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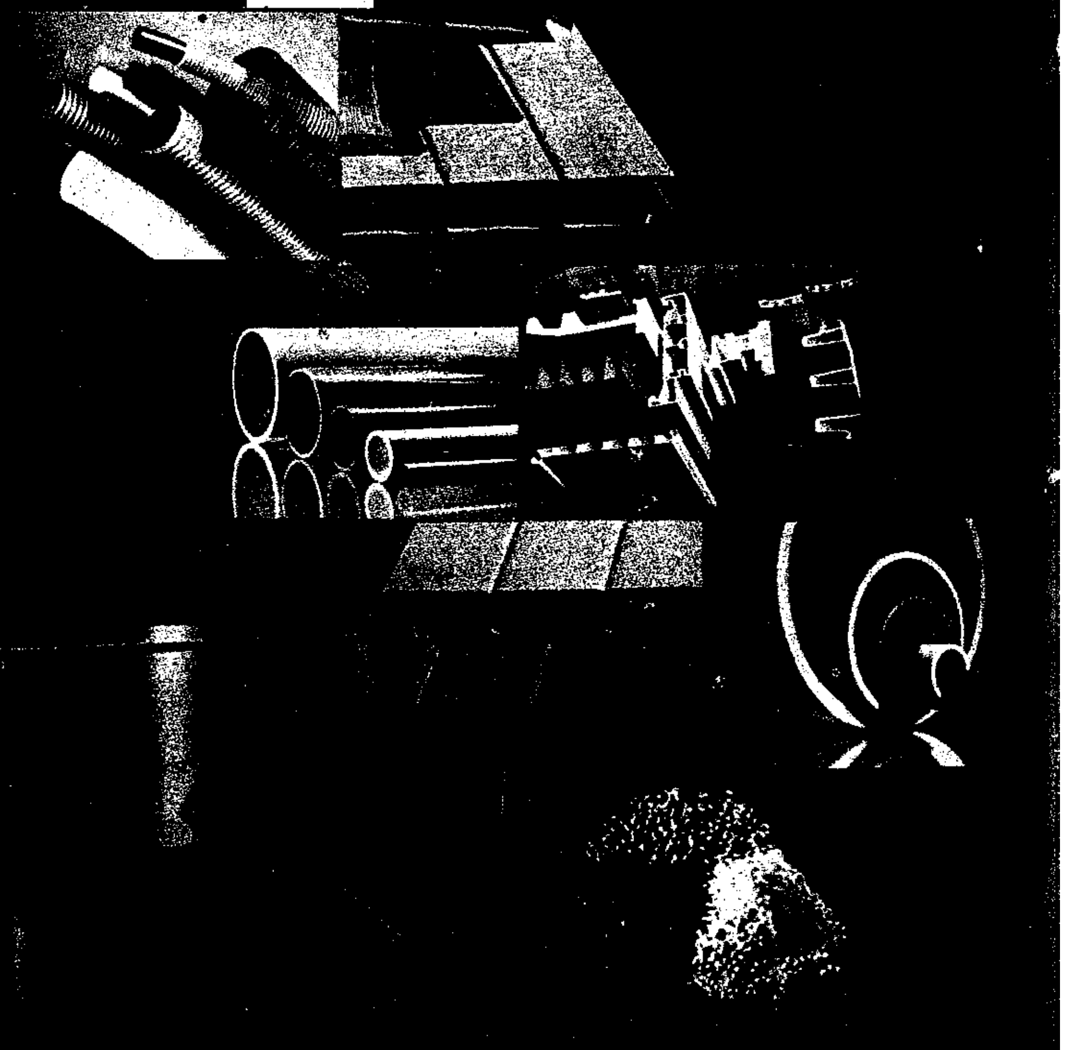

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Selection of Plastics for Buildings-A Fire Safety Point of View

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The homosapiens have entered into an age which could appropriately be called as the **Plastic Age.** Plastics are a development of the twentieth century and can be expected to perform a major role as materials of the twenty-first.

