



INDIAN HABITAT AND INFRASTRUCTURE

Need for Innovative Approach

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Flame and Smoke Retardant Materials for Building

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ABSTRACT

Natural and synthetic polymeric materials like, cellulose and plastics, rubbers and foams are extensively used in buildings for a large number of applications. Wood and wood based products such as plywood, particle board, fiber board etc are used for windows, door, partitions, thermal and acoustical insulation as well as for decorative purposes. Textiles are used for furnishing, partitioning and floor coverings. Now- a -days plastics are used for windows, doors, partitions, furniture, furnishings, electrical fixtures and cables etc. These materials are combustible by nature. If they are suitably treated for fire retardancy, the growth period of fire and the spread of flames will be reduced considerably thereby restraining fire hazards and loss of life & property.

To retard the ignition and flame spread several chemical treatments have been reported by researchers from time to time. However, many of the flame-retardants used are known to increase generation of smoke. To overcome this problem researcher at Fire Research Laboratory of CBRI, Roorkee are working towards development of various fire and smoke retardant treatments for different materials to reduce fire losses. These treatments include impregnation with chemicals, surface coating and incorporation of chemicals during manufacturing stage. Synthesis of smoke suppressant metal based organic complexes and flame retardant resins is also in progress. Use of the above mentioned treatments and the products synthesized for development of Eco- friendly materials are discussed in the paper.

INDIAN HABITAT AND INFRASTRUCTURE
 - NEED FOR INNOVATIVE APPROACH

Flame and Smoke Retardant Materials for Residential Buildings – an Innovative Approach

INTRODUCTION

Fire accidents account for a large number of casualties as well as loss of property. Be it an incident of fire in a chemical plant, a storage area, a cinema hall, a passenger train or a domestic dwelling, the uncalled-for incidents can be checked or minimized if fire retardant materials are used. Various natural and man made combustible materials such as wood and wood based panels like plywood, particleboard, fiberboard plastics as sheets, blocks or rigid and flexible foams, rubber etc. are normally used as building components and contents. Doors, windows, partitions, thermal and acoustic insulation normally involves the use of cellulosic materials. Cellulose based materials are also used in furnishings and furniture items. Lately, polymeric materials have entered these areas in a big way and find application in all the above mentioned areas besides some areas specific to them e.g. electrical fixture and cables, flooring, laminates storage etc. Unfortunately, leaving a few exceptions, they are intrinsically combustible in nature and hence pose serious fire hazards. These combustibles constitute a major part of the total fire load and thus help in growth and spread of fire from the point of origin to remote locations in the building.

In order that these materials meet fire safety guidelines, they are often treated with fire retardants. Development of flame retardant compositions for materials has been known for more than a century. A large number of fire retardant treatments based on organo-phosphorous and halogenated compounds are known for cellulosic materials. However, they are known to be toxic and expansive. Fire retardants based on inorganic salts are comparatively cheaper, readily available, non-toxic but they are not durable. Some fire retardant intumescent and non-intumescent coatings are known for wood and wood based materials. Polymeric materials may be rendered flame retardant by incorporation of chemical additives and/or fillers to the base polymer during processing stage. Their fire performance can also be improved upon by chemical modifications during manufacturing stage or by application of surface coatings to the finished products. Although a large number of flame-retardant treatments are known to be fairly effective, most of the flame-retardant chemicals are known to increase smoke generation. Therefore, there is an ample scope to develop flame and smoke retardant treatments. Materials suitably treated with such compositions will be of great help in reducing fire losses in buildings. Attempts to achieve this are being made at Fire Research Laboratory of Central Building Research Institute, Roorkee.

FLAME AND SMOKE RETARDANT TREATMENTS

A flame-retardant treatment should essentially possess the following characteristics:

- ❖ It should be non toxic and may not produce toxic decomposition products.
- ❖ It should not reduce the strength and finish of the material to be treated.
- ❖ It should be easy to apply, economical and easily available.

The chemicals largely employed for fire retardance are either chemical compounds or mixture of compounds of phosphorous, nitrogen, sulphur, boron, halogen and antimony. THPC (Tetrakis hydroxy methyl phosphonium chloride), APO (Aziridine phosphine oxide), Phosphorylamide and various combinations of THPC / APO have been investigated by various researchers to achieve fire retardancy¹⁻³. However, not a single composition of such treatments has been commercialized due to their toxic nature, smoke generation, high cost and problems encountered during application. The present communication reports some economical, non-toxic, low smoke producing flame-retardant compositions. The compositions are reported in terms of their mode of application.

Impregnation and Spray Method Chemical compositions based on phosphates, borates, amides, halogenated compounds and antimony oxide were studied for imparting fire retardancy in cellulosic materials such as cotton fabrics. Fabric was treated with the above compositions by dipping for a certain period, removed, squeezed, dried at room temperature and chemical retention was calculated on dry basis⁴. Curing the specimen at different temperatures for different duration enhanced the durability of treatment in terms of washing / leachability. Unreacted chemicals were removed by washing the specimen with tap water. Another treatment of fabric was done by employing suspension of borate salt and finely divided antimony oxide in a solution of halogenated copolymer binder and phosphate salt in a suitable solvent and curing was done by hot pressing⁵. Such treatments are water and weathering resistant. These treatments are also applicable to other cellulosic materials treated by spray and/ or impregnation method. Some compositions are reported in Table -1.

