

Assessing Fire Resistance of Steel Frameworks: Current Vulnerabilities and Resilient of Fire Safety Conditions for Steel Structures in Dhaka: Exploring Fire Resilient Design

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Abstract: Steel-framed buildings are essential to Bangladesh's socioeconomic development because of its greater flexibility and long spanning capabilities. However, the fire safety of steel buildings receives very little attention. This study aims to improve knowledge of fire safety conditions in the steel industry due to the absence of fire risk assessment. This study demonstrated steel's ability to withstand fire at 816°C for at least 30 minutes using software analysis. In order to visualize the real safety conditions in steel buildings, a field assessment was also carried out on twenty-five steel buildings in Dhaka, Gazipur, Savar, and Narayanganj. This study creates a fire risk index for each steel building after examining the survey data. This study creates a fire risk index for each steel building on a scale of 0 to 4 after evaluating the survey data. The average FRI of 2.46 indicates that most buildings have inadequate fire safety. The FRI values show significant departures from the Bangladesh National Building Code's (BNBC-2006) minimum fire safety criteria. It is recommended that authorities monitor and enforce regulations more strictly and raise awareness in order to improve safety conditions and practices among steel building users.

Keywords: Steel Structure, Fire Risk Index, Fire Safety, Fire Hazard, Fire Safety Index, Awareness.

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I. INTRODUCTION

➤ Background

The interest in the application of steel as a structural material has been almost continuously increasing throughout the last decades. Its main fields of application have been industrial shed and corporate office buildings [6]. The fire-resistant behavior of steel structures has drawn attention in the recent days. The analysis of structural response to fire has assisted engineers in formulating safer and cost-effective ways of design [7].

For structural design and analysis, the fire design should be considered as an important factor as inappropriate modelling and assumptions could lead to property loss and in some extreme cases death [2]. Still, the fear of uncontrolled fires and the desire to avoid their consequences have remained as a primary human reaction and as an important human objective. Fire protection involves the study of behavior, suppression and investigation of fire and related emergencies [4]. It also includes research and development, production, testing and application of suitable

fire protection systems. The primary goal of fire protection is to limit the levels of casualties, injuries and losses of property in a fire event [5]. In this research, a finite elements software such as Autodesk Robot was used to design and test steel frames under fire and how they react under those circumstances. Field Survey was also conducted to determine the present condition of fire safety in steel buildings.

II. RESEARCH DETAIL

➤ Software Analysis

Autodesk Robot Structural Analysis Professional module was used to design and test steel under fire and how they react under that circumstance [14]. An actually constructed steel building section was used in the analysis process.

Robot Structural Analysis Professional software provides structural engineers with advanced building simulation and analysis capabilities for large, complex structures.