Mankind, for many centuries, made use of materails which were directly obtained from natural resources such as wood, stone, clay etc. and later on those derived from these such as metals, bricks, lime, cement and concrete, ceramics etc., needed for all practical applications. The reserves of the natural resources are limited and have been dwindling. The population on the other hand has been continually on the increase requiring more and more materials for their consumption. Not only that materials are required larger quantities, the rapid advancement that is taking place has created a need for more materials for diverse applications. These have been some of the compelling reasons for seeking alternatives. Plastics are providing a range of materials for diverse requirements, can be tailored to suit any particular requirement and even can be made available at an affordable or a competitive price. Today, every manufactured product uses plastics in some way or the other.

Plastics have penetrated into almost every aspect of daily life of human life Plastics have been used for :

Vehicles for transportation (cars, aircrafts, ships, boats, trains, etc.),

Communications (cables, telephones, television and radio sets, etc.) :

Energy saving (thermal insulation, etc.) ;

Medicine (artificial limbs, dentures, Surgery, etc.) ;

Electronics (instruments, computer, clocks etc.) ;

Education (educational aids, tools, pens etc.) ;

Industry (leather, chemical, paints, printing, textiles etc.) ;

Electrical (power plants, cables, insulation tapes. etc.) ;

Nuclear (plant containment coatings, ablative materials, etc) ;

Sports (sports goods, artificial trufs, etc.) ; and Housing.

In buildings plastics are being used for roofings, domelights, floor coverings and carpets, doors, thermal and acoustic insulation, furniture, plumbing, containers domestic appliances, toys, clothes, objects of utilitarian or decorative value and many more. In fact, these are used so widely that it is not practicable to give a complete account here. Many more applications are probably in store.

The traditional materials have a familiarity about their use or behaviour. Metals as a class, for example, can be attributed to certain common properties. They are hard, would get corroded

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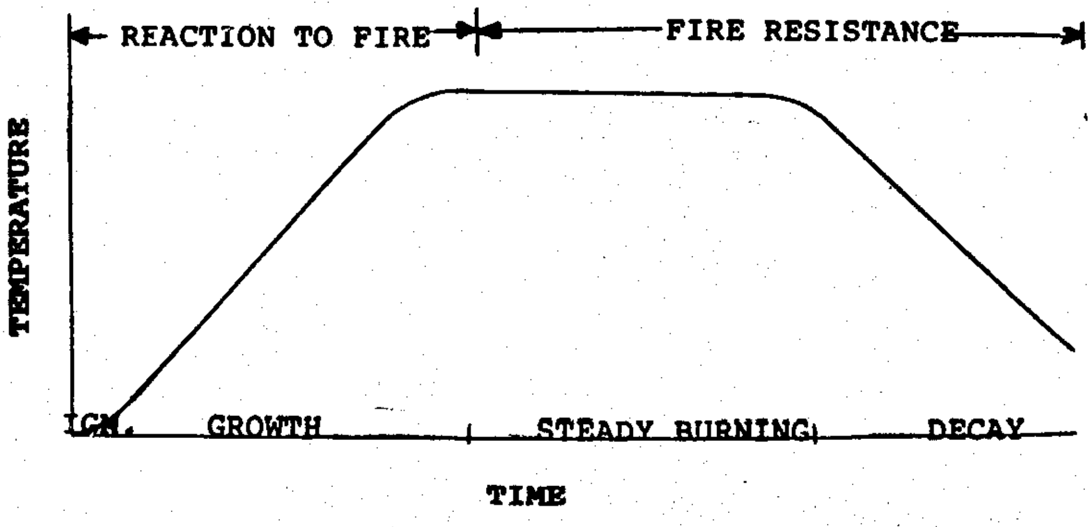
and have a higher conductivity. No such thing can be expected of plastics. Plastics are vastly different from each other in chemical composition and properties. One type of plastics does not behave like another. In fact plastics of the same type can be very different from each other. Wood was wood in earlier days, but all that is wood today may not be wood at all. What may look like glass, ivory or steel may be plastics. The term plastics encompasses a great variety of substances. Yet the scientific research that has resulted in the astonishing range of materials is barely half a century old. Plastics are naturally, therefore, relatively less completely understood. Most of the plastics that are produced would go into buildings either in construction and finish or as contents. The building activity is going to increase–shelter being a basic amenity. More of finances would have to be deployed to house the homeless millions. For making a thrust in this direction it is essential that not only the scarce and valuable funds provided are optimally utilised, but also, the losses due to disasters are minimised.

