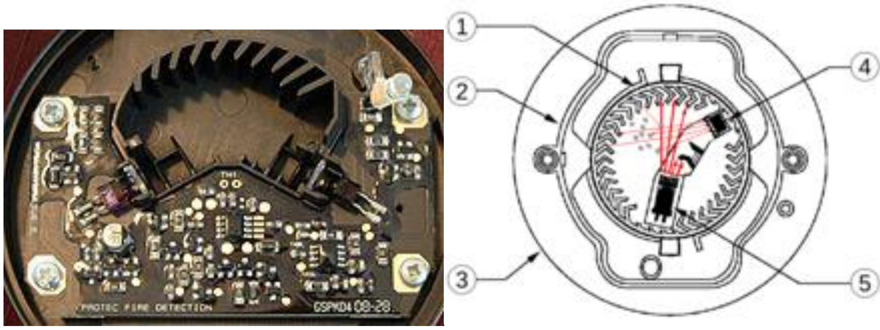


Fig 2.15: optical smoke detector

Carbon monoxide and carbon dioxide detection:
Carbon monoxide sensors detect potentially fatal concentrations of carbon monoxide gas, which may build up due to faulty ventilation where there are combustion appliances such as heaters and cookers, although there is no uncontrolled fire outside the appliance. High levels of carbon dioxide (CO_2) may indicate a fire, and can be detected by a carbon dioxide sensor. Such sensors are often used to measure levels of CO_2 which may be undesirable but not indicative of a fire; this type of sensor can also be used to detect and warn of the much higher levels generated by a fire. One manufacturer says that detectors based on CO_2 levels are the fastest fire indicators, and also, unlike ionization and optical detectors, detect fires that do not generate smoke, such as those fuelled by alcohol or gasoline. CO_2 fire detectors are not susceptible to false alarms due to particles, making them particularly suitable for use in dusty and dirty environments.

2.10. Fire Extinguishing System:

1. Fire Sprinklers system:
In this system a network of water supply pipes (normally 20 mm dia.) are fixed to the ceiling of the floor or roof slab. The center to center spacing of the pipes is normally 3 m. The pipes receive supply of water through header pipes normally 40 mm dia. which in turn are connected and fed from water storage tank. An insulation known as sprinkler head is filtered to the pipes in ceiling at regular intervals normally at 3 m c/c .For most fires; water represents the ideal extinguishing agent. Fire sprinklers utilize water by direct application onto flames and heat, which causes cooling of the combustion process and prevents ignition of adjacent combustibles. They are most effective during the fire's initial flame growth stage, while the fire is relatively easy to control. A properly selected sprinkler will detect the fire's heat, initiate alarm, and begin suppression within moments after flames appear. In most instances sprinklers will control fire advancement within a few minutes of their activation, which will in turn result in significantly less damage than otherwise would happen without sprinklers.
Among the potential benefits of sprinklers are the following:

- Immediate identification and control of a developing fire. Sprinkler systems respond at all times, including periods of low occupancy. Control is generally instantaneous.

- Immediate alert. In conjunction with the building fire alarm system, automatic sprinkler systems will notify occupants and emergency response personnel of the developing fire.
- Reduced heat and smoke damage. Significantly less heat and smoke will be generated when the fire is extinguished at an early stage.
- Enhanced life safety. Staff, visitors and fire fighters will be subject to less danger when fire growth is checked.
- Design flexibility. Egress route and fire/smoke barrier placement becomes less restrictive since early fire control minimizes demand on these systems. Many fire and building codes will permit design and operations flexibility based on the presence of a fire sprinkler system.
- Enhanced security. A sprinkler controlled fire can reduce demand on security forces by minimizing intrusion and theft opportunities.
- Decreased insurance expenditure. Sprinkler controlled fires are less damaging than fires in nonsprinklered buildings. Insurance underwriters may offer reduced premiums in sprinkler protected properties.

These benefits should be considered when deciding on the selection of automatic fire sprinkler protection.

Fig 2.16: Automatic Sprinkler system.

Water Mist:
One of the most promising automatic extinguishing technologies is the recently available fine water droplet, or mist systems. Potential uses include locations where reliable water supplies do not exist, where even sprinkler water discharges are too high, or where building construction and aesthetics impact the use of standard sprinkler pipe dimensions. One of the main drawbacks to mist systems is their higher cost, which can be 50–100% greater than standard sprinklers. This cost, however, may be reduced due to possible installation labor savings.. Water mist represents a very promising alternative to gaseous agent system.

2. Carbon dioxide fire extinguishing system:

Carbon dioxide (CO_2) is a colorless, odorless, and chemically inert gas that is both readily available and electrically non-conductive. It extinguishes fire primarily by lowering the level of oxygen that supports combustion in a protected area. This mechanism of fire suppression makes CO_2 suppression systems highly effective, requiring minimal clean-up, but should be used in normally unoccupied hazard locations or otherwise avoided by personnel when discharged. CO_2 suppression systems may utilize the gas through a total flooding approach but carbon dioxide is also the only gaseous agent that may be utilized through local application. Carbon dioxide may be stored in either high pressure spun steel cylinders ($HPCO_2$ suppression systems) or low pressure light wall refrigerated tanks (LPCO2 suppression systems).That is available in both versions In high pressure CO2 fire fighting systems, the extinguishing agent is stored in cylinders up to 70 bar pressure. In low pressure CO2 fire fighting systems, the extinguishing agent is stored in special refrigerated tanks, at 18 bar pressure.

- NOTE: Both HPCO2 and $LPCO_2$ systems are equally effective at fighting fires. Neither one is better than the other in terms of extinguishment. Fewer Components

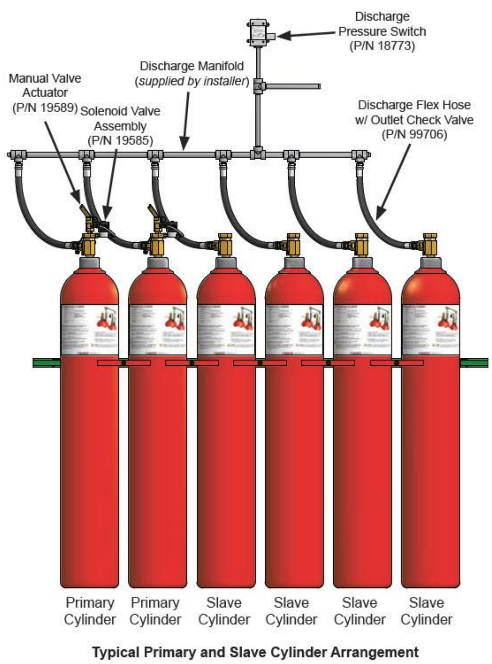


Fig 2.17: Carbon dioxide (CO2) extinguishing system

Carbon dioxide fire fighting systems are able to extinguish quickly any type of fire in areas not occupied by personnel, allowing the recovery, in a very short time, of all working operations because it does not leave any residue in the environment after its use.