Surface Coating Two types of coatings – non intumescent and intumescent – are often used to impart flame retardance to materials. The non-intumescent coatings are based on compounds that are stable at high temperature. Such coatings are prone to damage by prolonged heating as the surface film cracks and permits heat penetration to the substrate.

Intumescent coatings comprise certain basic ingredients such as a source of carbon polyhydric alcohols, a spumific agent such as amides, catalyst such as phosphates and a suitable binder along with pigments, plasticizers etc. Some intumescent coatings work by the synergistic effect of antimony oxide and halogenated compounds. Volatile reaction products such as antimony trichloride, formed during burning process act as flame suppressants. Under the effect of heat these paints swell up and produce a tough insulating char that protects the underlying material. The main advantage of these coatings over the non-intumescent type is their stability at high temperature and prolonged heating. Such coatings may be used for cellulosic lining materials as well as for polymeric materials such as PVC⁶. Results of few fire retardant intumescent coatings are given in Table -2.

Additives and Fillers Man made polymeric materials are basically carbonaceous in nature and generally prone to ignition. Some polymers such as PVC are naturally flame retardant in their virgin form, however, they loose this property when different processing aids are employed during manufacture of end products⁷. The various approaches to counter this drawback include⁸ use of additives, fillers surface coatings or polymeric modification. Additives may be either inorganic or organic complexes. They are used in small quantities only up to 20 parts per hundred parts of the virgin resin. Additives can either be incorporated in polymer system at the processing stage or may be made to impregnate the final product. Fillers are inorganic in nature and may be inert or reactive. The inert fillers such as chalk, clay etc. mainly help to reduce the overall quantity of the polymer in the end product. They are not reported to have any significant effect on the flame and smoke generation from the material. The reactive fillers such as Aluminium trihydrate (ATH) not only replace the polymer, but also take up the heat via endothermic reactions thus being very effective. Plasticized PVC samples were prepared by using the phosphate and the phthalate type of plasticizers. Commercially available processing aids such as heat stabilizers and lubricants were used during processing. Some transition metal salts and metal-based organic complexes were studied for their effect on flame and smoke retardancy of poly vinyl chloride. Flame and smoke retardance achieved by using some of the combinations is reported in Table-3.

METHODS OF EVALUATION

Fire performance of fabrics was determined in terms of char length, char area, after flame and after glow time in accordance with BS 3119. Here, specimens of size 318 x 51 mm were cut from each fabric and subjected to a standard flame for 12 seconds. Surface coatings were evaluated for their fire performance by 'Paint Cabinet' method as per ASTM D 1360. In this, the test panel of 6 x 150 x 305 mm size were prepared

from mango wood and coated with the surface coating under evaluation. The test panels were exposed to test conditions of a standard alcohol cup burner till the entire alcohol was consumed. Weight loss and char volumes were calculated. Surface spread of flame test as per BS 476 part 7 was used to assess the flame spread on lining materials. Samples of size 12 x 230 x 900 mm were prepared and subjected to a standard gas fired radiant panel of 900 x 900 mm. The time of spread of flame front for measured distances along the specimen was recorded for 10 minutes and used for classification of the material according to the procedure laid down in the standard. For measuring the smoke generation due to the treatment, treated and untreated specimen were subjected to test in the smoke density chamber based on ASTM E 662. Samples of 75 x 75 mm each were prepared from the treated and the untreated specimens and subjected to the standard fire sources. The non flaming mode comprise a radiant source of 2.5 W/cm² irradiance over the central portion of the test specimen while the flaming mode has a row of small flames impinging on the surface of the specimen in addition to the radiant source.

Polyvinyl chloride was studied for its flame retardancy and smoke suppression characteristics by using the limiting oxygen index (LOI) method as per ASTM D 2863 and a dynamic smoke measurement apparatus⁹. Samples of 150 x 51 mm were in both the cases. Samples were clamped vertically in a specimen holder and exposed to a small flame in side a chamber having controlled atmosphere comprising a mixture of oxygen and nitrogen. The test flame is applied for three minutes or till the flame front travels for 75 mm, whichever is earlier. The oxygen nitrogen concentration is adjusted so as to achieve the above criteria. The oxygen level required to achieve this is reported as LOI of the material. For smoke measurement samples are exposed at oxygen concentration of 2% higher than the LOI of the desired specimen. Smoke thus generated is allowed to flow through a duct at a known flow rate and the smoke is measured by using He-Ne laser across the duct. Area under the smoke density Vs time curve is used to arrive at the smoke generation by the material & hence the smoke suppression (SSI) by the treatments. The test is continued for three minutes.