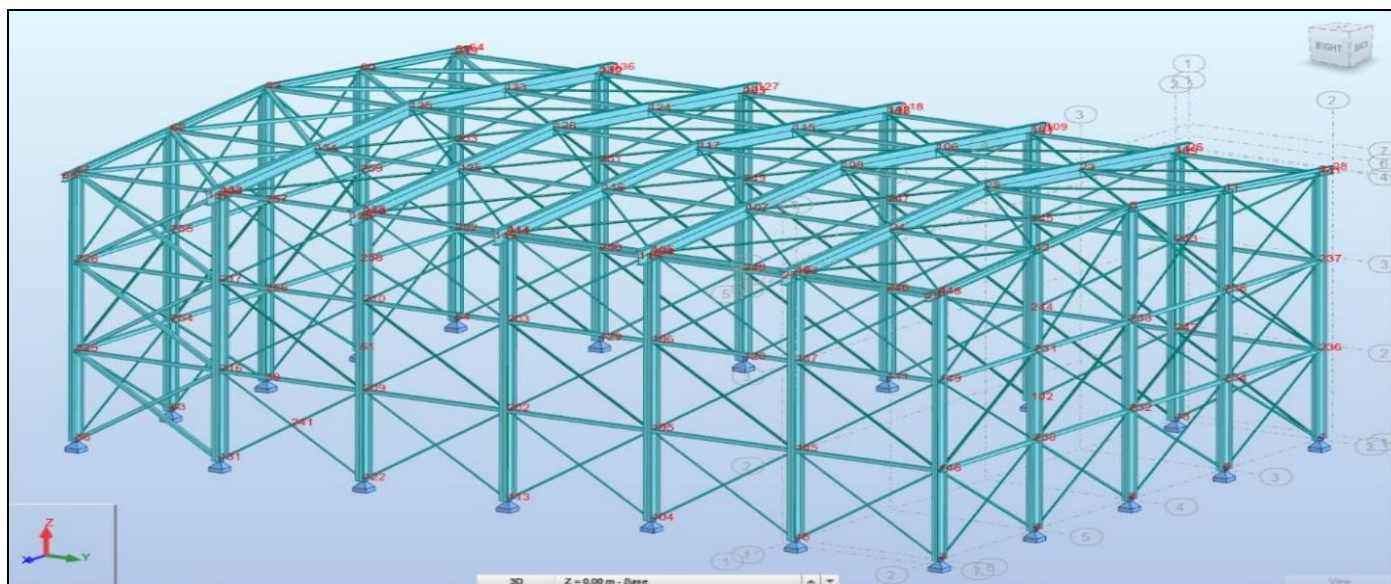


Fig 1 3D View of the Analyzed Model
(Source: Robot Software Analysis, 2020).

For this study, an existing steel building was chosen to create a simulation. The name of this steel building is ARAC Poly-wrap, situated at Gazipur. 3D model was generated using actual steel section provided in the building. This building was analyzed using following parameters:

- Design Code: Eurocode-2005
- Coating: Unprotected
- Time Duration: 30 minutes
- Temperatures: 818°C
- Temperature Curve: Standard ISO 834
- Unit Mass: 7850kg/m³
- Design Load: DL= Dead Load
- LL= Live Load
- Design Combination: DL+0.5LL

➤ *Development of the Weights for Field Survey*

Data analysis process has been carried out by providing importance factor on different safety requirements on the questionnaire. According to regulation of fire safety set by BNBC-06, some parameters were selected to check the safety

conditions [10]. A weight factor was assigned to each of the parameter to measure its importance in the safety insurance [11]. This importance factor was developed based on the Data analysis process has been carried out by providing importance factor on different safety requirements on the questionnaire. According to regulation of fire safety set by BNBC-06, some parameters were selected to check the safety conditions [10]. A weight factor was assigned to each of the parameter to measure its importance in the safety insurance [11]. This importance factor was developed based on the opinion of some specialist on fire safety. The specialist team consists of Disaster manager, Fire service officer, structural engineer, architect, doctor, safety inspector etc [13]. Thus, a parameter is given the maximum weight, 5, if an expert deems that deficiencies in this parameter will cause high damage to both life and goods, while the weight is minimum, if the expected damage is minimal [9]. To avoid a difference in the perception among the experts on the ‘measure’ of importance a weighting scheme was presented to the experts to guide their scoring, see Table.

Table 1 Weight Factor

Weight	Description of Consequences
5	Most important—if not present, very high damage of both lives and properties may occur
4	Important—if not present, considerable damage of both life and properties may occur
3	Essential—loss of life may not occur but other losses and injuries are high
2	Essential—loss of properties and injuries are considerable
1	Not essential but preferable

(Source: [8])

Table 2 Fire Risk Index Grade Point.

Grade point	Subjective observation	Quantifiable parameters % deviation from ideal case
4	Excellent	0 (zero)
3	Good	Less than 10%
2	Average	From 10% to 30%
1	Poor	More than 30%
0	Very poor	Not present

➤ *Performance Grading Scheme*

During the field inspection of the steel buildings, each of the ‘hard’ parameters is given a grade point, ranging from 0 (zero) depending on the factory’s performance, where 0 (zero) depicts the absolute absence and 4 represents a 100% compliance in that specific parameter [12]. to 4 For some of these structural parameters, there are prescribed standard values in the BNBC-2006 standard for measuring and comparing the present status of the parameters [8]. The performance in some of the parameters was difficult to

measure quantitatively, and grade points are awarded based on qualitative observation in these cases.