CO_2 Action:

Carbon dioxide is a gas odorless, colorless, non-corrosive, electrically non-conductive that does not dirty and does not damage the materials with which it comes into contact. Its fire extinguishing principle is twofold because of its action on the following factors:

- Reduction of oxygen in the air. It acts for suffocation and does not allow the combustion process;
- Cooling effect due to the rapid gas exposure

Advantages and Benefits of CO_2 fire extinguishing systems

CO_2 fire extinguishing system with a correct engineering and calculation does not damage the materials during the fire suppression, it does not cause corrosion and it does not leave residues. It is a versatile system that can be used on a wide range of risks, electronic equipment and high-voltage equipment, flammable materials.

Limitation of use of CO_2:

The main limitation for the use of the system is due to the hazard of CO_2 that, at the concentrations of use, it is dangerous for the occupants as it makes the air unbreathable for insufficient oxygen concentration. Therefore, this type of system is not recommended in areas normally occupied by people .After the extinguishing, the area involved must be adequately ventilated, considering that CO_2 is heavier than air and it is concentrated in low-lying areas.

3. Dry chemical fire extinguishing system:

Dry Chemical Fire Suppression Systems consist of dry chemical compounds that suppress fire effectively because they are easy to install in any industrial setting. The Dry Chemical Fire Suppression Systems provide excellent fire coverage. It needs to be recharged them after every operation. These fire suppression systems are affordable and great to use when a water supply is not available to help extinguish fires. Dry Chemical is a powder composed of very small particles usually of sodium bicarbonate, potassium bicarbonate, urea-based potassium bicarbonate, or monoammonium phosphate with added particulate material supplemented by special treatment to provide resistance to packing, resistance to moisture absorption (caking) and the proper flow capabilities.

It is important to remember that Dry Chemical Systems are required to comply with NFPA 17 (Standard for Dry Chemical Extinguishing Systems) and NFPA 33 (Standard for Spray Application to safely use on flammable and combustible materials).

4. Foam extinguishing system:

Firefighting foam is a foam used for fire suppression. Its role is to cool the fire and to coat the fuel, preventing its contact with oxygen, resulting in suppression of the combustion. The surfactants used must produce foam in concentration of less than 1%. Other components of fire-retardant foams are organic solvents (e.g., trim ethyl -trim ethylene and he xylene glycol), foam stabilizers (e.g., lauryl alcohol), and corrosion inhibitors.

Extinguishing foam is essentially a mixture of water, foaming agent and air. The mixture ratio of these three substances is adapted depending on the application. The extinguishing effect comes from the heat-resistant foam forming a solid blanket over the flammable materials. This creates a cooling, separating and suppressive effect depending on the type of foam. The foam isolates the flames from the oxygen supply and

Suppresses the development of toxic flue gases. The chemical reaction for combustion is therefore halted and the flame is extinguished.

Fig 2.18: Foam extinguishing system

The main properties of Foam fire extinguishing systems which possess effective extinguishing impact are as follows:

- It prevents the oxygen coming into contact with fuel vapor.
- It precludes the vaporization occurring on the fuel surface.
- Separates the flame and fuel surface from each other.
- It assists in cooling the metal surfaces existing around or on the fuel surface..

Foam extinguishing systems, with a pretty wide application areas, are usually preferred in; plane and helicopter hangars, warehouses, stations where fuels are loaded or unloaded, paint manufacturing workshops, plants where chemical substances are produced or stored, the areas where flammable and combustible liquids are stored, shipyards, docks, petroleum refineries, marinas and similar areas. Due to its property of immediate intervention and quickly taking the control; it affects the inflammable surface within a short time and precludes possible big fires.

Areas of application:

In general, foam can be used anywhere that water alone would not have the desired extinguishing effect or the use of gas extinguishing systems or water mist systems would not be effective. Its largest area of application is therefore for combustible and highly flammable liquids. Foam is a good solution if there is a particularly high risk of a reigniting and the burning material must therefore be separated from oxygen for a long period of time. It is also important to note that if one attempts to extinguish burning oil or fat fires with water, this could lead to an explosion.

Gas extinguishing system:

Gas extinguishing system is a fire extinguishing system that extinguishes fire with the help of a gaseous extinguishing agent either through oxygen displacement (reduction of oxygen content) or physical effects (heat extraction). In contrast to a sprinkler system, a gas extinguishing system

is designed to extinguish and not only suppress fire. Gas extinguishing systems are used when water, foam or powder extinguishing systems are not
effective or if extinguishing with the above-mentioned extinguishing agents could cause significant damage. Typical areas of use include all types of electrical switch rooms, IT and server rooms. Gas extinguishing systems are the "cleanest" extinguishing systems. Extinguishing gases have no influence on conventional electrical systems such as servers, etc. A range of different extinguishing gases can be used for the extinguishing system.

Fig 2.19: Gas extinguishing system

Areas of use of gas extinguishing systems include for example:

- IT systems and computer rooms
- Archive rooms, document safes
- Emergency call centres, flight navigation and control towers, mobile phone transmitter stations, internet service provider centres, television, radio and control rooms, microwave substations.
- Art galleries, libraries, film projector rooms, museums
- Medical sector: imaging systems, operating rooms, mobile stations
- Industrial facilities such as laboratories, control rooms, offshore drilling platforms, robotic equipment
- Emergency power generators, battery compartments, low-voltage compartments, cable compartments, etc.
- Flight simulators, ships, military vehicles

5. Fire ball:

Elide Fire ball and AFO Fire ball may seem like something of a magic prop, in reality, it’s much more — this unique little fireball could replace heavy, clunky, inefficient fire extinguishers altogether, giving us a brand new way to fight the blazes. Weighing in at just three pounds and smaller than a soccer ball, Its secret lies in its extinguishing powder mixture, which self-detonates when it comes in contact with extreme heat .Fire Extinguishing Ball will self-activate when it comes into contact with fire and give a loud noise as a fire alarm. Because of this feature, it can be placed in fire prone area such as above electrical circuit breaker or in a kitchen. The almost laughably easy operation of the fireball means that it doesn’t need any special training or skills to make use of the device.

Fire extinguisher in Bangladesh perspective:

Fire Hydrant:

• Water requirement for fire hydrants should be consistent with water supply/storage for any size facility.

• Fire regulation 2014 requires each RMG facility to have a water reservoir with a Fire Hydrant minimum capacity of 200 thousand (2 lac) gallons of water, irrespective of the size of the facility.

