

FIRE SAFETY DESIGN IN BUILDING

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ABSTRACT

The main themes for fire safety planning may be described as follows ; Prevention of outbreak and growth of fire , Fire protection of Building structures, smoke control and escape planning. Fire load in a building can be roughly classified into 3 groups: (a). buildings materials, (b). furniture, and (c). daily goods. Building materials including linings, interior material of walls, ceilings, floors, partition walls, etc, and daily goods such as books, clothes, and so on.

Keywords : Fire protection, Safety, Buildings materials, Furniture.

ABSTRAK

Untuk perencanaan bangunan gedung kita harus memperhatikan pencegahan dari bahaya kebakaran, cara menyelamatkan diri dari gedung bila terjadi kebakaran Beban api untuk bangunan secara garis besar dapat dibagi menjadi : (a). bahan bangunan, (b). mebel, dan (c). perlengkapan lainnya. Material bangunan termasuk lantai, dinding , atap, dinding partisi beserta isinya seperti buku, kertas dan lain sebagainya.

Kata kunci : Pecegahan kebakaran, Keamanan, Bahan bangunan.

1. INTRODUCTION

In general, through the word, fire safety of building is ensured by taking measures of the fire codes or standards usually require the safety performance for a certain hours in each building members in buildings.

However, keeping or following codes is usually very difficult not only for existing buildings, but for new ones in every country when new items for fire safety are introduce in the revised regulations. Measures for fire safety in buildings may be developed in accordance with more research work and experiences.

Development of fire safety measures are not same as that of electronics or mechanics, etc. The former is always based on the preferable ways or ideal ways for human lives. That is, fire safety may be based on the balanced between cost for safety planning and the lost when buildings get fire.

Then, we should always consider the principle of fire safety from the point of daily life and architecture. The main themes for fire safety planning may be described as follows :

1. Prevention of outbreak and growth of fire.
2. Fire protection of Building structures.

3. Smoke control and escape planning.

The problems are how can we get free from these items. It's easy to say, but difficult to conduct actually. Let's think together about the items in detail.

2. GROWTH OF FIRE

2.1 Start and spread of a fire

A fire starts by various cause. Fire is a rapid reaction of combustible materials with oxygen, producing heat and light. For combustion, the mixing ratio between the combustible gas released from combustible materials and an oxidizing agent (air, etc) must be in a certain range. The minimum ratio of the concentration of the combustible gas is called the lowest limit of combustion, and the maximum, the upper limit of combustion. Many materials ignite or catch fire at elevated temperatures as listed in Table 1

Table 1. Ignitation-Temperatures of various materials

Material	Ignitation Temperatures °C	Auto-ignition Temperatures °C
Wool	200	-
Paper	230	230
Cotton	230-266	254
Polymethylmethacrylate	280-300	450-462
Rigid polyurethane foam	310	416
Polyethylene	341	349
Polystyrene	345-360	486-496
Polister (glass fibre filled)	346-399	483-488
Polyvinylchloride	391	454
Polyamide (Nylon)	421	424
Phenolic resins (glass fibre filled)	520-540	571-580

The heat released by the combustion of materials is fed back to the material, to promote the thermal decomposition of the material and the release of combustible gases. Oxygen is needed to continue the combustion.

When the buildings materials burn, they give different calorific values as shown in Table 2.

The fire growth / spread characteristics such as ease of ignition of fire, spread velocity and emission of heat, smoke and hazardous gases etc, are determined by many factors such as the geometric conditions of the room, openings, initial fire source, distance

between the fire source and combustible materials, type and volume of materials and situation or arrangement in the room, etc.

Fire rapidly spreads upward by buoyancy and convection, and then spread laterally along ceiling when a fire occurs in a confined space. Combustions generates gases as well as heat and smoke. Hot gases will fill the entire room. The temperatures in the plume can be as 650 to 950 ° C. Unignited parts in the room will be preheated by the convection from hot gases and irradiation from the hot area. Combustible interior materials will have a significant influence on fire growth and spread in the room.