➤ *Determination of Weights for Each Parameter*

Average value for each importance factor was taken from different specialist. Thus, a weightage factor for each questionnaire was developed which was used to generate a safety score for each sample building collected [15]. Then, based on their score, sample buildings were categorized as safe, moderately risky, risky and unsafe structures [1].

Table 3 Checklist of the Questionnaire Survey

SL No	Safety Measures	Importance factor	Scale
1.	Number of emergency exits in the building	5	5
2.	Number of emergency stairs	4	5
3.	Width of stairs	4	5
4.	Width of corridors/walkways	4.5	5
5.	Distance of stairs or exits from different rooms	4	5
6.	Type of material used in surrounding	3	5
7.	Signs to provide direction to exits	3.5	5
8.	Fire alarms system	5	5
9.	Fire Extinguishers	5	5
10.	Availability of water source	4.5	5
11.	Separation of chemicals and fire rated materials	4.5	5
12.	Availability of lightening arresting system	3	5
13.	Ventilation system of the building	4	5
14.	Protection of power source from water and flood	4	5
15.	Earthing connection for electrical equipment	4.5	5
16.	Excess route for fire vehicles	5	5
17.	Level of awareness for fire safety among the users	5	5
18.	Fire drills at regular intervals	4	5
19.	Maintenance of fire protection system	4.5	5
20.	Designated area for smoking	3	5
21.	Safety system and sign for electrical equipment	3.5	5

(Source: Field Interview, 2020)

III. RESULTS AND DISCUSSIONS

➤ *Fire safety Detail*

The answers against the different parameters of the questionnaire were analyzed in this portion. This part provides the fire safety conditions of the sample buildings. Fire safety index was determined based on the presence and absence of different fire safety measure of the sample buildings.

• *Fire Safety Scores for all Sample*

The graph shows the safety grade point of all 25 samples. The grading system was considered as scale of 0 to 4 where 0 represents highly risky and 4 represents fire safe condition following all considerations from BNBC. From the graph it can be seen that most of the buildings have grade point below 3, even some of them have FRI value as low as 1.37. It indicates the vulnerable fire safety condition of the steel buildings.

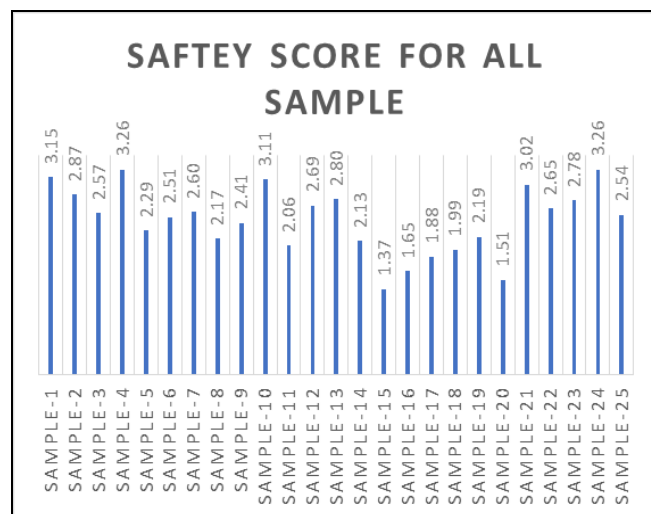


Fig 2 Fire Safety Grade Point for all Samples (Source: Field Survey, 2020).

➤ *Presence of Safety Measures in Different Occupancy Groups*

The bar diagram shows the presence of different safety parameters like fire safety director, fire extinguishers, fire

exits, fire maps in each group of samples based on their uses. From the figure it can be said that all these parameters are found in all the garments building, while the factory buildings have lowest presence of these parameters.