• Although BNBC specifies required water supply according to building size/hazard, the amount of storage remains fixed (by Fire Regulation 2014).

• Categorization of reservoir size should be done according to size of facility.

Distance from fire station:

• Fire protection systems to be incorporated in a RMG facility should be based on the distance of the facility from the nearest fire station and the time it would require for fire fighters to arrive to the facility.

• Guideline should include measures facilities will take depending on time required for external help to arrive.

Fire Extinguishers:

Certain regulations are too stringent but at times lag clarification:

• Fire Extinguishers are to be placed every 500 ft2 according to Fire Regulation 2014.

• Area to be covered by each fire extinguisher should be based on occupancy

• There should a guideline regarding the maximum distance to reach a fire extinguisher.

CHAPTER 3

METHODOLOGY

In this paper we focused on fire safety condition of READY MADE GARMENTS in Bangladesh on the basis of findings from various renowned national & international research papers, books, newspaper articles, online searching etc. We also focused on human response about fire incident & made survey of almost 150 students of different department of our universities. Due to some limitation we conducted the survey in our institution.

To find out the precise information about human response regarding fire accident, survey was the most appropriate way to meet our objectives & the information we are looking for. We had a particular respondents of age between 18 to 22.The survey was administrated face to face to conduct it a draft of short multiple choice question appropriate to each of our objectives was made to develop the analysis plan. We had a open & single response question appropriate to each of our objectives was made to develop the analysis plan. We had an open and single response question & the language was very simple avoiding double negation. Based on the answers respondents could skip some question. We needed resources like printed & photocopied materials to organize the survey. The survey was took manually so that each participants could take part in. After collecting data the result was analyzed straightly & it enabled us to make visual representations of data by presenting the result in pie chart. The final step was to write a report explaining our findings & the survey was successful to get the answers of our required questions

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CHAPTER 4

CASE STUDIES

Case studies of selected fire incidents occurred in Bangladesh

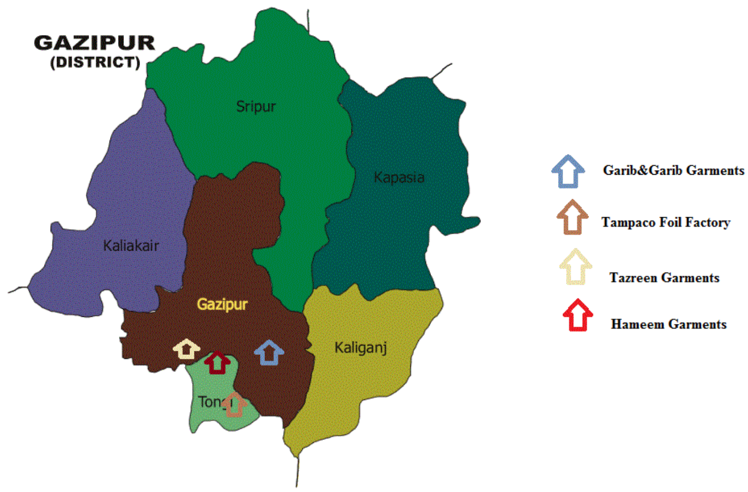

Fig 4.1: Google map of selected fire hazard location in Bangladesh (Tazreen Garments, Hameem Garments, Garib & Garib Garments, Tampaco Foil Factory)

CASE 4.1: Tazreen fire hazard

Fig 4.2: Tazreen Fashion ltd. status after the fire hazard

Fact:

On the night of November 24, 2012 there occurred a fire hazard at TazreenFashions, Nischintapur, Ashulia, Dhaka, Bangladesh. The factory employed more than 1200 workers almost 95% of whom were females. The annual turnover of the factory was over USD 36 million. Wal-Mart, KIK GMBH, Teddy Smith Ace, C&A, Li & Fung, Infinity Women, Karl Rieker, Carrefour, Dickies, Ikea etc world famous brands are the major buyers. The fire resulted in the deaths of 111 workers. And more than 300 workers are injured. The fire, presumably caused by a short circuit, started on the ground floor of the nine-story factory, trapping the workers on the floors above. Because of the large amount of fabric and yarn in the factory, the fire was able to quickly spread to other floors, complicating the firefighting operations. The fire burned for more than seventeen hours before the firefighters were successful in extinguishing it.

Most of the victims were found on the second floor, where at least 69 bodies were recovered. Witnesses reported that many workers had been unable to escape through the narrow exits of the building. Twelve of the victims died leaping from windows in order to escape the flames, some of which died of those attained injuries after being taken to area hospitals. Some lucky workers who had been able to escape to the roof of the building were successfully rescued. The fire department's operations manager stated that the factory lacked adequate emergency exits that would have made it possible to escape from the building. Especially, since the fire broke out in the warehouse on the ground floor and quickly moved up to the higher floors of the building's three staircases, all three led through the ground floor, making them extremely dangerous and unusable in the case of the ground floor fire .This left many workers trapped and unable to get safely out of the course of the fire. [Associated Press & Reuters, NBC News. November 2014.]

There were multiple investigations undertaken by the government and the garment association (BGMEA – Bangladesh garment Manufacture and Export Association) which termed the fire as ―pre-planned‖ and sabotage. The Bangladesh Occupational Safety, Health and Environment Foundation (OSHE) carried out an independent investigation into the incident to highlight the root causes and failures resulting in the large number of deaths and injuries in the incident. The team conducted field investigations, visited the factory site, met the workers and victims of the factory, met government officials and other Stakeholders. The findings of the report were presented during a multi-stakeholder consultation on ―Safe Work at Garments Factories in Bangladesh: Lesson Learned from Tazreen Fire Accidents- Challenges and Way Forward‖ held at the CIRDAP Auditorium, Dhaka on January 7, 2013.

Fig 4.3: Tazreen Fashion ltd.during rescue mission

FINDINGS:

OSHE presented the findings of the investigations.

- There was no fire or emergency exits or stairways. There were three stairways in the building but none of them was fire exit.

- There was only one main entrance and exit way which is situated on the ground floor which was in itself not wide enough to accommodate the number of workers in the factory fire extinguishers and other fire defense materials were inadequate and were not to be found during the fire.
- fire extinguishers and other fire defense materials were inadequate and were not to be found during the fire.

