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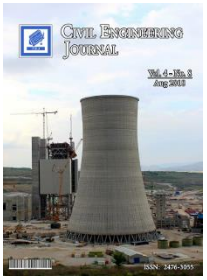

Evaluation of Heat Resistance Adequacy and Non Combustible Materials Construction of a Multifunctional Building

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Abstract

Fire in buildings is one of the major threats. This threat is increasing day by day. This problem necessitates the building designers, construction professionals and the fire professional to find the solution. A detailed study with analysis requires towards the existing fire safety measures. This study analysis results will reveals the adequacy of existing measures. In this article one of the multifunctional building is selected as research sample. In this building applied research type is adopted. Case study method is used to study the each component of the building. The planning parameters of the building and the designing of the structural position are observed in depth manner. The non-combustible materials are identified in the construction of the building. The heat resistance adequacy of each components of the building is evaluated with respect to codel recommendations. The basic concept of fire and life safety measures in buildings are common in international, national and the regional level. These recommendations are thoroughly applied in this research work. These works are analyses and the results or findings are derived. These results are summed up and explained about its objectives. The paper is concluded with comprehensive fire safety measures applications in buildings and recommends fire related various factors research in future. The ultimate aim of this article work is to safe guard lives and property in buildings.

Keywords: Multi-Functional Buildings; Various Functions of the Building; Fire Products; Heat; Flame; Smoke; Fumes and Toxic Sub Stances; Degree Centigrade.

1. Introduction

Fire is the combustion process of burning. It is a chemical reaction, initiated by the sources of heat energy to join with the combustible fuel substance at a particular temperature. The joining of heat source and the fuel starts the chemical process, it is called fire [1-4]. When this chemical process is exposed to direct atmospheric oxygen supply, the chemical process will be in continuous. This continued stage of fire is called burning. During this chemical process of burning, the process will emit energies. The energies are in the form of Heat, Light and Sound. The burning extinguishment will take place when the sources of heat energy is absent or if the heat energy is not having required level of heat capability to initiate the fire with in the combustible fuel substances or the combustible fuel substance is absent or the oxygen supply is absent. The building fire is also requires sources of heat, combustible fuel substances and the oxygen supply [5, 6]. The heat sources are available in the buildings are from electrical appliances, gas appliances, oil appliances, fuel appliances, smoking, rubbish burning, children are playing with match boxes, intentional fire makers and other many un known heat sources. The combustible fuel substance is available in the buildings are in the form of combustible materials (every day activities required materials). These combustible materials types, quantity will be different in different buildings. It is depends upon the occupancy type or the type of activity or process going in side of the building.

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The type of fire, intensity of heat is depends upon this combustible materials storage capacity. The supply of oxygen is gets from the atmospheric pressure through the openings. These openings are provided in the walls, which are provided for ventilation or services purpose. In certain situation few square meter area of open spaces are allocated for interactive, ventilation or services purposes. Highly services oriented buildings needs these types of many openings in the building design. These three sources are joining together at any situation within the buildings the fire will start. Extinguishment of fire will take place after the complete consumption of fuel combustible substance by fire. It is observed that, building fire will emits more heat, light, flame, fumes and other toxic substances as compared to other open fire. The reason is that, the burning process is happening in a closed atmosphere of built form. Building fire creates two types of impacts. The first one is the fire flame will consume all properties which are kept in side of the building. The second one is the fumes, smoke and other toxic substances, these out breaks are the direct responsible agents for destroying human lives. Especially in multi-functional high rise buildings the lives loss will be large in numbers [7]. As per the survey the fire accidents in buildings are increasing every year. This current emerging problem is existing in all places of the world. Practicable solutions are required to overcome this serious problem. All buildings are provided with all fire safety measures in practice as per the code recommendations. These existing fire safety measures are to be searched and its counter acting capacities towards fire are to be analyzed. The derived results will reveal the correct positions of existing fire safety measures. These results will direct the professionals to implement possible solution.

1.1. Development of Fire in Buildings

The development of fire in buildings consists of four stages. The first one is ignition stage, second one is temperature growth stage, third one is fully developed fire stage and the fourth one is decay stage [8, 9]. Ignition stage: This stage the combustible fuel substances are pre heated, this heat will develop full gasification in side of the fuel substances. The development of gasification within the fuel substances are in visible, this gasification with pre heating creates ignition. All these reactions are invisible during the process and this stage is known as ignition stage. Temperature growth stage: This stage the fire gets visible position. When the fire gets growth the temperature is also gets growth simultaneously. This temperature growth will be very fast. Consumption of fuel substances by the fire flame gets stats. Very high temperature of heat, smoke, fumes, toxic substances and other chemical substances are comes out slowly. These fire products are tends to hamper the escape routes. Practically it is observed that, very little amount of fuel materials are burned out but the temperature growth is very high rate and this stage is known as temperature growth stage.