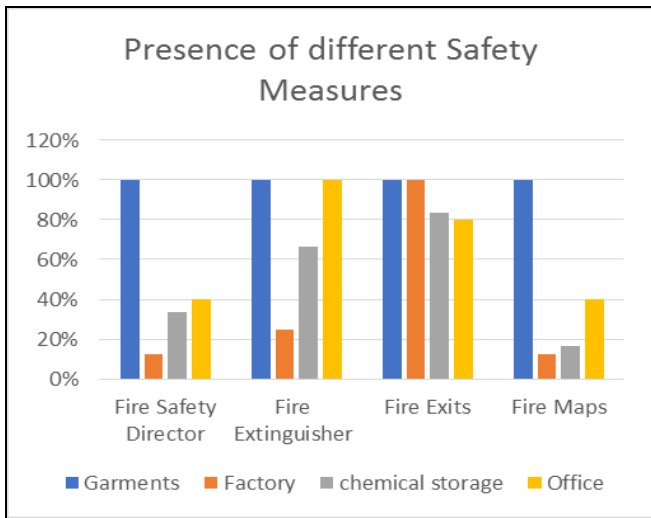


Fig 3 Fire Safety Measures for Different Group of all Samples
(Source: Field Survey, 2020).

➤ *Fire Safety Index in Different Occupancy Groups*

All 25 samples were evaluated for fire safety condition based on the response against questionnaire parameters. After the evaluation, it was found that garments buildings scored higher than the other groups. After the collapse of Rana Plaza at Savar in 2013, a foreign authority named Accord and Alliance launched their activities in Bangladesh. As all garments require Accord certification to continue their operation, garments buildings are found to obey the safety rules more than the other groups. As a result, fire, garments authority tends to follow the fire safety measures accurately and have higher safety scores. The following charts represent the scores of different groups of buildings.



Fig 4 Comparison of Safety Grade Between Different Buildings
(Source: Field Survey Data, 2020).

➤ *Specific Smoking Zone*

Smoking is very common habit among the workers. But in most of the steel buildings, there was no specified smoking area. Only 6 buildings had been found with smoking area while 19 buildings did not have any smoking area. Even some buildings with chemical storage have no smoking area which increases the risk of accident. Again, in some buildings smoking is prohibited in the premises, although workers are often caught with cigarette.

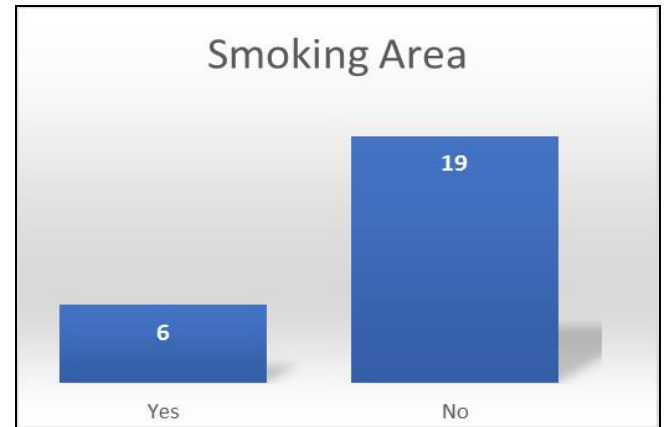


Fig 5 Specific Smoking Zone
(Source: Field Survey, 2020)

➤ *Condition of the Chemical Storages*

During the survey, we found 6 steel building storing chemical materials. Most of the chemicals found in the buildings were flammable. It is a matter of great surprise that most of these buildings do not have sufficient fire protection measures. The graph above shows that among the 6 buildings only 2 buildings have safety scores more than 70%. There are buildings with safety scores in the thirties. So, it can be said that if fire breaks out in these buildings, amount of damage will be very high.