- 111 workers lost their lives out of which 58 have been identified. 53 bodies are still unidentified.
- Most of the workers died due to suffocation and burns. Only 6 workers died due to fall from height.
- The second floor collapsible gate was locked and the highest numbers of dead bodies (69) were recovered from this floor. Supervisors on the 2nd and 3rd floors stopped the workers from evacuating the factory when the fire alarm went off stating the alarm as a false.
- Owner did not follow building code, had a nine storey factory but had permission only for three floors.
- Raw materials were stored on the ground floor and in close proximity to the high voltage electric transformers which resulted in the flames spreading at a fast rate.
- The factory did not have a renewed fire safety certificate either.
- Almost 300 workers are injured, some seriously although BGMEA has so far prepared a list of only 63 injured workers. The OSHE team has compiled a list of 89 injured and 58 cases of death due to the fire tragedy.
- Only 40 workers out of 1200 had received a basic fire safety introduction.

Building Analysis:

The factory building not designed as per Bangladesh National Building Code of Building Construction Act. Authority has approved for 3 storied but the building was constructed as 9 storied without any fire exit.

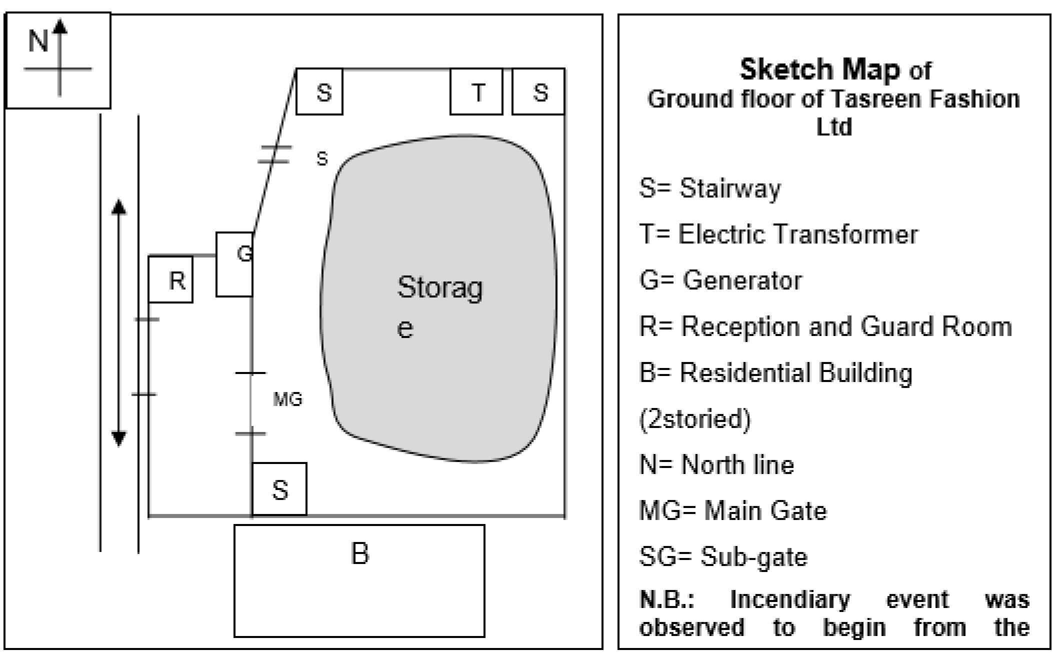

Fig 4.4: Ground floor of tazreen fashion Ltd

A brief description of ground floor of Tazreen Fashion Ltd, Nischintapur, Savar:

• There are three stairways, including one which is situated at the south-west part of ground floor, another two are situated at the north-west and north-east corner of the ground floor.
• All stairways were removed inside of the ground floor.
• There is only one main exit and entrance way from ground floor.
• There is also a narrow sub-gate at ground floor, but all the time it’s kept lock.
• There are two high voltage electric transformer are take place near beside north-east stairway.
• All the electric cables are connected with those transformers.
• There is a high powerful generator, which is take place at the mid position attached with west side wall of the ground floor.
• Whole the ground floor were using as storage of spin, fabric and other raw materials.
• The stuck of spin and fabric was much closed to high voltage transformer.

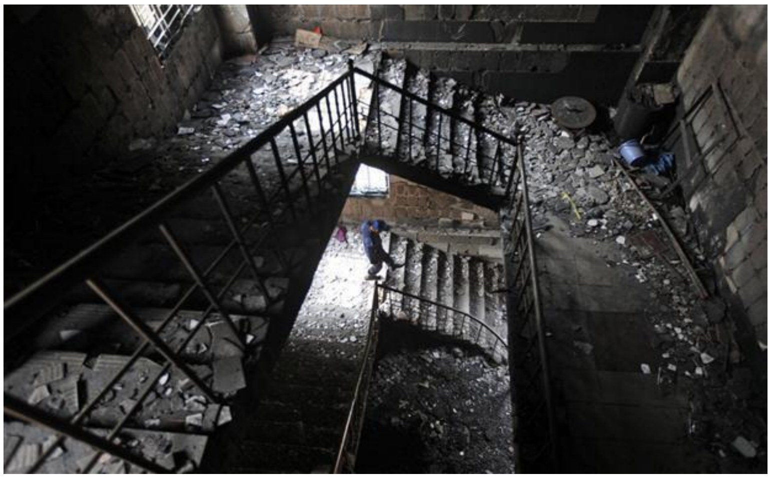

Fig 4.5: Tazreen factory stair

CASE 4.2: TAMPACO FOILS FACTORY:

Tampaco foils are the leading flexible and tobacco packaging company in Bangladesh since 1978.

Fig 4.6: TAMPACO FOILS FACTORY.

A devastating fire had broken out at a factory in the Tongi BSCIC industrial area of Gazipur, near the Dhaka capital of Bangladesh early on Saturday Sep 10, 2016. At least, 39 people were killed and injured more than 150. In its investigation report General Manager (marketing)of Titas Dhaka North RanaKabir, who headed the investigation committee, told that the factory used twice the amount of gas it was permitted. Earlier in 2005, Tampaco was fined twice for excessive gas use, according to Titas officials. Without going into details, he added that the factory should have stored its inflammable chemicals in a more secured place. “The fire became more devastating because of those chemicals.
Primary findings show that, the fire was caused due to an explosion of the boiler in the factory but till now the causes of explosion have not been identified. Further the structure of the factory building was completely unsuitable for industrial production. In addition, the building was cramped, full of flammable materials and had only one exit.

Fig 4.7: Tampaco during fire.

In light of the fire incident at the factory of Tampaco Foils Ltd in Tongi, Gazipur the issue of workplace safety in non-export manufacturing industries has once again come under spotlight. According to Srinivas Reddy, country director of International Labor Organization (ILO) in Bangladesh claimed that Tampaco fire is a reminder for the Department of Inspection of Factories and Establishment (DIFE) to step up inspection in all the factories and guarantee safety. We are encouraging and supporting the DIFE to reach out to the factories that do not have the standard safety measures in place, and implement and monitor said measures as per Bangladesh Labor Act, 2013, Reddy added.