Fully developed fire stage: This stage the fire flame gets full growth, which occupies the full volume of the room, (This stage of fire is called fire tower by the professionals). The major amount of combustible materials in the building are burnt out, the fire flame, with very high temperature, the fire products with other scrambles are engulfing the entire building, this stage of fire is knows as fully developed fire stage. This happens around 500`0C. At this stage all the structural elements are subjected to failure due to heavy heat, this leads to endangering the collapse of the building. This collapse will take place in between 500`0C to 550`0C as per the standard test results. Decay stage: This is the last stage of building fire. These stages all combustible materials are consumed by the fire but the emission of high temperature with fire products are not reduced. The temperature falling, reduction of flame sizes are take place. The temperature falling from fully developed fire stage to decay will take place rapid in within few seconds. This stage is knows as decay stage. Figure no: 1. The total times taken from 0`0C to reach 550`0C is 30 minutes. The ignition stage and the flame occur in between 0`0C to 200`0C. The temperature growth stage is occurs above 300`0C. The fully developed fire stage occurs in between 300`C to 500`0C. The Decay stage is occurs after the 500`0C. This is a falling temperature which will take place from 500`0C to below 200`0C.

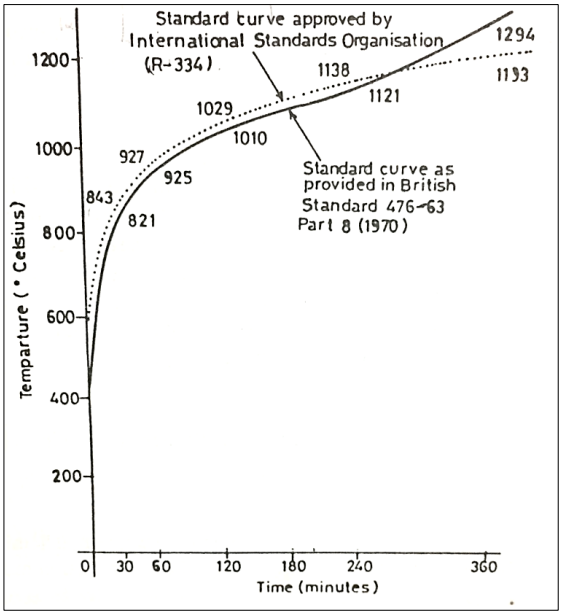

Figure 1. International Temperature – Time Curve

2. Research: Case Study of the Building

A multifunctional high rise building is selected for this research case study. In this study the site planning parameters, building planning parameters, life safety elements of escape routes parameters, interior finishing materials noncombustible materials construction identification of the building and structural and nonstructural members of the building, its composite materials bindings, thermal insulations and stability of the structure and the built form are observed, studied and analyzed. The study part shows that, the existing positions of fire safety measures, its working conditions and the level to meet the objectives at the time of emergencies. The analyses are done by the application of code minimum recommendations. The analysis part shows that, the temperature tolerance of materials as well the structures. The results and the positioning of existing fire safety measures are explained in the results discussion and the conclusion session.

2.1. Site Planning Study (Figure 2)

Accessibility by Road and Reach Ability of the Building: The building is accessed by 40 m wide high road on its north side and 30 m wide road on its west side. These roads are connecting the main parts of the city. Other two sides are surrounded with commercial buildings [10, 11]. Main Entry and Exit Gates width: The building is provided with 12 m wide main gate for pedestrian entry, which is provided from its north side. 20 m wide main gate is provided for the vehicle entry, which is provided at the west side of the building. Both the entries are located at midpoint of its sides. The west side of the building 7.6 m wide entry and exit gates are provided at both the ends of the building. Building set back: The building is provided with 20 m wide set back on north and west side. This set back space including open space reservation. 8 m wide set back is provided on east and south side of the building. Fire escape stair cases: one fire escape stair case is provided nearer to northwest corner of the building.

Results: The building is accessible by road, adequate number of entry and exit gates are provided for smooth entry and exit of people and vehicle. This building is provided with adequate width of set back the required number of fire fighting vehicles can enter and stand in the setback for firefighting operation. The number of ambulances can also stand and save the lives. This building is provided with fire escape stair case, people can reach out the building through this fire escape stair case. Firefighting operation can also carried out through this stair at the time of emergencies.