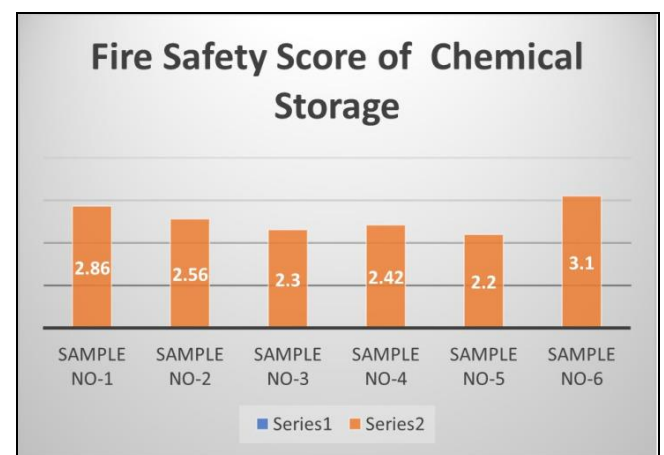


Fig 6 Fire Safety Grade point for all Chemical Storage Samples
(Source: Field Survey Data, 2020).

➤ *Fire Maps*

Fire map is an important safety measure that enables a smooth evacuation process. The graph represents that among 25 buildings only 9 buildings have fire maps in front of the

main gate. Others do not have any fire map. Most of the garment buildings and some office buildings have fire maps.

➤ *Presence of Fire Safety Director*

Among 25 buildings surveyed during this study, 10 buildings have assigned fire safety director. On the hand 15 buildings have no fire safety manager. So, these buildings have no official regulation against fire accident. Even some of them do have regulation, but there is no on field implementation of the rules.

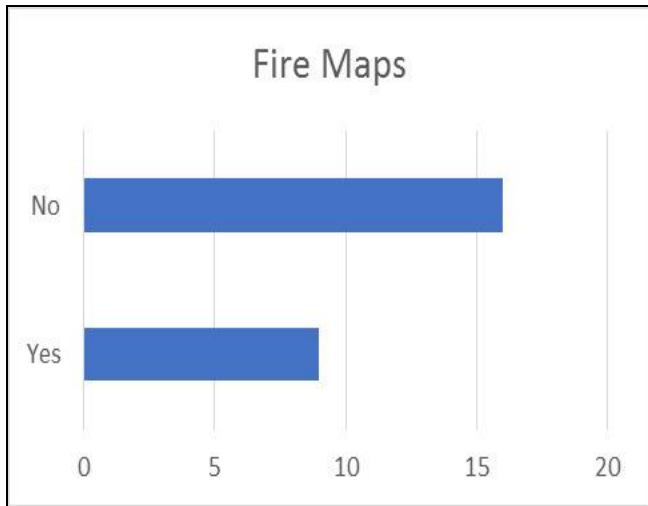


Fig 7 Fire Maps in the Steel Buildings (Source: Field Survey, 2020)

➤ *Fire Safety Measures*

• *Portable Fire Extinguishers*

Among the buildings surveyed, it was found that 60% of them have portable fire extinguishers, rest have no fire extinguishers. It is a good sign that most of the buildings have fire extinguishers. But they are not properly maintained. Some fire extinguishers are found without expiration date, while some are found date expired. Again, in the chemical storages, required types of fire extinguishers are often not used.

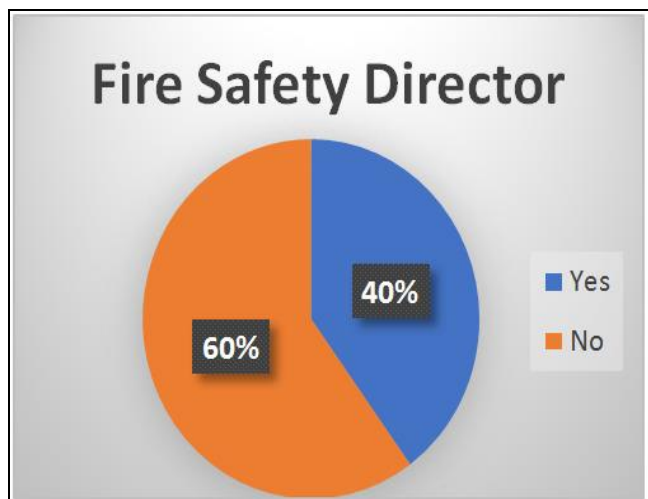


Fig 8 Fire Safety Director (Source: Field Survey, 2020)