After the fire at Tampaco, the government is focusing on factories which work with boilers, chemicals and plastics, as well as explosive and flammable material, for workers safety in order to avert further untoward incidents.

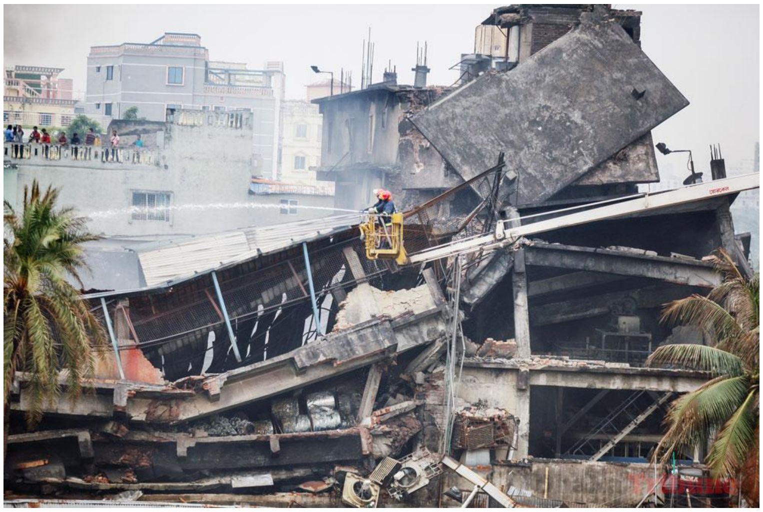

Fig4.8: Tampaco after fire hazard.

CASE 4.3: Fire in Ha-Meem Factory

Fig 4.9- Ha-meem fire hazard

Around noon on December 14, 2010, a fire emerged at the Ha-Meem garment factory resulting in 28 fatalities and more than 150 injuries. The time when the fire emerged coincided with the lunch break. Consequently, although more than 5,000 employees work at the facility, many of them had gone home or otherwise left the building. The fire was caused by a short circuit in the electric wiring on the 10th floor, where the factory was located. About 450 employees were having lunch on the 11th (highest) floor when the fire broke out, while there were virtually no people on the 10th floor. The fire spread through openings in the outer wall and the freight

elevator shaft. On the 10th floor (where the fire emerged) and the 11th floor, there was no fire-retarding partitioning in the main building space (with a floor area of about 4000 m2), and therefore the propagation of the fire in the horizontal direction could not be prevented . The roof on the 11th (highest) floor was severely damaged. According to the employees of the Ha-Meem Group, three out of the six available evacuation staircases were usable; however the ascension of smoke could not be prevented since fire-retardant doors were not installed. Also, according to reports, if all evacuation staircases had been unlocked, evacuation via the staircases would have been easier, and there would have been fewer casualties. In a hearing with the employees of the Ha-Meem Group as part of our on-site investigation, we found that three out of the 28 fatalities occurred on the top floor due to asphyxiation. The remaining 25 fatalities occurred when it became impossible to use the evacuation staircases due to hot air and smoke, when people started jumping out of windows or attempted to make lifelines from joined rags and used them to escape down the walls. However, officials [[I assume that this refers to investigating personnel (fire inspectors) and/or company officials.]] stated at the hearing that some of the employees were using the evacuation staircases even after others had started jumping from the windows. It was assumed that after some of the staircases had become unusable due to a sudden surge of smoke and hot air, employees who were close to them did not look for other staircases, even though there was one which was unlocked and still usable, and instead panicked and started jumping from nearby windows.
[Sarkar K, Mollah S, The Daily Star, December 15, 2010]

Issues and improvements in terms of fire safety

The reasons why the fire could not prevent from spreading but expanded and took heavy toll of lives are described below along with the solutions for each in the brackets.

(1) There was no horizontal fire compartment. (Create horizontal fire compartment)

(2) There was no fire door/shutter and thus no vertical fire compartment at stairs could be formed. (Install proper fire door/shutters at the entrances of stairs)

(3) Doors to three emergency stairs out of six were locked. (Always leave the emergency stair doors unlocked, monitor the emergency doors)

(4) Workers did not know where the emergency stairs were and it resulted in their dangerous attempts including jumping out of a window. (Educate workers with regard to fire evacuation)

As mentioned above, improvements included not only the formation of a self-defense fire brigade and the installation of fire fighting facilities, but also the installation of emergency unlocking systems on the evacuation staircases.

・ Tokyo University: Prof. TokiyoshiYamad

CASE 4.4: GARIB AND GARIB FACTORY FIRE

Fig 4.10: Garib and Garib factory

Around 9:30 p.m. on Thursday evening, February 25, 2010, a fire broke out on the first floor of the Garib&Garib factory, which burned out of control for more than two hours before fire fighters could contain it. As it was believed that an electrical short circuit had caused the fire, a factory security guard shut off the main electrical switch, plunging the factory into darkness. This left 25 to 30 workers trapped on the sixth floor. Twenty-one garment workers on the sixth floor, including 16 women, died of smoke inhalation. Thirty or more of the workers on the lower floors were also injured, some seriously. The workers have again confirmed that the main entrance/exit gate to the factory was locked, as were the exit doors on the 6th floor where 21 of the trapped workers died.(institute for global labor and human rights).The fire never spread above the first floor, but the burning bales of acrylic yarn caused a thick black toxic smoke to fill the factory. The main fire exit on the sixth floor was chained shut. The remaining staircase was piled high with bales of yarn and other boxes. The windows on the sixth floor had also been locked. Engulfed in impenetrable darkness and smoke, and lacking fresh air, the workers were disoriented and helpless. Some had tried to reach the blocked exits, while others died of smoke inhalation on the factory floor. They had never been trained to deal with such a crisis.

Garib & Garib Factory floor in ruins. (Photo rights belong to the *Daily Star*[1])

Fig4.11: Garib&Garib Fire Hazard

The sixth floor which was constructed of tin was also apparently built illegally, without permits or approval from the building codes office of the Municipality of Gazipur. The original permit allowed the factory to build up to five stories. There were also problems with the factory's fire extinguishers. Mr. Abdur Rashid, deputy director of Fire Services and Civil Defense in Dhaka, told the Daily Star newspaper, February 26, 2010, that the numbers of fire extinguishers were not sufficient given the size of the factory.
Thus it is unlikely that workers had enough education and training on safety evacuation from fire or space organization of the building.

Suggestions for Improvement

There were two reasons why the fire could not prevent from spreading but expanded and caused death. The reasons are described below along with the solutions for each in the brackets.