While a fire grows, it effects to surrounding materials which will be degraded, melted, burnt and collapsed etc. Examples of effect at elevated temperatures are shown in Table 3.

Table 2. Calorific values of building materials

No	Material	Calorific value (MJ/Kg)
1	Asbestos slate (specific gravity 1.8)	0
2	Rock wool sound absorbing board (starch 7%)	0.84
3	Rock wool sound absorbing board (starch 12%)	2.09
4	Plaster board (without paper)	0.42
5	Plaster board (with paper)	6.28
6	Pulp cement board (pulp 8%)	1.47
7	Pulp cement board (pulp 15%)	2.09
8	Excelsior board (excelsior 45%. Specific gravity (0.70-0.85)	3.14-5.36
9	Japanese cedar board (specific gravity 0.45)	18.92
10	Plywood (specific gravity 0.50)	18.84
11	Particle board (specific gravity 0.55)	16.74
12	Hard fiberboard (specific gravity 0.85)	20.09
13	Soft fiberboard (specific gravity 0.40)	14.65
14	Polyvinyl Chloride tile (vinyl chloride 10%)	15.07
15	Polyvinyl Chloride tile (vinyl chloride 30%)	19.38
16	Asphalt tile	17.33
17	Buber tile	15.91
18	Linoleum	21.35

Table 3. Effect of temperature on selected materials

Substance	Typical examples	Conditions	Approximate temperature
Polystyrene	Thin wall food containers Foam, light shades, handles, curtain hooks, radio casings	Collapse	120 °C
		Softens	120-140
		Melts and flows	250

Polystyrene	Bags, Films	Shrivels	120
	Bottles, buckets	Softens and melts	150
Polymethyl methacrylate	Handles, covers, "glazing"	Softens	130-200
		Bubbles	250
PVC	Cables	Degrades	100
		Fumes	150
		Browns	200
		Charing	400-500
Cellulose	Wood, paper, cotton	Darkens	200-300
Solder	Plumbing joints	Melts	250
Lead	Plumbing Sanitary installations, Toys	Melts, sharp edges	200-350
		Rounded Drop formation	
Alumunium And Alloys	Fixture, casings Brackets, small mech Parts	Softens	400
		Melts	650
		Drop formation	
Glass	Glazing, bottles	Softens, rounded	500-600
		Flowing easily viscous	850
Silver	Jewellery, spoons	Melts	950
		Drop formation	
Brass	Locks, taps Doorhandles, lapes	Melts (particularly At edges)	900-1000
		Drop formation	
Copper	Wiring, Cables Ornaments	Melts	1000-1100
Cast iron	Radiators Pipes	Melts	1100-1200
		Drop formation	
Zink	Sanitary installation Sutter, Down pipes	Drop formation	400
Bronce	Windows, fittings, door bells, Ornamentation	Rounds	1000
		Drop formation	
Paints	-	Deteriorates	100
		damages	250
Wood	-	ignits	200

2.2 Flashover

One of most peculiar phenomena occurs in the early stage of fire.. It is called "flashover" which is the sudden growth of a fire involving the whole room with a big flame.

A thipical growth of a room fire is drawn by the temperatures rise which is shown in fig.1. At the stage of O to A in the figure, a small fire grows gradually, and its behavior changes depending on the conditions of fire source, materials, openings and volume of the

room, etc. The stage of B to C after the flashover is a developed stage. The behavior of the fire depends upon the sizes of windows, the heat insulation inside the room and volume of fire etc.