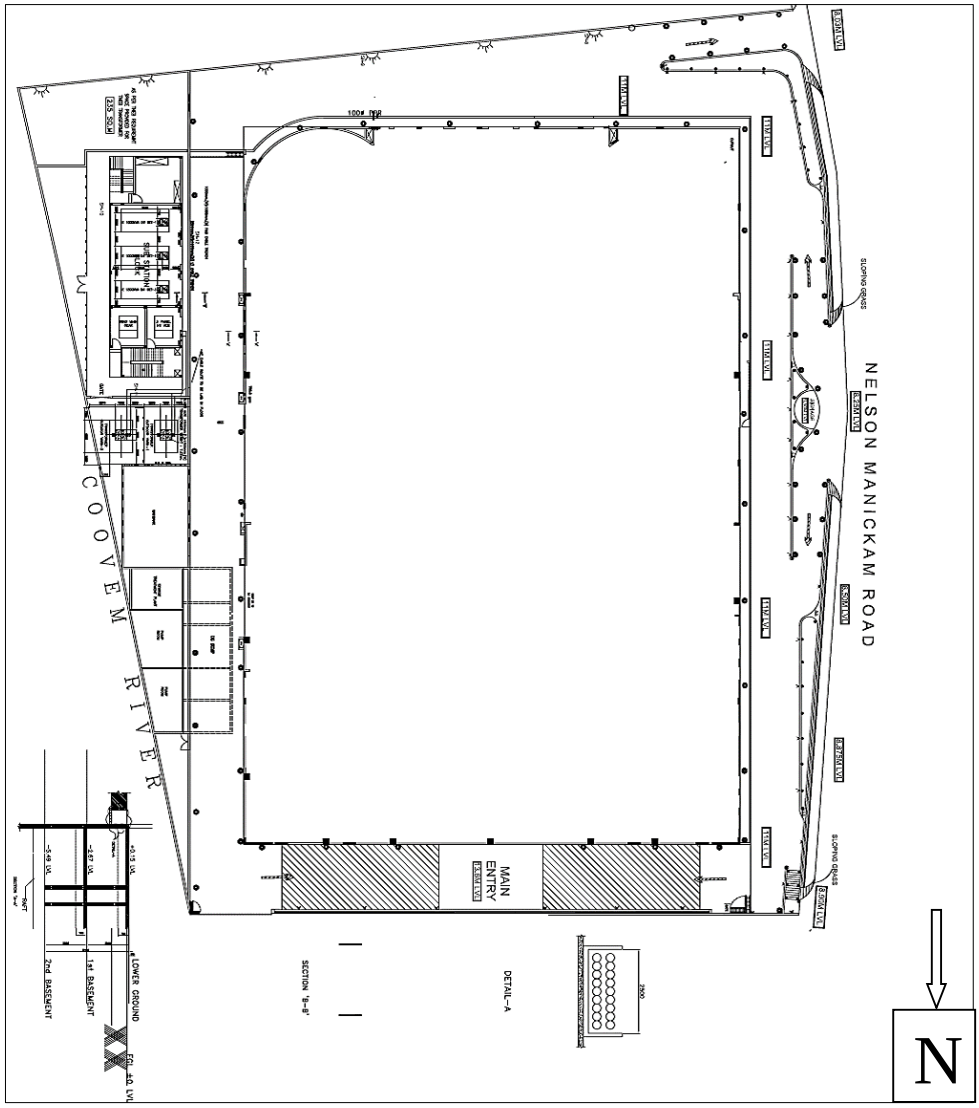

Figure 2. Site plan of the case study building

2.2. Building Planning Study (Figure 3)

Total area of the site is 12460 m^2. The built up area on the ground floor is 3599 m^2. The average plot coverage of the building is 40%. Floor space index is 2.25. The building is having different space requirements and multi-level car parking on each floor. **Space Planning:** 1587 square meter area allocated for parking and car lifting in all floors. Two basements lower ground floor, ground floor surface level and terrace floor is also allocated for multilevel parking. The remaining area is allocated for various functions in all floors. The atrium occupies the middle space, which is directs the crowed for various floors. The corridor served as single loaded corridor around the atrium.

Building Dimensions: The site giving the dimensions 143 m on its west side, 92 m on its north side, 194 m on the east side and 127 m on the south side. The east side site is not straight it is inclined. Over all site area is 12460 m^2. After set back the ground floor is giving the dimension of 97 m in length wise and 67 m in breath wise. The shape of the building is rectangle. It is a single unit development from the basement floor to the terrace floor. The building is having two basement floors, one lower ground, one ground floor, five upper floors, one mezzanine floor and terrace floor. The each basement floor and lower ground floor height is 2.82 m. Ground floor height is 4.58 m. First, second and third each floor height is 4.26 m. The fourth floor height is 5.55 m. Fifth floor is provided with theatre, foyer, seating, mezzanine, projection room and false ceiling, the total height is 10.81 m. At the terrace level the parking parapet height is 3.65 m. Lightning arrester height is 6.4 m and lightning arrester tower height is 2.38 m. The height of the basement floor is 5.64 m. The total overall height of the building from the ground level to tip of the lightning arrester is 46.30 m.

Atrium, Circulation and Ventilation: The atrium is located in the middle area of the building; it is semi-circular in shape. It occupies 175 m^2 area on each floor including its corridor space. It is the main focal point of the building. The atrium is covered with transparent material for lighting purpose [12, 13]. The crowed is attracted by this space only. It divides the crowed and directs them for various functions on each floor. The atrium around the corridor serves the building for smooth circulation. It is a centralized air condition building; there are no window provisions except in few

areas. **Occupancy Feature of the Building (Function):** First and second basement floors, south wing of the building in all floors and terrace floor allocated for two/four wheeler parking. The lower ground floor is allocated for hyper market as well as surface level parking. The ground, first, second and third floors are allocated for shopping. The fourth floor is allocated for food court, rooms, suits and family entertainment activities. The fifth floor and mezzanine floor allocated for theatre and related activities. **Open Spaces:** Small size shaft openings are provided for cabling, AHU and other services purpose. A long wider duct is provided in between the car lifting, parking area and other functional area, this long duct is used for taking sewer pipe line from all floors. There is no open space provision for interaction or ventilation purpose in the middle of the building.

Results: The space allocation, grouping of activities, floor allocation for different activities, the way of planning are excellent. Circulation, ventilation and services planning are good and appreciable. The building dimensions and the floor space index are obeys the local development regulations. The good circulation, escape routes planning will help the people to evacuate the building with in the permissible time limit in case of any emergency.