(1) The evacuation routes for two-way escape were prepared but they did not have fire door/shutters and thus no shaft enclosure, or vertical fire compartment could be formed. (Install properly-rated fire door/shutters at the entrances of staircases)

(2) Although there were large openings that could serve as natural smoke extraction vent, workers could not find and open the windows due to the lack of understanding in fire prevention and space organization. (Education and training on safety evacuation from fire and space organization of the building)

CHAPTER 5

FINDINGS & DISCUSSION

5.1. Comparison among selected case studies

Table 5.1: Comparison of basic facts of 4 cases: Tazreen Fashions, Tampaco, Garib&Garib and Hameem Factory fire incidences.

Factors	Tazreen Fashions	Tampaco Factory	Ha-Meem Factory	Garib&Garib Factory
No of Floor	9	5	11	7
Number of people working at that moment	1200	100	300	80
Building Occupancy type	Factory	Factory	Factory	Factory
Construction Quality	Poor	Good	Good	Poor
Electrical & Mechanical facilities	Poor	Good	Good	Poor
Violation of BC ACT	Yes	No	No	Yes
Illegal connections of electricity & gas	Not evident	Not evident	Not evident	Not evident
Time of occurrence	12.00 AM	7.30 AM	1.30 PM	9.00 PM
Major cause of accident	Electric Short Circuit	Boiler explosion	Electric Short Circuit	Electric Short Circuit
Narrow & insufficient number of staircase	No	No	No	Yes
Presence of firefighting equipment.	Not sufficient	Not sufficient	Yes	Not sufficient
Condition of exit door	Poor	Poor	Poor/locked	Poor
Congested air circulation	Yes		No	Yes, window was shield

After analyzing Tazreen, Tampaco, Ha-meem, Garib&Garib factory fire hazard, it was found that the main reason for the accidents was the negligence of the owner and the midlevel managers of the factory in practicing the OHS provisions properly. Another reason for these accidents are the lack of adequate fire exits. Moreover, the storage of raw materials like fiber and yarn in an open space near the high voltage electric transformers accelerated the spread of the flames. Also, the lack of sufficient fire extinguishers and inadequate preparedness and training to handle accidents contributed considerably to the incident. So it is clear that the major reason for casualties in a fire breakout in a factory is not the fire itself. Rather the triggering components for fire (electrical short circuit etc.) and the subsequent impacts of the fire on human mind (panic causing stampede etc.) are the major reasons of casualties. The major reasons for fire are given below: gist reasons for fire and the causes are given below:

1. Unplanned work environment
2. Disorganized workers
3. Electric short circuit
4. Faulty electrical wiring
5. Smoking materials
6. Boiler explosion
7. Kitchen stove and carelessness
8. Fire from existing structure

9. Poor building design
10. Lack of concern of industry owner in this issue

Reasons for casualties in RMG factories
1. Stampede Locked exit route
2. Inadequate number of stairs
3. Deliberately blocked pathways
4. Smoke and suffocation

5.2. Survey on human behavior about fire

Survey results on Human Behavior about FIRE INCIDENT are shown below by PIE CHART……

Q1: Have you ever faced any fire incident?

a) Yes
b) No, if no, then skip question no. 3.

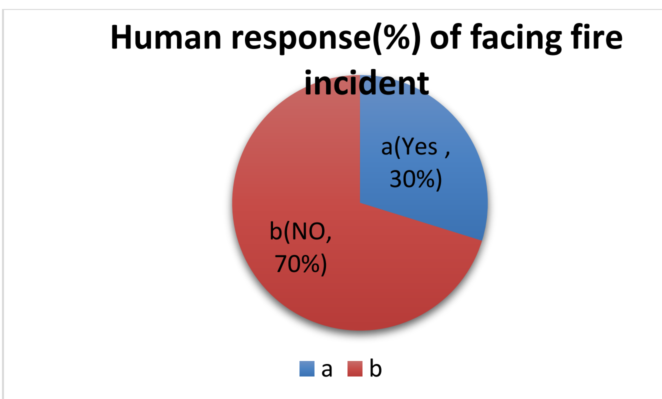

Fig 5.1: Human Response (%) of facing fire incident

Q5.2: Do you know how to use fire extinguisher?

a) Yes
b) No

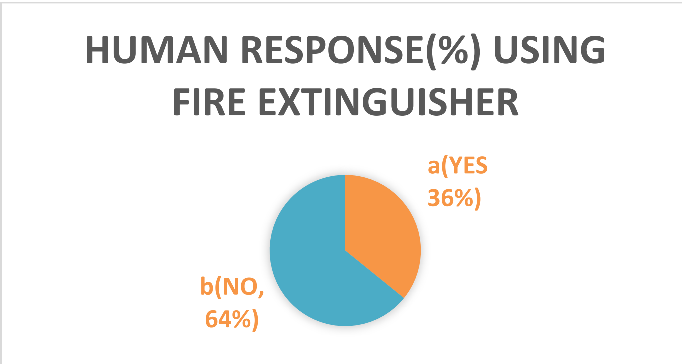

Fig5.2: Human Response (%) using fire extinguisher

Q5.3: What was the first thing you noticed to realize that there was a fire incident?

a) Saw smoke
b) Smelt smoke
c) Heard alarm
d) Someone urged to leave the place

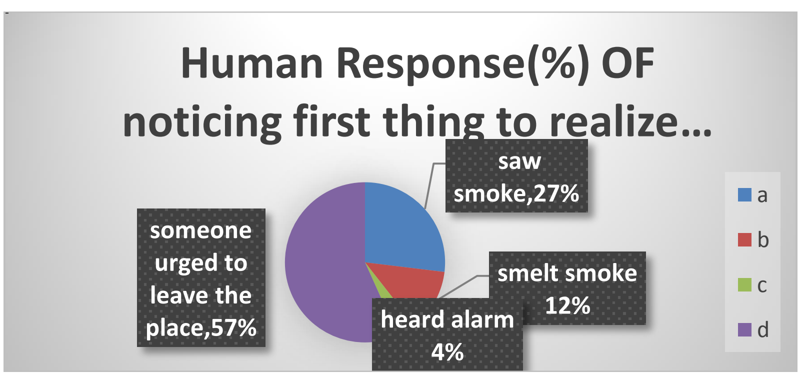

Fig5.3: Human Response (%) to realize fire incident

Q5.4: What should you do if you discover a fire?