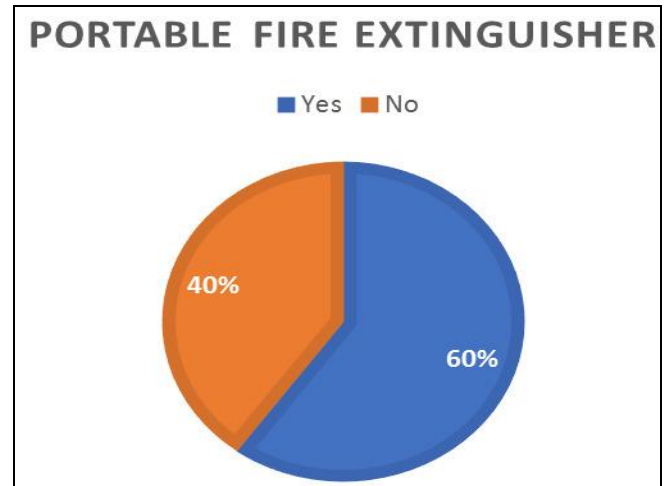


Fig 9 Portable Fire Extinguishers (Source: Field Survey, 2020).

• *Fire Alarm System*

Most of the steel buildings surveyed during this study have fire alarm system. Fire alarm system has been found in 20 out of 25 buildings. But primary concern is that only 8 of them are found functioning. In most cases proper maintenance is not done. Without an active fire alarm system fire protection system is ineffective.

• *Regular Fire Drills*

Each and every user should have taken part in fire drills to have practical knowledge about what to do during the fire. It was found in the survey that only 28% of 25 buildings perform regular fire drills. Some of the building’s manager claimed they held fire drills regularly. But during the workers interview, a different story was found. Some worker said that they have never taken part in a fire drill. Some safety officers also admitted that due to lack of time and resource they cannot perform fire drills regularly. As a result, the users often have no knowledge on what to do during a fire and they panicked. This results in hindrance in the rescue activity after a fire accident.

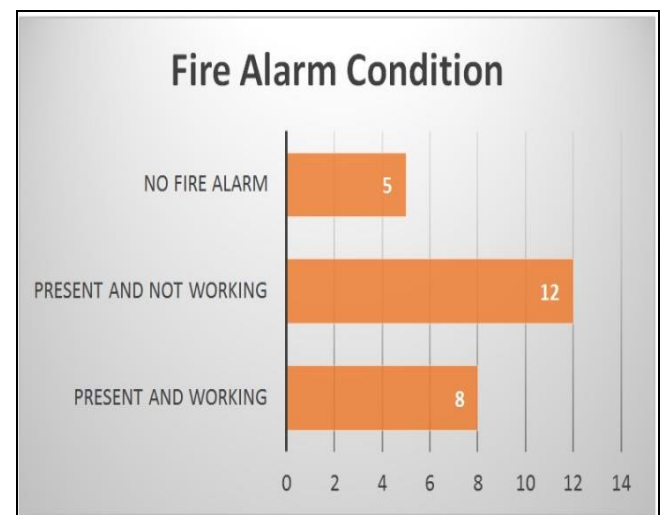


Fig 10 Fire Alarm System in the Buildings (Source: Field Survey, 2020).