Fire is a major threat to humanity. Fires cause considerable losses to lives and property resulting in erosion of precious GNP. Such losses can however be curtailed by adopting safe practices.

Fire is a chemical reaction accompanied by the evolution of heat, light and emission of sound. It results when an exothermic combination of oxygen and a 'fuel' takes place. The fuel, in case of buildings, is a material which can burn. Fire can be initiated by a small source known as an ignition source such as a spark or an arc, glowing cigarette, match flame etc. The ignition source raises temperature of a small portion of material to a critical value when the combustion process starts and can become self sustaining. Fire can then spread via combustibles and grow. In a room or a compartment, the growth of fire can be represented by the figure.

From the compartment of origin the fire may spread to other areas of a building. During the growth period of a fire, combustible materials have a major role to play. The time to reach flashover conditions, a term denoting simultaneous involvement of all combustibles in a compartment is closely linked with the time available for occupants to escape and save themselves. It is strongly dependent on the nature and arrangement of combustible materials used besides other factors.



From fire safety point of view it is essential that the materials used do not contribute to the growth, and spread of a fire significantly. This places an important restriction on materials to be used and therefore a proper selection is essential.

From the foregoing brief outline of fire growth,it can be concluded that the parameters that are of relevance can be :

(a) Ignition Characteristics

Ignition is the onset of combustion. Time to ignition, ignition temperature & ignitability are some of the characteristics to be determined.

(b) Heat Release

As material burns heat is released which gets dissipated within the compartment. Heat can be transferred to other materials by familiar modes of conduction, convection and radiation. The net effect is an increase in temperature of different materials within the compartment. These can get ignited when raised to their ignition temperatures and burn. Rate of Heat Release by materials is therefore an important factor for fire growth.

(c) Flame Spread

A combustible material, once ignited, can permit flames to travel over its surfaces. These flames can travel to locations which are at a distance from the initial outbreak thereby involving other materials in fire. Where long continuous surfaces of combustible materials are available as in false ceilings, wall linings, duct insulations etc,, this property assumes considerable importance from fire spread point of view.

(d) Smoke Production

In the event of a fire, smoke is produced. Smoke obscures vision and hampers escape and therefore smoke produced from materials in fires is normally characterised by a property known as optical density of smoke or specific optical density of smoke (which is a function of the apparatus used). This property is related to the percentage reduction in light flux due to smoke across a light path and hence visibility. If smoke produced is very dark and cuts off more light people may not be able to find their way through smoke.

(e) Toxicity of Combustion Products

Products of combustion fires can be toxic. The physiological effect of these gases can manifest in the form of nausea, headache, unconsciousness or even fatality depending upon the composition of the combustion products and duration of exposure. Toxic products can be considered either as irritants or as narcotics. Irritants are those which attack the membranes and can make escape difficult. Narcotics get absorbed in the body system and affect adversely. Although the toxic compounds from a burning material can run into hundreds, carbon monoxide is still believed to be main toxic constituent of fire gases. Toxicity of combustion products is of important consideration from life safety point of view.

(f) Fire Resistance

From flashover onwards, till the time fire is extinguished or dies out by itself, fire can be said to be fully developed or a steady burning one. During this stage, the structure and its components are required to contain fire and to withstand the effect of fire. The ability of the elements of structure to prevent itself fiom cracking, collapse or permitting temperature on the unexposed face to rise beyond a certain specified limit is termed as **fire resistance** and is measured in terms of time. Walls, floors, beams, columns, partitions, doors with frames, fire dampers can be evaluated for this property.

In order to incorporate fire safety in buildings it is essential that materials used are such that they do not contribute significantly to a fire. Whether a material is safe or whether it complies with the building regulation, can be found out by making suitable tests. Different countries have, over a period of years, evolved their own set of standard fire tests for materials, including Plastics. Some of these tests are used for quality control while others are used for testing and certification by recognised laboratories and for regulatory control.

Standard fire tests can be grouped into three main categories :

1. Tests which are used to ascertain a fire property or one of the **reaction to the fire** characteristics such as noncombustibility, ignitability, flame spread, heat release, specific optical density of smoke generated, toxicity of combustion products, etc.