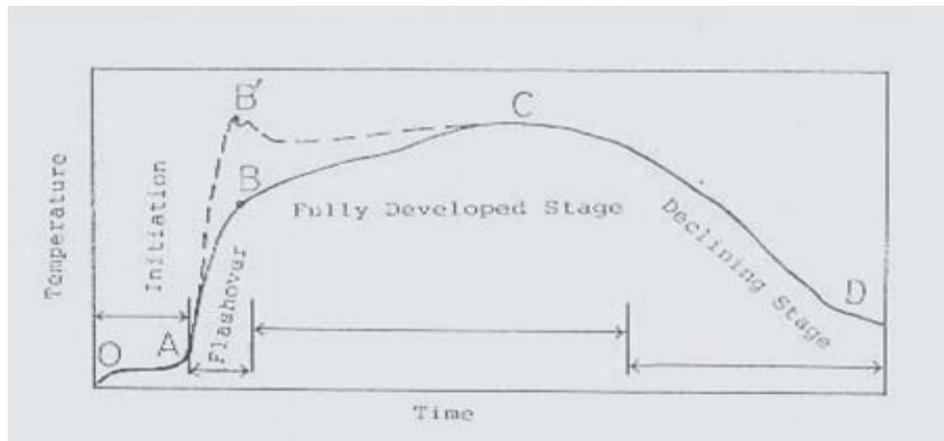


Figure 1. Typical pattern of stages of fire growth

When flashover occurs, heat, smoke and gases are vigorously released. Therefore, the duration from the start of a fire to flashover has an important role.

A phenomenon like intermittent explosive combustion can be seen as a special case of flashover, depending on the relationship between the kinds and volume of combustion gas, etc.

For the prevention of outbreak of a fire, “How can we do?”. The answer should be left to the participants today. For the prevention of growth of it in a room, minimum use of combustible materials for walls, ceiling, floors, furniture and daily goods will be required. For the stop of fire from a room to another, compartmentation of building space must be taken.

A better compartmentation in each building member such as wall, beam, column, floor etc, must consist of fire resisting.

3. FIRE LOAD

Before consideration of compartmentation, we must consider the phenomena of fire.

The main factors governing the duration of the fire are the volume of combustible materials contained in the building and the openings as mentioned above. For fire protection design of a building structure, it is essential to know the volume of combustible materials in a designed building, for prediction of a burning rate.

Fire load in a building can be roughly classified into 3 groups:

- a. buildings materials,
- b. furniture
- c. daily goods.

Building materials including linings, interior material of walls, ceilings, floors, partition walls, etc, and daily goods such as books, clothes, and so on.

These combustible materials have different calorific values to release heat in combustion.

The heat release from the different materials in a room during a fire are often expressed by the “relevant fire load” which means the equivalent heat value of that of a similar amount of wood.

Therefore, for a design of fire-resisting building, the equivalent fire load is often used for simplification.

Mean volume of fire load in various types of building in Japan is shown in Table 4. These data were obtained by actually weighed in many buildings.

Concerned to each building, there figure do not accurately meet, but there will be useful for engineering treatment

Fire load at the Hotel Bali Beach is shown in Table 4 as an example.

Table 4. Fire load at the Hotel Bali Beach

Application of building	Ordinary range (Kg/m ²)
Hotel Bedroom	7- 11
Meeting room	2 - 6
Office	30 - 80
Hospital (bad room)	3 - 5
Library	62 - 93
Dweling (apartement house)	35 - 60
Classroom	30 - 45
Warehouse	640 - 1020
Shop (excuding bookstore and other stores containing much combustible materials)	100 - 200