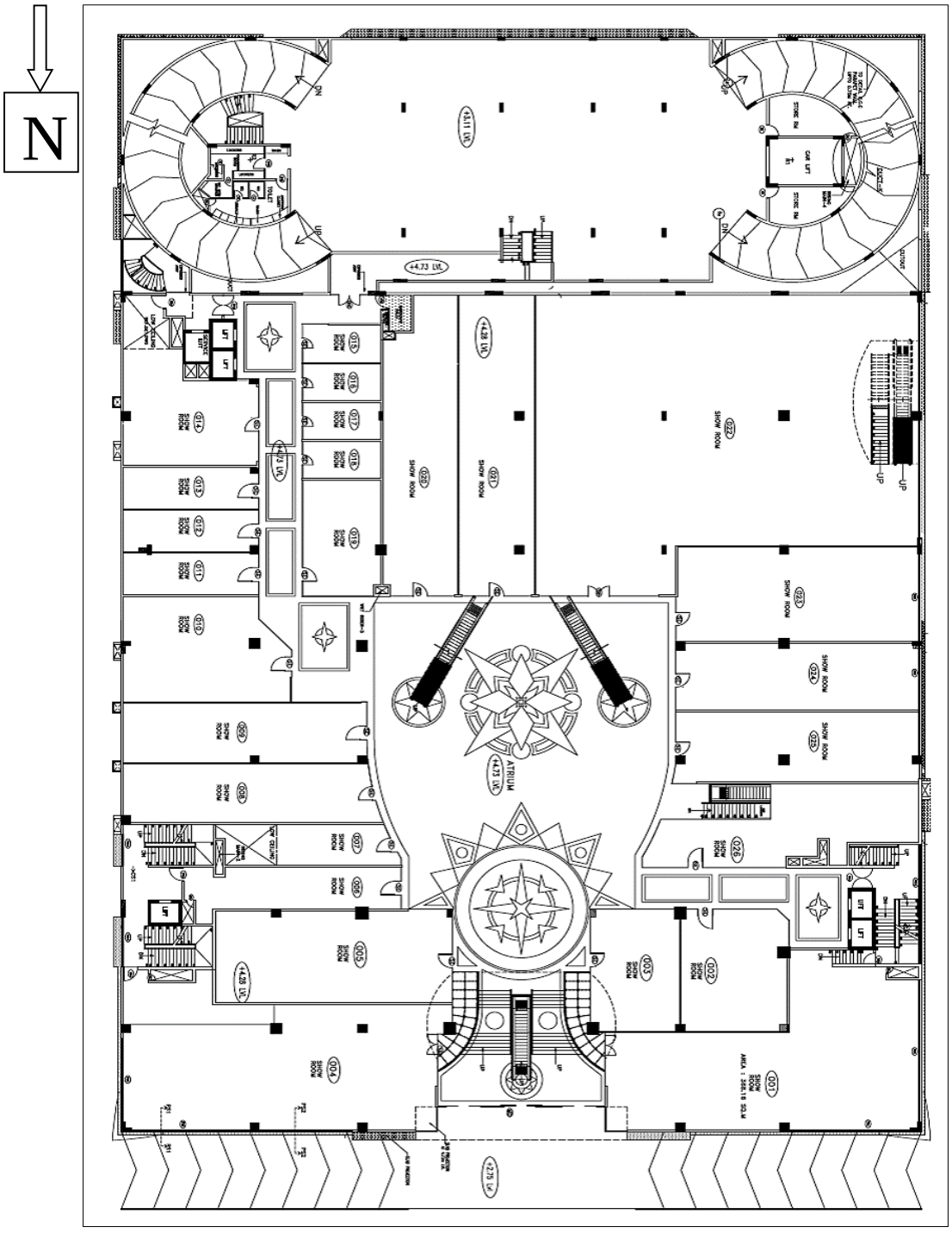

Figure 3. Typical floor plan of the case study building

2.3. Life Safety Elements Study (Figure 3)

Parking Accessibility and Drive Ways: The parking lots are provided in the basement, lower ground floor and the ground floors, the drive ways of 7.2 m wide is provided in the parking area. The pedestrian walk area width is 7.2 m. The main entry with is 7.0 m, the exit width is 10 m. The main entrance width is 16.0 m in the ground floor for vehicle entry and exit purpose. Separate ramps are provided for incoming and outgoing. The ramp slop is 1:10, width is 3.7 m and length is 72 m. C**orridor Width in All Floors:** All the shops are connected with the corridors, the corridors connects the stair and lift core in all floors for accessibility. The corridor width around the elliptical atrium is 4.2 m, the corridor width around the circular, rectangle atrium and all shops are 3.2 m. The service corridor width is 2.5m, which is running from the atrium corridors. Sam width level is followed in all floors. **Door Opening Width:** Main pedestrian open entry width is 16.0 m. Main gate entry for pedestrian and vehicle width is 28.0 m. The main door width is 4.0 m on the ground floor. Shops, building services door are 1.0 m. Double shutters width in all area, atrium and theatre are1.8 m. Toilet opening width is 0.7 m. Service corridor width is 0.9 m. **Lift and Stair Cases:** The lift core is consists of two lifts one stair case and lobby to an area of 115 m^2 and enclosed by 0 .20 m thick wall. The lift size is 2.4 × 2.4 m. The stair cases width is 4.0 m. Each single flight width is 2.0 m. Three stair cases are provided. Two stair cases are allocated for services purposes and one is allocated for fire escape purpose [14-19].