2. Tests which are designed to evaluate property of a class of materials e.g. flammability of thin plastic sheetings, incandescence resistance of rigid thermosetting plastics etc., and

3. Tests which are used to assess suitability of material for a particular end use, e.g., flammability of floor coverings, external fire exposure roof test, etc.

Faciltities for assessment of fire performance characteristics of materials, conforming to various national and international standards, have been provided at the **Central Building Research Institute, Roorkee** for the first time in the country.

Some of the major ones which can be applied to plastics are :

Name of the Test	Standard (s)
Method of Test for Noncombustibility of Building Materials	IS : 3808-1971 BS 476 : Part 4 : 1970 ISO 1182-1983 (E) ASTM E 136-79
Ignitability Test for Materials	BS 476 : Part 5 : 1968
Method of Test for Fire Propagation for Products	BS 476 : Part 6 : 1981
Surface Spread of Flame Test for Materials	BS 476 : Part 7 : 1971 IS : 1642-1960
Surface Burning Characteristics of Building Materials	ASTM E 84-81
Early Fire Hazard Properties of Materials	AS 1530, Part 3-1976
Specific Optical Density of Smoke Generated by Solid Materials	ASTM E 662-79

Name of the Test	Standard (s)
Methods of Testing Plastics-Flammability	BS 2782 : 1970
Rate of Burning	Method 508 A
Flammability of PVC Extrusion Compound	Method 508 B
Flammability of PVC Sheeting	Method 508 C
Flammability of Plastics Materials (alcohol cup method)	Method 508 D
Incandescence Resistance of Rigid Thermosetting Plastics	Method 508 E
Rate of Burning and/or Extent and Time of Burning or Flexible thin Plastic Sheeting Supported on a 45° Incline	ASTM D 1433-77
Rate of Burning and/or Extent and Time of Burning of Self Supporting Plastics in a Horizontal Position	ASTM D 635-81
Rate of Burning and/or Extent and Time of Burning of Flexible Plastics in a Vertical Position	ASTM D 568-77
Flammability of Plastic Sheeting and Cellular Plastics	ASTM D 1692-65
Flammability of Textile Floor Coverings	BS 4790 : 1972
Fire Retardancy of Paints (Cabinet Method)	ASTM D 1360–79
Fire Test for furnitures	BS 5852 ; Part 1 : 1979
Fire Resistance of Vertical Elements	IS : 3809-1979
Fire Resistance of Horizontal Elements	IS : 3809-1979
Fire Resistance (Thermal Insulation Criterion only)	IS : 3809-1979

The facilities for evaluation of various fire properties of materials are being extended to the manufacturers of building materials and to those engaged in development of new materials and to those engaged in development of new materials and products. Using these facilities, data on fire performance characteristics of materials have been generated. These would be useful to architects, users, insurers, fire safety officials and many others. Efforts are being made to compile data on important building materials in a useful format so that the information is available for reference. Fire performance data on some of the characteristics are given in the attached table.

FIRE PERFORMANCE CHARACTERISTICS OF PLASTIC MATERIALS

Material	Thickness mm	Density kg/m^3	Test Results						
			Non-Combustibility	Ignitability	Fire Propagation Index		Flame Spread Class	Smoke Density, Dm	
					i_1	I		Flaming	Non-Flaming
1	2	3	4	5	6	7	8	9	10
PVC Panel	0.8	200	C	P	04.5	08-00	*		
PVC Profile	21	198.6	C	P				> 924	302.9
PVC Profile	21	198.6	C	P				585	393.5
Polyurethane Foam-Rigid (Castor Oil Based)	26	56	C	X	19.66	30.36		300.9	171.0
Phenolic Rigid Foam Slab	25	37–43	C	P				7.5	5.0
Polyisocynanurate Foam	50	30.7	C	P	6.83	13.28	1	58.5	11.0
Polystyrene Foam	25	15.5	C	X	07.90	10.50	*		
Polystyrene Foam–Fire Retardant Grade	25	23	C	P	06.20	08.40	*		
PVC flooring sheet	2	1492	C	P	7.72	20.03	4	610.0	186.0
3 mm Plywood, Aluminium 1 mm as Surfaces, Polystyrene Foam Slab 25 mm as Core Plywood Exposed	29	198.1	C	P	20.40	43.34	3		
3 mm Plywood, Alumrnium 1 mm as Surfaces, Polystyrene Foam Slab 25 mm as Core Aluminium Exposed	29	198.1	C	P	01.01	04.25	1		
Surfaces of Plywood 3 mm, Aluminium 1 mm, Core of Resin Bonded Bloated Clay Aggregate 20 mm, Plywood Exposed	24	923.2	C	P	20.71	45.52	3		