Table 5. Fire load in Building in Japan

<p>A. Bed Room , Bath room (standard room) Ukuran (7,6 x 4 x 3,55) m Bahan lantai dan atap : dari beton massive Bahan dinding samping : beton masive Bahan dinding luar koridor : diasumsikan beton ringan Bahan dinding balkon : kaca (diasumsikan segera pecah)</p>	
1. Bed (spring bed) dan perlengkapan	210 kg
2. Furniture:	
Meja, kursi, lemari	35 kg
Alas duduk	5 kg
Kulkas, TV	5 kg
3. Karpets	174 kg
Alas (Busa polypropilen)	44 kg
Karpets	130 kg
4. Gordyn + virtrage	42,5 kg
5. Ceiling	100 kg
Acoustic tile	86 kg
Kayu konstruksi.....	14 kg
6. Kusen balkon dan koridor	40 kg
Total fire load	613,5 kg
Luas ruangan	30,4 kg
Fire load dalam kamar	20,18 kg
<p>B. KORIDOR Size (2,6x4x3,55)m</p>	
▪ Carpet.....	22,4 kg
▪ Ceiling (plywood) +construction.....	23 kg
▪ Penutup plumbing	15 kg
▪ Konstruksi kayu pendukung kaca	30 kg
Total	90,4 kg
Luas koridor	10,4 m ²
<p>C. BALKONI Ukuran (2,35 x 4 x 3,3)m</p>	
▪ Ceiling (plywood) + konstruksi	30 kg
▪ Meja + kursi	25 kg
Total	55 kg
Luas balkoni	9,4 m ²
<p>D. REKAPITULASI</p>	
Fire load total (per room)	758 kg
Square total	50 m ²
Fire load typical floor (3 th – 9 th)	15,2 kg/m ²
Area floor south wing (12,5 x 60)	750 m ²
Area floor north wing (12,5 x 60)	750 m ²
Area floor east wing (17,6 x 44)	775 m ²
Luas bukaan SW dan NW (dianggap lantai tanpa kompartemen)	
▪ Pintu koridor (0,8 x 2) m ² x 13 bh	10,8 m ²
▪ Pintu jendela kaca balkoni 44,2 x 2,6	114,2 m ²
Total bukaan	125 m ²
Faktor bukaan	0,8
Bukaan efektif	100 m ²

4. TEMPERATURES AND DURATION OF A ROOM FIRE

In a fire-resisting building, the combustion rate is controlled by area of the openings.

The relationship between the burning rate R at the stage of a fully developed fire in a room is expressed as follows. The burning rate is mainly related with the area and the height of the opening.

$$R = k \times A \sqrt{H} \quad (1)$$

- Where :
- R : Burning Rate (Kg/min)
 - K : Coefficient (5.5 – 6.0)
 - A : Area of the opening (m²)
 - H : Height of the opening (m)

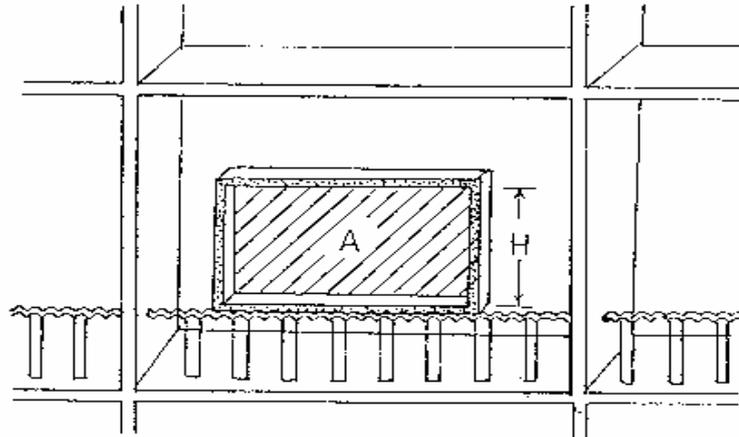


Figure 2. Opening of a compartment

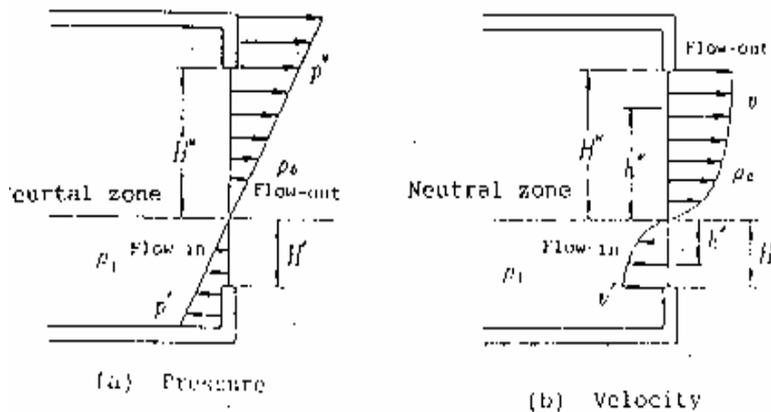


Figure 3. Air flow at the opening in fire

If temperatures anywhere in a room are assumed to be uniform, a neutral zone of flow-in and out of air appears as shown in Fig.3 with linear pressure distribution which is proportional to the height. The air velocity pattern is expressed in Fig.3 (b).