Results: The parking space allocation, drive widths, corridor widths in all floors, escape routes widths and lift dimensions are adequate. This factor will help for easy, smooth and quick flow of the people from all floors and assures minimum distance to reach out the building for life safety.

2.4. Non Combustible Materials Construction Study (Figure 4)

Foundation, Columns, beams, flooring, ceiling, parapet wall and stair cases are constructed with reinforcement materials by the ratio 1:2:4 with proper cover thickness of Concrete: External Walls are constructed by brick work of 0.23 m thick with one inch plastering of ratio 1:2 on both the sides. Floorings are finished with Grand Granite stone. Interiors are painted with plastic emulsion and exteriors are finished with exposed aggregate finish. False ceilings are constructed with stainless steel frame, gypsum board and plaster of parries. The elevations are treated by block work for full signage and display. The Atriums is covered with12 mm thick transparent fibber glass, supported by stainless steel materials. **Door Assemblies:** Glass panels with marble frame, Flush door with Granite and marble Frame , Laminated panel door with Aluminium Frame, Flush door with marble frame, Glass ventilator with Aluminium framing, Various boards, Steel, timber panels, Vermicute boards, are used as door components in various floors. Gas seals Strips, Smoke Seals Strips, positive latching mechanisms, Automatic Closing Devices, ball bearing hinges are used as door`s hard ware (Figure 4) [20-22].

Results: The construction materials are comes under non-combustible materials list recommended by the codes. These materials will not emits heat, flame, fumes, smokes and the toxic substances and having heat resistance capability is up to 650ºC in case of fire emergency.

2.5. Structural and non-Structural Members Study (Figure 4)

Column position: 0.6 × 0.9 m and 0.6 × 0.12 m size columns were used in the building. The lengthwise twelve numbers breath wise eight numbers of columns covers the built up area of the building. Centre to centre distance are maintained as per design space requirements. **Beams:** 0.5 × 0.6 m size. R.C.C. beam with 0.12 m thick cover is provided. **Brick Wall:** 0.2 3m thick brick wall is provided. 0. 025 m thick cement plastering is provided on both the sides. **Roof Slab:** 0.375 m thick. R.C.C. roof slab is provided. 0.12 m thick cover is provided on both the sides. R.C.C. work enclosed area used for car lifting in all floors. A separate enclosure of 1540.71 m^2 area is allocated for multilevel car parking on the south wing of the building Up and down car ramp and automatic car lift facilities are provided in this enclose. Service lift core is also provided in this enclosure. The terrace floor is used as parking area, 3.65 m height R.C.C [23-25]. Parapet wall is provided for safety.

Results: The structural and the non-structural members of the building physical dimensions are above the recommended dimension of the codes. Therefore these members are adequate to offer required heat resistance up to 650ºC.