a) Call the fire service
b) Tell someone else about it
c) Raise the alarm

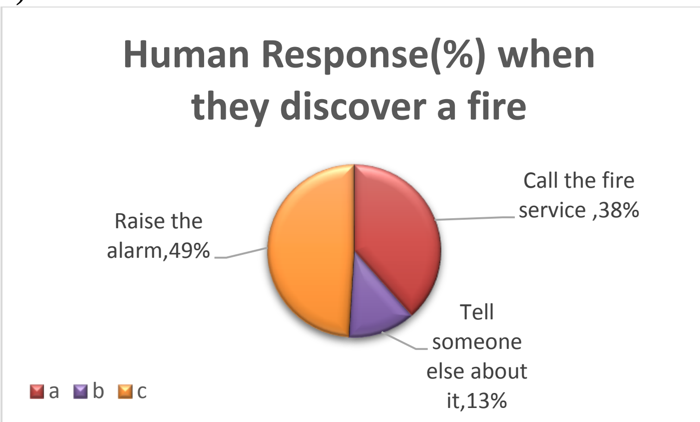

Fig5.4: Human Response (%) to discover a fire

Q5.5: What is the purpose of fire doors?

a) To stop the spread of smoke &flame

b) To help people evacuating without panic

c) To reduce the spread of smoke

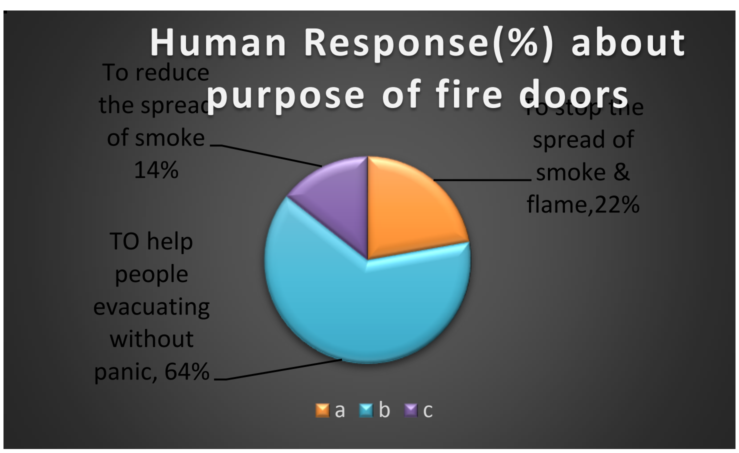

Fig 5.5: Human Response (%) of fire doors

Q5.6: Where can you learn what to do 'in the event of fire'?

a) A fire action notice

b) A fire training session

c) A friend or colleague

Fig5.6: Human Response (%)what to do in fire

Q5.7: To evacuate what you would use?

a) Stair

b) Elevator

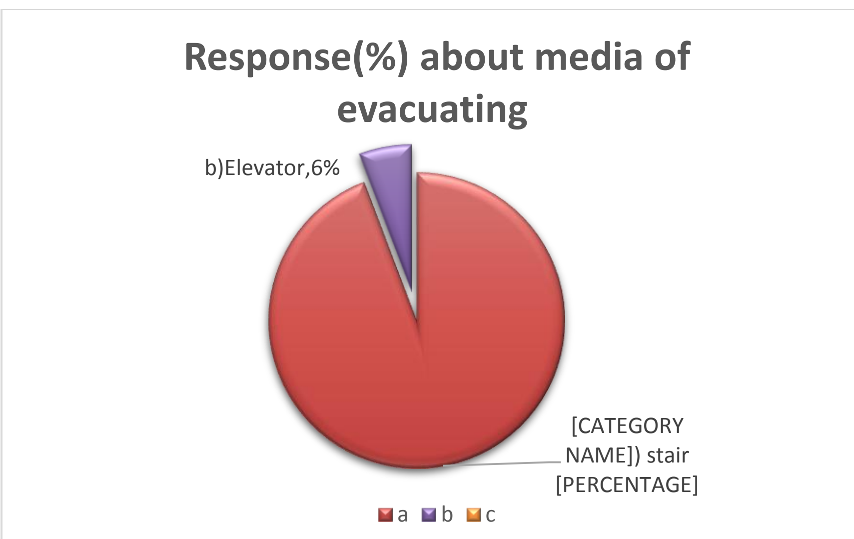

Fig5.7: Human Response (%) media of evacuating

Q5.8: To what extent do you believe elevators are safe to use during fire?

a) Never safe

b) Rarely safe

c) Safe as stair

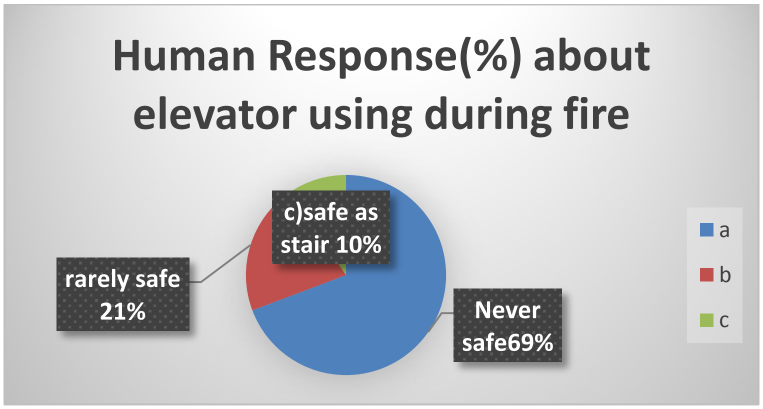

Fig5.8: Human Response (%) using of elevator during fire

Q5.9: Does your institution approve fireworks and pyrotechnic displays?

a) Yes

b) No

c) Fireworks and pyrotechnics not allowed on campus

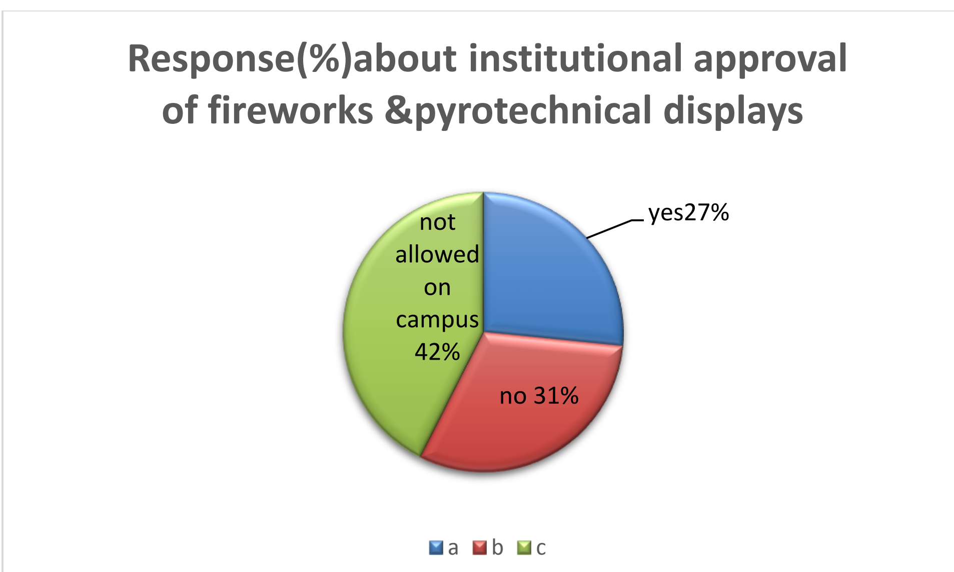

Fig5.9: Human Response (%) about institutional approval

Q5.10: Do you know the location of fire extinguishers?