CONCLUSIONS

The problem with flame and smoke retardant systems is that two characteristics require diagonally opposite conditions of burning. While flame retardancy requires that the combustion does not extend beyond desired levels, the requirement for low smoke is high or preferably complete combustion. When a material burns carbon is produced. In gaseous phase the carbon particles suspended in combustion gases form a colloidal solution called smoke, while in the solid phase the resultant carbon occurs as char. Thus one of the ways to suppress smoke is by forcing the resultant carbon particles to be char rather than smoke. The twin condition of flame and smoke retardancy is achieved either through formation of extensive char as in the case of intumescent surface coatings or use of fillers in polymeric materials or through modification of the products of pyrolysis through use of certain complexes as in the case of PVC reported here. In case of Plasticized PVC such metal complexes were used which served the dual purpose of pyrolysis product modification as well as increase in char formation reported as percentage of back bone char (BC%).

TABLE -1
EFFECT OF COMPOSITIONS ON FIRE AND SMOKE RETARDANCE
(Impregnation & Spray Method for Cellulosic Materials)

Sr.No.	Composition	Dry Chemical Retention %	After Flame Time, s	After Glow Time, s	Char Length, mm
1.	Phosphate- Borate	5.18	2	22	14.7
2.	Phosphate- Borate	10.22	0	0	11.4
3.	Phosphate- Borate	15.10	0	0	5.50
4.	Phosphate -amide	5.87	0	0	20.8
5.	Phosphate -amide	9.94	0	0	11.2
6.	Phosphate -amide	15.55	0	0	5.94
7.	Antimony- halogenated Co polymer	60.35	5	195	21.60
8.	Antimony- halogenated Co polymer	71.54	0	189	9.20
9.	Antimony- halogenated Co polymer	79.88	0	185	8.80
10.	Antimony- halogenated Co polymer - Glow retardant	60.15	0	2	8.60
11.	Antimony- halogenated Co polymer - Glow retardant	70.42	0	0	7.80
12.	Antimony- halogenated Co polymer - Glow retardant	80.10	0	0	6.98

TABLE -2
EFFECT OF SURFACE COATING ON FIRE AND SMOKE RETARDANCE

Material	PERFORMANCE AS PER						
	ASTM D 1360		BS 476 Part 7			ASTM E 662	
	Weight Loss g	Char Volume cc	Flame Spread at		Classifi cation *	D _m Non- Flaming	D _m Flaming
1.5 min. mm			10 min. mm				
UnCoated							
Mango wood	21.12	50.40	0	0	Class 3	329	228
Plywood	22.65	63.00	0	0	Class 3	221	107
Fiberboard	Burnt Completely	Burnt Completely	0	0	Class 4	308	190
Coated							
Mango wood	2.25	4.25	230	715	Class 1	31.8	37.5
Plywood	2.92	5.50	250	740	Class 1	29.3	32.1
Fiberboard	3.36	6.40	325	900	Class 1	36.0	42.2

The surface coating used for the present study comprised of phosphate, polyhydric alcohol, amide, pigment binder and water. Mango wood and Fiberboard were 12 mm thick while the plywood was only 6mm thick.

* Class 1,2,3 and 4 represent the surfaces of Very low, Low, Medium and Rapid flame spread respectively. D_m is the maximum specific optical density measured under flaming or non flaming conditions

TABLE -3
EFFECT OF METAL BASED ORGANIC COMPLEXES ON FLAME RETARDANCE
AND SMOKE SUPPRESSION OF PLASTICIZED POLY (VINYL CHLORIDE)

Sample	Plasticizer	Phr	LOI	SSI	BC%	CO	CO ₂
Molybdenum Complex	Phthalate	3.0	29.2	57.57	61.38	12	600
Molybdenum Complex	Phosphate	2.5	33.2	56.08	67.21	80	900
Vanadium complex	Phthalate	3.0	28.1	39.13	74.29	23	1350
Vanadium complex	Phosphate	2.5	32.8	38.57	58.30	14	1050
Chromium complex	Phthalate	2.0	27.5	50.30	61.43	20	1450
Chromium complex	Phosphate	2.5	32.1	48.57	55.71	20	900
Cobalt Complex	Phthalate	2.5	26.26	72.96	72.96	18	950
Cobalt Complex	Phosphate	3.0	33.4	63.54	84.43	34	1050
Molybdenum Complex + ATH	Phosphate	2.0	38.5	82.59	103.64 [#]	10	1400
Chromium Complex + ATH	Phosphate	1.0	38.4	82.70	121.58 [#]	15	1000

Phr Parts per hundred parts of resin

LOI Limiting Oxygen Index (Measure of Flammability/ flame retardancy)

SSI Smoke suppression index (measure of smoke generation/ smoke suppression)

BC% Percentage backbone char formation

CO Carbon monoxide

CO₂ Carbon dioxide

* The concentrations of CO and CO₂ reported are the peak concentrations over a three-minute test duration and are over and above the base line i.e. the concentrations observed in case of control samples.

BC% in case of samples filled with 60 phr of ATH appear to be >100%. This is because the weight of the non- PVC components is much higher, thus resulting in higher BC%.

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