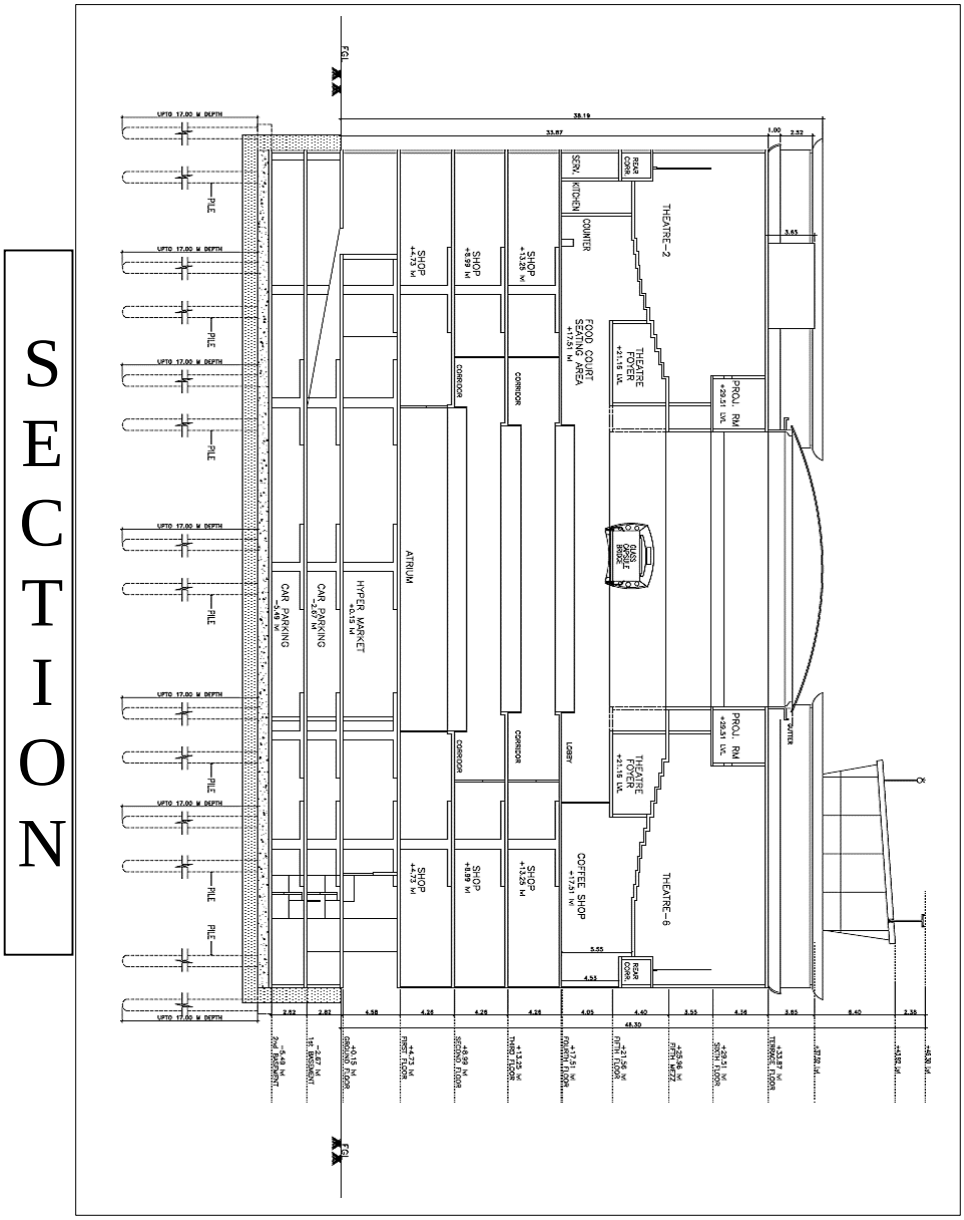

Figure 4. Sectional elevation of the case study building

3. Analysis

The construction materials, structural and non-structural materials are listed from foundation to terrace parapet in a column and are analyzed from the code recommendation. If the constructed materials are identified with in the recommended list [26], the materials are having the required tolerance ability to limit the fire impact in the building.

Table 1. Identification of non-combustible materials construction in building

S.no	Structural and Non Structural Members	Construction Materials	Recommended material as per the code	Tolerance limit in degree centigrade
1	Foundation footings	Reinforcement Cement Concrete	Recommended	Up to 650^{o}C
	Foundation fillings	Reinforcement Cement Concrete	Recommended	Up to 650^{o}C
2	All Columns	Reinforcement Cement Concrete	Recommended	Up to 650^{o}C
	Cover	Plain Cement Concrete	Recommended	Up to 650^{o}C
3	All Beams	Reinforcement Cement Concrete	Recommended	Up to 650^{o}C
	Cover	Plain Cement Concrete	Recommended	Up to 650^{o}C
4	Wall	Bricks	Recommended	Up to 650^{o}C
	Wall Plastering	Cement Plastering	Recommended	Up to 650^{o}C
5	Lift Construction	Reinforcement Cement Concrete	Recommended	Up to 650^{o}C

	Lift Cover	Plain Cement Concrete	Recommended	Up to 650°C
6	Roof Slab	Reinforcement Cement Concrete	Recommended	Up to 650°C
	Cover	Plain Cement Concrete	Recommended	Up to 650°C
7	Parapet wall	Reinforcement Cement Concrete	Recommended	Up to 650°C
	Parapet Wall Plastering	Plain Cement Concrete	Recommended	Up to 650°C
8	Car lifting floors, Wall& Roof	Reinforcement Cement Concrete	Recommended	Up to 650°C
	Cover	Cement plastering	Recommended	Up to 650°C
9	Door assemblies	Non Combustible	Recommended	Up to 650°C
10	Interior Construction Materials	Non Combustible	Recommended	Up to 650°C
11	Interior Construction Finishing	Non Combustible	Recommended	Up to 650°C

Results: The building is constructed by non-combustible materials, the codel recommendations are adopted.

The site planning, building Planning life safety elements parameters and all of its sub parameters are analyzed by the application of code and regional regulations [27]. If the building is provided with same or above the recommended physical dimensions, the building is adequate for emergency operation.

Table 2. Planning Factors Analysis

S. no	Main Parameters of Case study	Sub Parameters	Recommended Dimension	Adequacy
1	Site Planning	Access ability by Road width	Above the Recommended Dimensions	Adequate
		Entry / Exit widths	Above the Recommended Dimensions	Adequate
		Set backs	Above the Recommended Dimensions	Adequate
		Escape Routes	Above the Recommended Dimensions	Adequate
2	Building Planning	Space planning	Excellent	Adequate
		Building Dimensions	Above the Recommended Dimensions	Adequate
		Circulation, Ventilation & Open space	Good	Adequate
		Functional allocations	Excellent	Adequate
3	Life Safety Elements Planning	Parking location, drive w way widths	Above the Recommended Dimensions	Adequate
		Corridor widths	Above the Recommended Dimensions	Adequate
		Escape routes widths	Above the Recommended Dimensions	Adequate
		Lift car dimensions	Above the Recommended Dimensions	Adequate

Results: All the parameters are above the recommended dimensions, the codel recommendations are adopted.

The structural and non-structural members physical dimensions and interior finishing materials are analysed by the application of code recommendations. If the existing physical dimensions are same or above the recommended physical dimensions, the structural and non-structural members are having tolerance ability above the collapsible temperature [28, 29].