5. PHENOMENA OF STRUCTURES

As regards reinforced concrete structures, their members generally lose strength depending on the depth of protecting insulation of mortar.

Concrete members gradually lose their outer layer in fire and the steel inside becomes exposed to fire. Fig.4 show the typical phenomena at the depth of the concrete when heated under the standard fire exposure.

The phenomena, i.e., popping of the concrete, significantly affects the fire resistance of the material. It is also more likely to occur in pre-stressed and pre-cast concrete structural members.

According to the results of fire-resistance test, the following conditions are found to be significant for members:

1. heat source
2. the early stages of fire retardancy
3. water content of loaded force
4. application of loaded force
5. the corner section of beams and columns, etc.

Fig.4 and Fig.5 show the affect of temperature on the compressive strength of concrete.

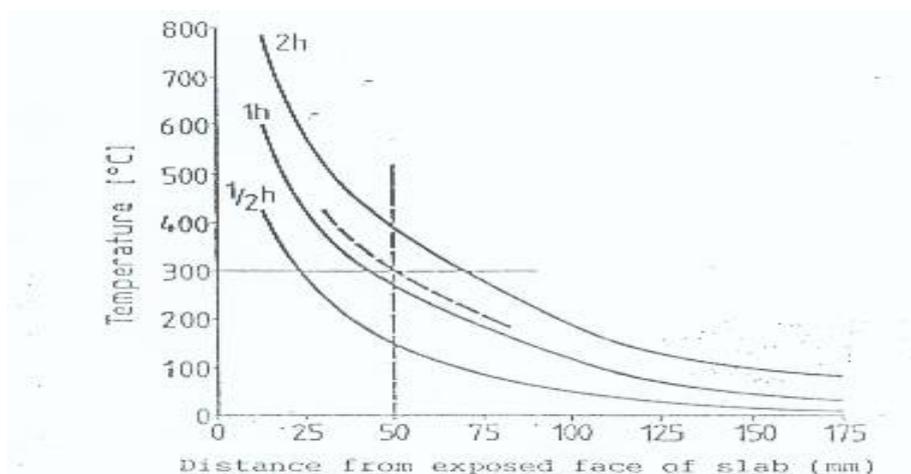


Figure 4. Temperature distribution in slab exposed to a standard fire

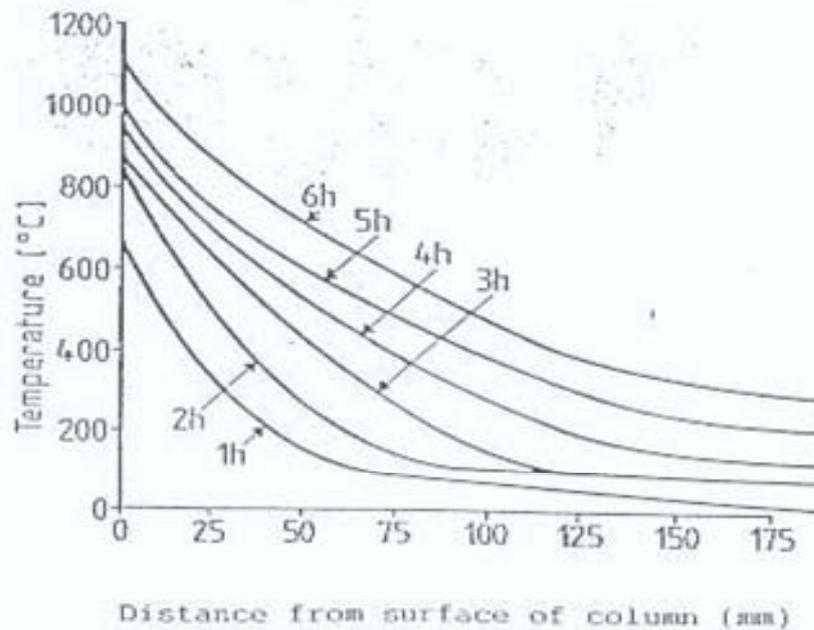


Figure 5. Temperature distribution in 350 mm columns exposed to a standard fire

6. FIRE PROTECTION OF BUILDING STRUCTURE

6.1 Fire-Resisting Design

For the protection of buildings from structural damage during fire, structural members are required to be protected by means of fire protection methods.

Fire-resistance requirements are made depending on the type, design and size of building.

The regulatory control for fire protection is required to be concerned with safeguarding the occupants in the building where a fire may occur. To minimize the risk to adjacent buildings and avoiding conflagrations, consideration must be given to the plan, layout and construction of the building for controlling the growth of a fire.

The fire performance is usually rated into four classes which are 3 hours, 2 hours, 1 hours and half an hour endurance.