a) Yes

b) No

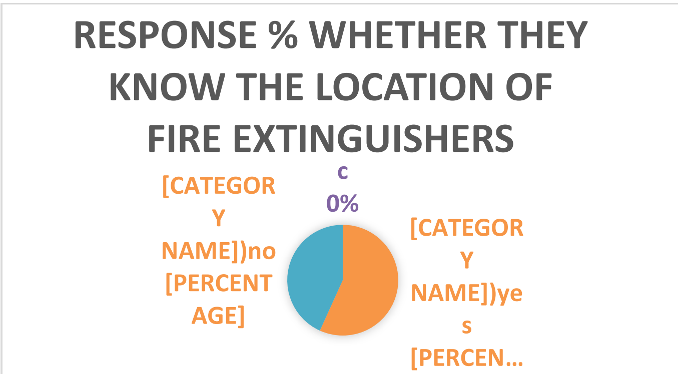

Fig5.10: Human Response (%) of knowing the location of extinguisher

From this survey it was found that during a fire, occupants will panic & for the limited knowledge that people have on fire development and fire dynamic do not prepare them to have the best response during fires. Also it was seen that 64% people do not know how to use fire extinguisher and also even the location of it during emergency from this survey. Also occupants have the tendency to move through smoke even though they know that smoke kills. The movement speed of occupants in a smoky environment can drop dramatically due to the difficulty on seeing and breathing. Movement in smoke should be absolutely avoided for its potential lethal effect. The reality is however, that occupants in fire often move though smoke which reduces their speed of movement. Movement calculations are usually over-optimistic compared to actual movement speed during fires since a number of dimensions interplay to reduce the speed of movement to leave the building.

Although adequate fire safety systems are often installed in buildings, failure of these systems to work as planned is regularly observed when an actual fire occurs. Problems frequently arise during fire incidents because systems were put in place with false expectations regarding how occupants actually behave during fires. Many problems could be foreseen if there was more attention given to human behavior in fire.

Table5.2: Factors having an impact on Human Behavior in Fire .

Occupant characteristics	Building characteristics	Fire characteristics
Profile • Gender • Age • Ability • Limitation	Occupancy • Residential (low rise, midrise, high-rise) • Office • Factory • Hospital • Hotel • Cinema • College and University • Shopping Centre	Visual cues • Flame • Smoke (color, thickness) • Deflection of wall, ceiling, floor
Knowledge and Experience • Familiarity with the building • Past fire experience • Fire safety training Other emergency training	Architecture • Number of floors • Floor area • Location of exits • Location of stairwells • Complexity of space/Way finding • Building shape • Visual access	Olfactory cues • Smell of burning • Acrid smell
Condition at the Time of Event • Alone vs. with others • Active vs. passive • Alert • Under Drug Alcohol Medication	Activities in the Building • Working • Sleeping • Eating • Shopping • Watching a show, a play, a film etc.	Audible cues • Cracking • Broken glass • Object falling
Personality • Influenced by others • Leadership • Negative toward authority • Anxious	Fire Safety Features • Fire alarm signal (type, audibility, location, number of nuisance alarms) • Voice communication system • Fire safety plan • Trained staff • Refuge area	Other cues • Heat
Role • Visitor • Employee • Owner		

Chapter 6

CONCLUSION & RECOMMENDATIONS

6.1. Conclusion:

Ready Made Garments (RMG) is one of the leading industries in Bangladesh perspective, so ensuring its fire safety is a big deal. Fire safety enhances the comfortable & safe environment of working place for workers. Fire Risk Assessment is essential which will help to identify any possible danger & the way to get them reduced well ahead in time. Fire Safety Management is very important in the concept of providing total safety in a structure. For this, it's necessary to maintain provision for means of escape, inspection of all regular exit doors, passages & staircases. It is also needed to ensure regular fire drill &give information for various fire fighting techniques to workers. In Bangladesh due to lacking of fire safety management in RMG many devastating incidents happened in last few years. The main reason behind these is violation of BNBC provisions in RMG constructions, lacking of safe workplace for workers & their unconsciousness about fire safety knowledge. So at the time of summing up it needs to be focused that Bangladesh government must give more attention in this important sector,& fire safety management authority needs to be concern about it by ensuring that all garments owners are following BNBC rules & regulations& maintaining garments workers safety under the supervision of Accord & Alliance. For this, they must keep all types of required fire protection & extinguisher system in the garments, provide training to the specific staff about fire fighting in emergency & most of all create public awareness about fire safety. Due to having limitations like political instability, honest & integrity of RMG owners & lacking of awareness about fire safety among the workers, these incidents increased. But by our initiatives & motivations these situations can be overcome easily & ensure safe sound environment for garments works to flourish the RMG sector in Bangladesh.

6.2. Recommendation:

The recommendations in relation to the thesis topic are given below:

a. Sufficiently wide fire exit doors and enough ventilation with proper maintenance for air circulation should be designed for industry building
b. Proper exit sign and safety sign should be applied in appropriate areas of the industry
c. Multi sensor detectors or heat detector are recommended on the sewing, cutting, iron, knitting& finishing and other areas where there is a possibility of floating fabric dust, threads and cottons etc. to avoid false alarm.
d. Keeping adequate number of extinguishers systems and its proper use should be ensured & must keep a prior relationship with local fire service.
e. Separation of store house from the factory is needed & blockage of corridors or passages should be prohibited.
f. Electrical equipment & wiring must be properly designed, installed & maintained.
g. Escape route must be lighted all the times and keep clear for safe evacuation.
h. Regular fire drill & fire safety management training for all kinds of worker must be ensured.
i. All the buildings of garment industries should have proper announcement system as to how to get out of the buildings in emergency.
j. Every factory owners should establish building properly following the Bangladesh National Building Code and fire safety guideline.
k. Proper implementation of Bangladesh Labor Law and other relevant laws in all factories must be confirmed & Government should take steps to operate mobile courts in factory level regularly for inspection.
l. Most of all to create awareness among the occupants about fire safety is very necessary & to identify the problems and find out the way of solving, every factory must have a research wing.

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