1	2	3	4	5	6	7	8	9	10
Surfaces of Plywood 3 mm, Aluminium 1 mm, Core of Resin Bonded Bloated Clay Aggregate 20 mm Aluminium Exposed	24		C	P		01.00	1		
Asbestos Cement Sheet 3 mm both sides, Core of Expanded Polystyrene 50 mm	56		C	P	03.24	05.10	1		
Asbestos Cement Sheet 33 mm, Aluminium Sheet 22 Gauge as Surfaces; Core of Expanded Polystyrene 50 mm, Aluminium exposed	22 Gauge + 53		C	P	03.40	07.07	1		
Asbestos Paper 0.5 mm and PVC Sheet 0.25 mm as Surfaces; Core of Expanded Polystyrene 12.5 mm, PVC Surface Exposed	13.25		C	P	13.34	23.35	4		
Rigid Polyurethane Foam as Core, Glass Fibre Tissue Surfaces, White Coated one side	20	44.35	C				4		
Fire Retardant Expanded Polystyrene	12.5		C	P	05.85	08.12	*		
Rigid Polyurethane Foam as Core, Glass Fibre Tissue Surfaces, White Coated	30	41.8	C				3		
Rigid Polyurethane Foam as Core, Paper Surfaces both sides	24	55.5	C	X	29.93	38.89		353.5	124.0
Rigid Polyurethane Foam as Core Laminate Facings	50	76	C	P	14.60	33.10	1	48.0	80.5
Decorative Laminative — I Laminated Surface Exposed	1.6	1400	C	P			1	92.7	34.0

1	2	3	4	5	6	7	8	9	10
Decorative Laminate — II Laminated Surface Exposed	3.0	1480	C	P			1	120.0	48.0
Decorative Laminate — III Laminated Surface Exposed	2.0	1454	C	P			1	48.0	61.5
Decorative Laminate — IV Laminated Surface Exposed	3.0	1540	C	P			1	198.0	45.5
Decorative Laminate — V Both Surfaces Laminated	3.0	1580	C	P			1	158.0	67.0
Decorative Laminate — VI Laminated Surface Exposed	2 0	1570	C	P			1	80.8	63.0
Decorative Laminate — VII Laminated Surface Exposed	2.0	1600	C	P			1	125.0	30.0
Mineral Fibre Marine Board (Glass Cloth Surface)	25.0	85.00					1		
Mineral Fibre Marine Board Glass Wool Surface)	25.0	85.00					1		
Mineral Fibre Tissue Faced Board	25.0	71.53					1		
Mineral Wool Starch Bonded White Coated, Punched Surface	18.0	364.00	C	P	07.36	13.54	1		
Mineral Wool Starch Bonded White Coated, Punched Surface	18.0	364.00					2		
Mineral Wool Bonded with Inorganic Binder, White Painted	18.0	461.00					1		
Mineral Wool Bonded with Inorganic Binder, White Painted (Back Surface)	18.0	461.00					1		
Plywood	3.0	716.90	C	P	18.56	36.52	4	74.2	162.7