Fire doors or fire protection assemblies are to be applied to the openings on the exterior wall of a fire-resistance construction where there may be imminent danger of spread of a fire.

6.2 Compartmentation Planning

A fire which start in a space a building spread to a junction spaced, finality involving the whole building, due to the hot current from the burnings rooms through corridors, staircases, opening of windows, doors, etc.

Therefore, in large-scale and / or high rise buildings, it is important to stop the fire in a restricted enclosure in a certain time after initiation.

This is called fire compartmentation, and is protected by fire resistant walls, floors, columns and beams.

For the design of the fire-resistance building, fundamental consideration is given to the type, design and size of buildings as shown in Fig.6 and detailed components are shown in Fig.7.

The principle for fire-resistance design is as follows:

1. Scale of fire is to be estimated in each fire zone. The main structural components are designed to endure for the estimated fire load and duration in each fire zone.
2. Fire safety for the whole building is to be estimated with the product of safety coefficient based on the data from each fire zone, depending on the use, scale and structure etc.
3. Main structural components are to be resistant for more than estimated fire duration.

In many years ago, there was no idea or no regulation for compartmentation of space in building in most countries.

Japan introduced the idea into fire regulation in there twenty years. The Hotel Bali Beach was constructed by a Japanese constructor in 1965. Then, there was no regulation for compartmentation.

That's why fire spread very easily through the whole building in not longer time. Fortunately no facilities are there during Fire on Wednesday January 20, 1993. Smoke control and escape planning are also very important measures for fire safety planning. There subjects are left to Mr.I. Hagiwara.

We must consider the fire safety from the point of architecture prior to consulting fire fighting after catching fires.