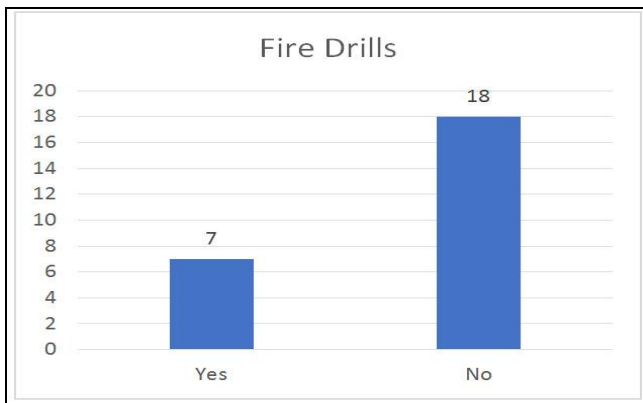


Fig 11 Fire Drills in the Sample Buildings
(Source: Field Survey, 2020).

➤ *Results from Autodesk Robot Software Analysis*

After software analysis, most of the members of the steel building were found failed to survive for 30 minutes at 816-degree temperature. Following image shows the output of the analysis.

In this image we can see that the red lines in all the columns crossed out next to them, indicating that they failed the analysis. The ratio of allowable fire and given fire (816°C) is well above 4. This means that columns can sustain temperature around 200 °C.

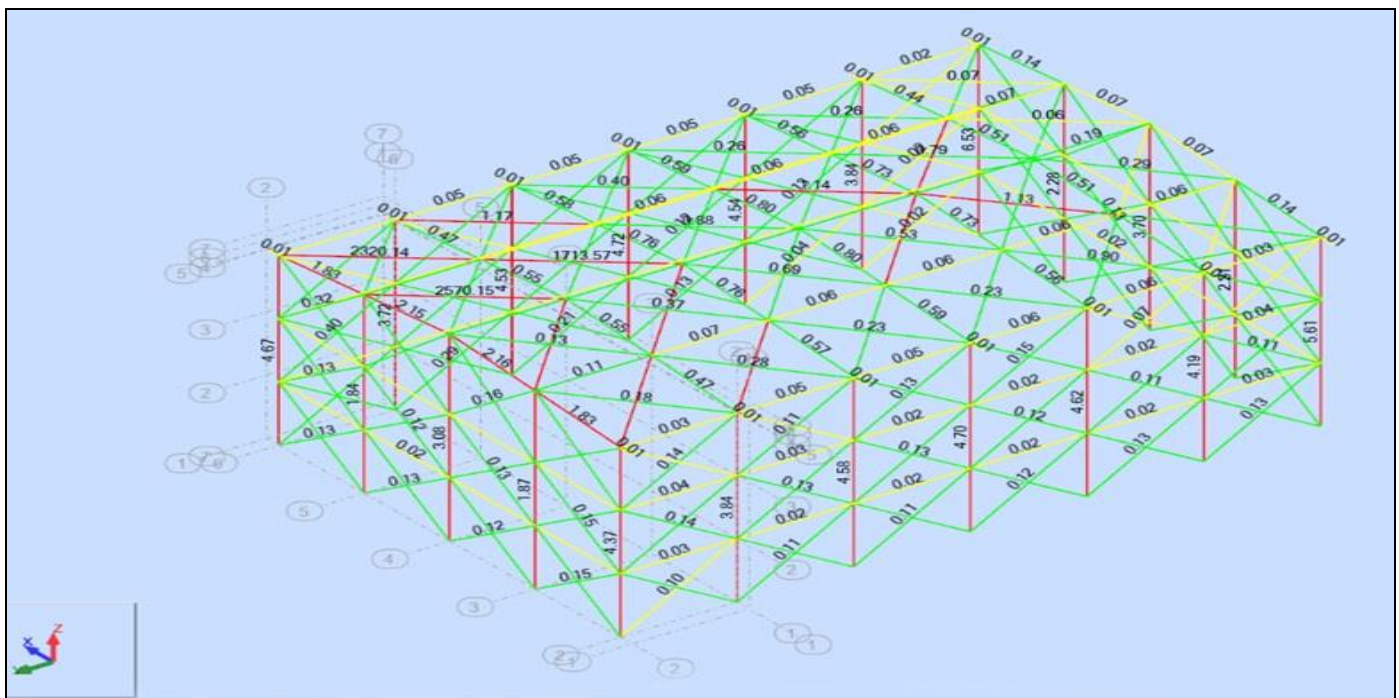


Fig 12 Result of Columns from Robot Analysis
(Source: Robot Software Analysis, 2020).