1	2	3	4	5	6	7	8	9	10
Plywood	6.0		C	P	07.47	25.52	3		
Kailwood	12.0	495.00	C	P	16.14	41.5	4	228.0	328.7
Fibre Board	12.0	235.00	C	P	33.1	56.00	4	217.5	308.1
Particle Board	12.0	400.00	C	P	14.21	36.52	3	261.5	410.0
Particle Board Perforated one side Fire Retardant Coated	12.0	540.00	C	P	13.67	32.11	2		
Fire Retardant Particle Board Perforated one side Coated (Black Surface)	12.0	540.00	C	P	07,12	21.76	2		
Particle Board Medium Density	19.0	815-00	C	P	13.29	32.67	2		
Particle Board Medium Density (Back Surface)	19.0	815.00	C	P	05.47	21.06			
Prelaminated Particle Board	18.0	818.20	C	P	03.95	25.32	2		
Phenolic Foam Laminated with Fire Retardant Surface	50.0	76.00	C	P	14.6	33.1	1		
Fire Retardant Paint on Mango Wood 12 mm				P	14.15	41.25	3		
Fire Retardant Paint on Fibre Board (2)	12.0			P	02.47	15.00	1		
Fire Retardant Paint on Fibre Board (3) Primer Plus 2 coats of Paint	12.0						3		
Fire Retardant Paint on Aluminium 1 mm (1)	1.0			P	01.00	01.80	1		
Fire Retardant Paint on Kail Wood 12 mm (4)							1		

1	2	3	4	5	6	7	8	9	10
Fire Retardant Paint on Ply Wood 3 mm (5)			C	P	11.84	27.74	3		
Fire Retardant Paint on Particle Board 12 mm (5) Spreading Rate 3.53 m^2/lit				P	04.24	22.53			
Fire Retardant Paint on Particle Board 12 mm (5) Spreading Rate 2.7 m^2/lit							1		
Fire Retardant Paint on Particle Board 12 mm (5) Spreading Rate 6.06 m^2/lit								134.5	218-1
Fire Retardant Paint on Fibre Board 12 mm (5) Spreading Rate 2.30 m^2/lit			C	P	06.84	22.26			
Fire Retardant Paint on Fibre Board 12 mm (5) Spreading Rate 1.75 m^2/lit							1		
Fire Retardant Paint on Fibre Board 12 mm (5) Spreading Rate 1.80 m^2/lit								127.0	93.2
Intumescent Paint on Fibre Board 12 mm Spreading Rate 2.40 m^2/lit				P	04.20	19.35	1		
Clear Varnish on Ply Wood 6 mm Spreading Rate 6.28 m^2/lit				P			2		

LEGEND : C—Combustible, NC—Noncombustible ; P—Not Ignitable, H—Easily Ignitable, i, — sub-index, I—Fire Performance Index; Class 1—surfaces of very low flame spread, Class 2—surfaces of low flame spread, Class 3—surfaces of medium flame spread, Class 4—surfaces of rapid flame spread, Dm—Maximum specific optical density of smoke generated.

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PAINT CABINET TEST

Paint	Density	Test Results	
		Mean Weight Loss (gms)	Mean Char Index (cc)
Intumescent Paint		6.35	25.0
Clear Varnish		13.10	47.25
Fire Retardant Paint (1) Fire Retardant (2)		05.40	16.58
Heat Resistant Coating	1024	06.97	32.14
Fire Resistant Primer for Wood Unleached Specimens	1416	09.69	58.55
Fire Resistant Primer for Wood Leached Specimens	1416	10.42	62.77
Fire Retardant Paint (3) Unleached Specimens	1164	07.34	25.46
Fire Retardant Paint (3) Leached Specimens	1164	07.37	21.05
Fire Retardant Paint (4) Unleached Specimens	1234	06-86	18.48
Fire Retardant Paint (4) Leached Specimens	1234	08.12	16.97
Fire Retardant Paint (5)	1260	09.45	23.54

Conclusions

Plastics are exciting materials to use. Whilst it is true that plastics can be used for many applications, it is obvious that not all plastics that can be considered for a given application would be found suitable. From a fire safety point of view caution must be exercised while using plastics in buildings, as these are inherently combustible. These should not be used indiscriminately and a proper selection based on standard fire test methods is essential. Only those found relatively safe should be recommended for use in a building.

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References

1. Bhatnagar, S.K., Plastics in Buildings and Fire safety. Paper presented at UNIDO-NBO Seminar on Processing and Use of Plastics in Buildings, New Delhi, 10—15 May, 1976 also Popular Plastics, Annual Number, 1976.

2. Bhatnagar, S.K., Materials in Buildings and Fire Safety, Symposium on Building Services, Institution of Engineers, New Delhi, March 1—2, 1984.

3. Badami, G.N. and Bhatnagar, S.K., Fire Protection of Buildings, Three Decades of Buildings Research in India, M/s. Sarita Prakashan, Meerut, Chap. 8, 1985.