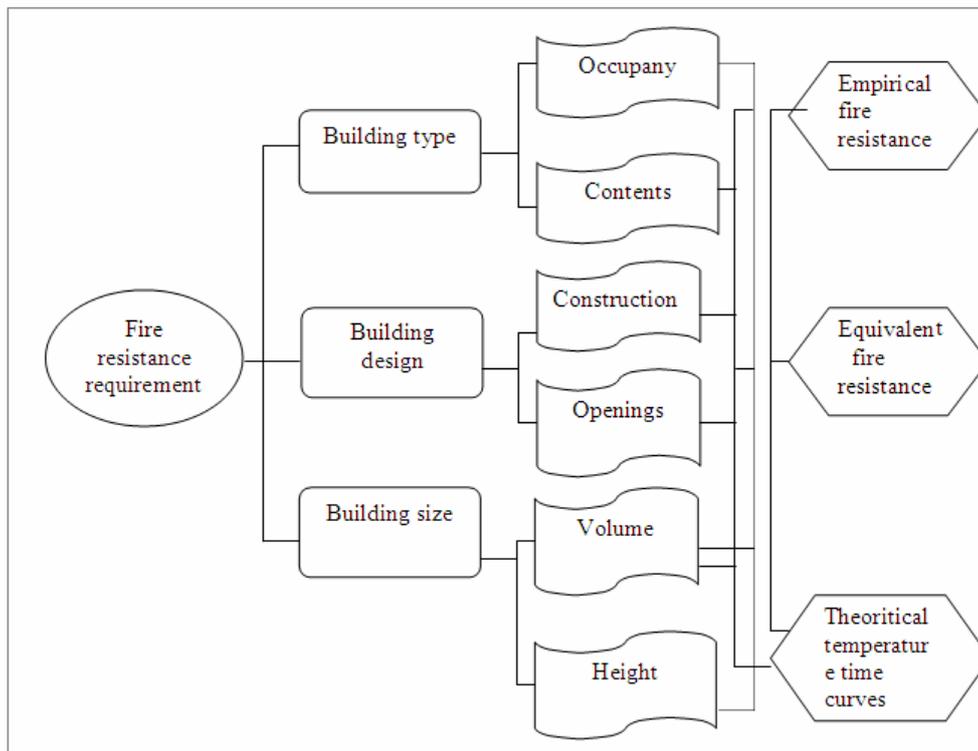


Figure 6. Method of defining fire resistance need

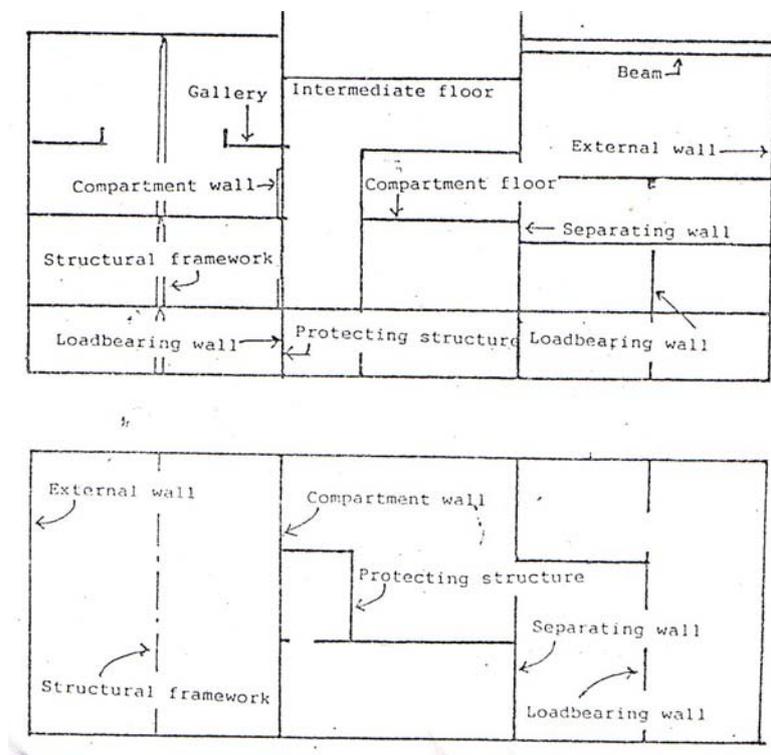


Figure 7. Various components of a building to which fire resistance requirements apply

7. SUMMARY AND CONCLUSION

The principle for fire-resistance design is as follows:

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2. Fire safety for the whole building is to be estimated with the product of safety coefficient based on the data from each fire zone, depending on the use, scale and structure etc.
3. Main structural components are to be resistant for more than estimated fire duration
4. The fire performance is usually rated into four classes which are 3 hours, 2 hours, 1 hours and half an hour endurance.
5. Fire doors or fire protection assemblies are to be applied to the openings on the exterior wall of a fire-resistance construction where there may be imminent danger of spread of a fire.

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