From the image we can see that all the columns failed in the analysis. Most of the rafters and secondary members passed. This is a graphical representation of the stress ratio of the columns where all the columns have ratio higher than 3. So, either the column can sustain 816°C temperature for only 7 minutes or they can sustain 200°C for 30 minutes. Within 10 minutes the whole evacuation process will not complete. So, either way this structure cannot be considered as safe in fire accident.

IV. CONCLUSION AND RECOMMENDATION

➤ *Field Survey Results*

The outcome of the field survey can be summarized as:

- The garments steel buildings have higher fire safety measure due to their accountability to ACCORD and ALLAINCE.

- Most of the steel buildings have fire alarm system although not all of them are full functioning.
- Fire director has not been assigned in most of the industry buildings. In some cases, fire director expressed short of resources and eagerness in fire safety from the users and the owners.
- The width of the stair and corridors satisfied the BNBC requirement in most buildings. But in some cases, it was found that the corridors are blocked by the owners. They use this space to store goods. Thus, they have shortened the width of the walkway.
- Portable fire extinguishers are found in most of the buildings. Some of them were out of date. Most importantly most of the user do not know how to use fire extinguishers.
- Standpipe and water system were found in most of the buildings. But the source of water was not ensured in all cases. There was small amount of water found in the reservoir which was inadequate to put out fire

immediately.

- Fire resistant door was found in some garment's buildings. But their location does not cover all directions.
- Buildings containing chemical materials do not have separation between the hazardous chemicals and workers. Most of the chemicals are stored in open areas which makes the situation worse.
- In the garments building, most of the workers do not have sufficient knowledge of fire safety. Although there are fire maps, the workers do not understand the maps properly. Training arrangement is also inadequate for them. As a result, they are still vulnerable to fire accident even though the safety condition is good in the garments.
- The level of awareness among the user, owner and neighboring people is very inadequate which makes them more vulnerable.

➤ Recommendation

Some important outcome of this study has been described in the result section of this report. Based on the results, following recommendations can be generated:

- Rules and regulation should be strict, so that the owners have to follow them in order to make the steel building operational.
- Existing provisions of BNBC for fire safety should be highlighted to both the structural engineer and the owners.
- Fire safety provisions should be updated to keep up with modern technology.
- The level of awareness among the users should be increased.
- Participation of the users in fire safety activities should be ensured.
- More fire drills, training, and seminar on fire risk should be arranged to raise the level of awareness among the mass people.
- Mass media should be used to acknowledge the risk and raise concern about fire safety issue.
- New technologies should be included to make a steel building more fire resistance.
- Use of fire proofing paint should be encouraged among the construction companies.
- Proper maintenance of fire extinguishers, fire alarm system should be ensured.
- Specific fire extinguisher should be used for specific type of fire risk.

➤ Conclusion

The current study investigated the effect of fire in the strength capacity of steel by using Auto Desk Robot Software. The result of the analysis is quite alarming as most of the columns member failed to survive in fire situation. Alongside with software analysis, this study highlighted the current fire safety situation by conducting a field survey on 25 steel buildings situated in or near Dhaka. After analysis, this study indicated that most of the steel buildings in Dhaka exhibits poor fire safety conditions. Steel has been used in building construction for quiet several times, and its use is increasing day by day. For timely and

industrial construction, the use of steel is a must.

Certainly, a rethinking of the current fire regulations, with a view to a better assessment of the fire risk and safety objectives, would give a better approach to an optimum level of fire protection design.[3] Despite the implications of the above-mentioned problems much will be gained if suitable fire design strategies relative to active or passive protection measures are clearly defined at an early stage, in the conception of a project. In such a design within the framework of these strategies, the load bearing structure should be dealt with as a component in an integrated fire hazard evaluation of the total active and passive fire protection for a building.

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