Table no 3. Evaluation of Structural and Non Structural members Heat Resistance Adequacy

S. no	Elements of the Building	Existing physical dimension (Column A)	Recommended physical dimension as per code (Column B)	Evaluation (Column C) C = A - B	Heat Resistance Adequacy
1	STRUCTURAL and NON STRUCTURAL MEMBERS				
	R.C.C. Column size	0.6×0.9 m and 0.6×1.2 m	0.54×0.54 m	> 0.06×0.36 m > 0.06×0.66 m	Adequate
	R.C.C. Beam size	0.5×0.6 m in	0.42×0.42 m	> 0.08×0.18 m	Adequate
	Brick wall	0.25 m thick wall	0.22 m thick	> 0.03 m	Adequate
	R.C.C. Roof slab	0.375 m thick	0.280 thick	> 0.95 m	Adequate
	R.C.C. column cover	0.12 m, in all sides	0.04m in all sides	> 0.08 m	Adequate
	R.C.C. Beam cover	0. 12 m in all sides	0.07m in all sides	0.05 m	Adequate
	plastering	0.025 m on both sides	0.025m in both sides	sufficient	Adequate
	R.C.C. Roof slab cover	0.12 m on both the	0.055m in both the sides	> 0.65 m	Adequate

2	NON COMBUSTIBLE MATERIALS CONSTRUCTION.			
Foundation, Column, Beam & floor and roof slabs	R.C.C. work with cement cover provided	R.C.C, brick works are recommended	Recommended materials used	Adequate
Outer &Inner wall	Brick work with Cement plastering provided	R.C.C, hollow blocks, brick are recommended	Recommended materials used	Adequate
Floor finishing	Grand Marble stone	Hard rigid materials used	Recommended materials used	Adequate
False ceiling & egress area	Gypsum, board, plaster of parries, Stainless steel frame	Gypsum, Plaster of parries	Recommended materials used	Adequate
Interior finishing	Plastic emulsion paint finish on the interior.	Less fire spread materials allowed	Recommended materials used	Adequate
Atrium top coverage	The atrium 10mm thick transparent fibber glass, rested on beam by holting	Transparent lightweight materials allowed	Recommended materials used	Adequate
Elevation finishing	Wired fibber glass & exposed aggregate finish on the block work	Aggregate finish allowed	Recommended materials used	Adequate

Results: The physical dimensions of the structural and non-structural members are having above the recommended physical dimensions. The interior finishing materials are falling within the recommended list. The codel recommendations are adopted.

4. Results and Discussion

From the Research Case Study and Analysis of the Building: Site Planning study and analysis results shows that: All parameters are existing, working, the building is having firefighting abilities and can meet the objectives at the time of fire emergency.

Building Planning Study and Analysis Results Shows that: The way of planning of the building is excellent. Therefore the building can meet the objectives of quick, easy and smooth flow of people from all floors for evacuation; the evacuation operation will take place within the permissible marginal time limit at time of any emergency.

Life Safety Elements Study and Analysis Results Shows that: Life safety elements in the escape routes are well connected with fire escape stair case in all floors, this effective life safety planning will facilitate the people to reach out the building to safer place by less walk distance and minimum time requirements.

The non-Combustible Materials Construction Study and Analysis Results Shows that: The non-combustible material construction and the interior finishing materials will not emit the fire products and is having tolerance limit up to 650`0C. The materials will offer time rate from thirty minutes to two hours. Therefore the fire impact lives losses will not take place.

The Structural and non-Structural Members Study Heat Resistance Analysis Results Shows that: the structural and the non-structural members of the building is having heat resistance ability up to 650`C. The structural and non-structural members will offer time rate from two hours to four hours. The structural form will not get disturbed till the above said temperature. This temperature is higher than the collapsible temperature, the collapsible and fire impact lives losses will not take place.

The materials integrity, insulation and the stability of the structural and the non-structural formation, the planning of the building, designing of the escape routes, noncombustible material construction and the physical dimension and heat resistance capability of each components of the building reveals that, the research case study building is provided with full fire safety and life safety measures.

5. Conclusion

The full implementation of fire and life safety passive provision of the building and firefighting ability of the apparatuses will help to extinguish the fire after occurrence in the building. Avoiding of fire occurrences in buildings is important. Proper Housekeeping, hazard management, functional management and all internal managements will avoid the fire occurrence in side of the building. The internal fire hazard management, passive resistance planning and the provision of fire suppression system are mandatory in all types of buildings and it should be applied in correct stages. This comprehensive application of all fire and life safety measures will help the buildings away from fire in future.

In this research case study, the passive design major parameters with fire rated materials constructions are analyzed in multifunctional building. Along with these results, the fire related factors of open spaces, internal, external fire spread parameters, fire load calculation, fire indexing and other related parameters are to be analyzed. This type of study and analysis is to be carried out in all type of buildings. The commercial, high rise and high scrapers buildings are getting more important in these researches. The reason is that, the large amount of valuables and heavy populations

accommodations [30, 31]. These results will revels the truth and demands further improvement in fire and life safety measures in buildings.

6. References

[1] David M Wharry, and Ronald Hist. "Fire Technology Chemistry & Combustion, Institution of Fire Engineers, Belvoir offset limited Publication, England" (1992).

[2] Jain V. K. "Fire Safety in Buildings, New Age International Publication, New Delhi, India" (2010).

[3] Sesha Prakash N. "Manual of Fire Safety, CBS Publication, New Delhi" (2013).

[4] Gupta. R. S. "A hand book of Fire Technology, University Press, Hyderabad. India" (2009).

[5] Robertson J.C. "Introduction to Fire Prevention, Mac Mill on Publication, New York"(1981).

[6] Robert Levine S. "Fire Science for Fire Safety, Fire Sciences Publication, Great Britain" (1984).

[7] Council on Tall Buildings & Urban Habitat. "Fire Safety in Tall Buildings, McGraw Hill Inc. Publication, USA" (1992).

[8] Hawagoe K."Fire Behaviour in Room, Building Research Institute Publication, Japan" (1958).

[9] Carslaw H. S, and Jaeger J.C. "Conduction of Heat in Solids, Oxford University Press Publication, New York" (1959).

[10] Tamil Nadu Fire Cum Rescue Services Department. "Commercial Buildings Special Types 2008 Regulations, TNFRS Publication, Chennai" (2008).

[11] Callender, and De Chiara. "Time Saver Standards Building types, McGraw Hill Publication, New York" (1980).

[12] Cristian Malul, Michael Woodrow, and Jose Luis Torero. "The Potential of Integrating Fire Safety in Modern Building Design". Fire Safety Journal (March 2017). Doi: https://doi.org/10.1016/j.firesaf.2015.12.006.

[13] Mark L Janssens. "Evaluating Computer Fire Models,Fire Protection Engineering Publication,U.K"(2002).

[14] Chongfir Hvang, and Jing x in. "Fire Risk Analysis of Residential Buildings based on Scenario Cluster and its Application in Fire Risk Management". Fire Safety Journal (September 2013). doi: https://doi.org/10.1016/j.firesaf 2013.09.022.

[15] Jian Jiang, Lingzhu Chen, Shouchao Jiang, Guo-Qiang Li, Asif Usmani." Fire Safety Assessment of Super Tall Buildings: A case study on Shanghai Tower". Case studies in Fire Safety Journal. Volume: 4. P: 28-38. doi: https://doi.org/10.1016/ jcsfs.2015. 06.001.

[16] Graham Spinardi. "Fire safety regulation: Prescription, performance, and professionalism". Fire Safety Journal (February 2016). Volume: 80, P: 83-88. doi: https://doi.org/10.1016/jfiresaf.2015.11.012.

[17] Manuela Tancogne - Dejean, and Patrick Laclémence, "Fire Risk Perception and Building Evacuation by Vulnerable Persons: Points of View of Laypersons, Fire Victims and Experts". Fire Safety Journals (February 2016). Volume: 80. P: 9-19. doi: https://doi.org/10.1016/jfiresaf.2015.11.009.

[18] Norman.E., and Groner. "A Decision Model for recommending which Building Occupants should Move Where during Fire". Fire Safety Journal (February 2016). doi: https://doi.org/10.1016/jfiresaf.2015.11.002.

[19] Council on Tall Buildings & Urban Habitat. "Planning and Designing of Buildings, Vann Strand Reinhold Company Publication, USA" (1981).

[20] B. Schartel, and T. R. Hall. "Development of Fire – Rated Materials – Interpretation of Cone Calorimeter Data". Fire and Material Journal (May 2007). Doi: https://doi.org/10.1002/fam.949.

[21] Watts J.M. "Fundamentals of Fire Safe Building Design, NFPA Publication, Quincy" (2003).

[22] Watts J. M, and Marilyn Kaplan. E. "Fire Safety Codes and Heritage, NFPA Publication, Quincy" (2000).

[23] A.Z. Mohd Ali, Jay Sanjayan, and Maurice Guerrieri. "Specimans Size, Aggregate Size and Aggregate Type Effect of Spalling of Concrete in Fire". Fire and materials Journal (July 2016).P: 59-68. doi: https://doi.org/10.1002fam.2457.

[24] Egle Rackuskaite, Guillermo Rein, and Panagiotis Kotsovinos. "Structural Response of a Steel Frame Building to Horizontal and Vertical Travelling Fires in Multiple Floors". Fire Safety Journal (July 2017). doi: https://doi.org/10.1016/jfiresaf.2017.04.018.

[25] G. Jomaas, M. Valkvist, R. Vancoile, F.B. Steffensen, and N.D. Hansen. "A Fire Risk Assessment Model for Residential High Rise with a Single Stair Well". Fire Safety Journal (January 2018). doi; https://doi.org/10.1016/j. firesaf.2017.11.006.

[26] National Fire Protection Association. "NFPA Safety Codes 2007, NFPA publication" (2007).

[27] Chennai Development Control Authority. " Second Master plan for Chennai Metropolitan Area 2026, TNG. GO no: 190H& UD Publication, Chennai" (2008). Volume I, II, and III.

[28] International Code Council. Inc. "International Building Code, Int. Code Council Inc Publication,USA" (2009).

[29] Bureau of Indian Standard. " National building code of India, BIS Publications, India" (2005).

[30] Fire Department Home Office. "Building Construction and Structural Fire Protection, Akademica Book Publication, London" (1992).

[31] Watts J. M. "Fire Risk Indexing, NFPA Publication, Quincy" (2002).