# SMOKE HAZARDS AND BUILDING MATERIALS

*In this paper S/Shri Sunil K. Sharma and N.K. Saxena, Scientists, Fire Research Laboratory, Central Building Research Institute, Roorkee have described the smoke producing characteristics of some common building materials which have been determined by them as a result of the tests carried out in their laboratory.*

***Editor.***

## INTRODUCTION

Combustion products in the form of solids, liquids and gases are the main threat to life in building fires. They comprise of gaseous products including the flammable and the toxic gases. The solids and liquids suspended in gas phase are known as smoke. Due to it's particulate nature smoke can reduce the ability of a person to see when trying to escape from a fire zone. Smoke also affects occupants in remote locations since it migrates to different parts of the building hitherto unaffected by fire, thereby vitiating the environment and trapping more people who would have escaped had there been no smoke.

Different materials produce different levels of smoke. The information on smoke levels generated by different materials is not readily available in India. For the first time in the country a facility for quantification of smoke generated by solid materials has been provided at the Central Building Research Institute, Roorkee. The information generated by using the above facility is very useful in selection of building materials from fire and life safety point of view. Smoke generation characteristics of some common building materials are reported in this communication.

## SMOKE AND ITS HAZARDS

Smoke is defined as "airborne solid and liquid particulates in gases evolved when a material undergoes pyrolysis or oxidation" (1). Of the many undesirable characteristics of smoke that have been recognized (2) its toxicity and opacity constitute the main problem. Smoke is a lachrymatory irritant and is accompanied by toxic combustion products which can lead to incapacitation, impaired motor function, adverse physiological disorder or even death.

Smoke particles reduce light transmittance across the smoke filled path causing a reduction in visibility thereby delaying the escape of occupants from the site of fire. This also enhances the effect of toxic gases, oxygen depletion and thermal radiations.

## QUANTIFICATION OF SMOKE

Smoke density is measured by various test methods based on gravimetric and optical techniques (3). Propensity of a material to produce smoke is measured experimently under controlled conditions in a smoke density chamber (4-7) where the smoke is collected in a chamber of volume 0.5 $M^3$ and the resulting observations recorded. The most commonly used standard test apparatus for evaluation of smoke generation characteristic of building materials is the NBS Smoke Density Chamber developed by the National Bureau of Standards, USA. ASTM E 662 (4) specifies the detailed method using the NBS smoke density chamber.

The apparatus consists of an enclosed chamber of volume 0.5$M^3$ (914 x 610 x 914 +3mm) in which a vertically oriented specimen (76.2 x 76.2 +0, -0.8 mm) of material is subjecteild to the test conditions. Two exposure modes are simulated : (a) radiative heating in absence of ignition and (b) an open flame combustion of the specimen in the presence of supporting radiation. The irradiance level of 2.5 $W/cm^2$ is provided by an electrical tubular furnace. A multi flamelet burner is used for open flame exposure and utilizes propane-air mixture for fuel. The smoke collected in the chamber is measured by a photo optical system. Smoke levels are expressed in terms of the specific optical

Density $D_s$ which is defined as :

$D_s = (V/AL) d$

$d = Log(100/T)$

T = Percentage light transmittance

V = volume of the chamber

A = area of the specimen, and

L = path length

V/AL for the NBS smoke chamber is 132

**MATERIALS**

Materials which are combustible in nature and produce smoke find many different applications in buildings. From fire safety point of view, it is desirable that these materials do not produce smoke in excessive quantities. It is imperative, therefore, that the materials, before they are recommended for use, are evaluated for their tendency to generate smoke.

Some of the building materials available in the market were used in the study. They included wood and wood based materials, laminates and plastics. Some fire retardant intumescent coatings (8) were also evaluated for their smoke generattion characteristic. The fire retardant ingredients used were of commercial grade and included the following :

| | |
|---|---|
| Antimony Oxide | 5-10 % |
| Borate salts | 4-7 % |
| VC/VA copolymer | 10-15 % |
| Phosphate salt | 21-30 % |
| Amides | 16-20 % |
| Polyols | 8-12 % |
| Thickening agents | 2-4 % |
| Pigment | 2-4 % |
| Binder | 16-20 % |
| Solvent | 8-14% |

The coatings were prepared by mixing different ingredients of 325-400 mesh in different ratios with 2% solution of sodium salt of d-mannuronic acid and appropriate quantity of binder. A requisite amount of water was added in order to obtain brush consistency.

The coatings were applied by brush on combustible surfaces such as wood, ply wood, particle board and fibre insulation board at appropriate application rates to achieve effective fire retardancy (Table 1). Materials were rendered water repellent by applying a coat of VC/VA in ethyl acetate at the rate of 220 ml/M².

**EVALUATION PROCEDURE**

NBS smoke density chamber was used for smoke generation studies on the commercially available as well as coated materials.

Test specimens of dimension 76.2x 76.2 mm and thickness upto 25.4 mm are covered across the back, along the edge and over the front surface periphery with a single sheet of aluminium foil and exposed to the test conditions. All specimens are backed with a 12.7 mm asbestos millboard.

An electrically heated radiant source is used to provide an irradiance level of 2.5 W/cm² averaged over the central 38.1 mm diameter area of the vertically mounted specimen facing the radiant heater, for the non-flaming exposure conditions. Multiple flamelet burner is used in addition to the above mentioned irradiance level in the flaming mode.

During the test, as the smoke enters the vertical collimated light beam, the extent of light transmitted is measured. The percentage of light transmitted is used to calculate the specific optical density ($D_s$) at any given time. The maximum value of $D_s$ ie., the maximum specific optical density ($D_m$) is reported.

**RESULTS AND DISCUSSION**

The data generated by use of smoke density chamber are means for characterisation of smoke generation from a material with an accuracy far in excess of any applicable requirements. The test results can be used for comparative assessment of building materials and may be used as a guiding tool for selection of materials from their smoke generation point of view.

Results reported herein (Table 2) are on some of the typical building materials. These materials include . timber, wood based products, laminates, plastics foams, composites and alternate building materials. Wood and wood based products have been found to generate more smoke during non-flaming exposure as compared to the flaming exposure mode. The trend is just the reverse in case of most of the plastics materials. Though the wood wool board and the particle board are both wood based materials, the difference in their $D_m$ values seems to be due to the binder used. In case of wood wool an inorganic binder has been used while in case of the particle board the resin used is phenol formaldehyde-an organic binder.

Laminates have been found to generate smoke in the following range :

Flaming Exposure : $D_{mF}$ = 48 to 198

Non-Flaming Exposure : $D_{mF}$ = 34 to 67

depending on their thickness and surface finish etc.

Composites having plywood facings as skin and a core of polyurethane based foam were found to produce more smoke ($D_{mF}$ = 472) compared to the core alone ($D_{mF}$ = 136). The increase in $D_m$ is probably due to an additional smoke contributed by the plywood facing. This is also evident from the fact that more smoke was observed in case of non-flaming exposure as is the case with wood based materials. Red Mud Plastic (RMP) sheet even though based on PVC (about 75% PVC) and showing a typical behaviour of plastics was found to produce far less smoke as compared to PVC itself. This can be attributed to the red mud which is an inorganic additive used at about 25% w/w thereby reducing the net amount of polymer available as a fuel and hence acting as a smoke suppressant.

The use of fire retardant intumescent coatings on wood and wood based materials have been found to be effective in smoke suppression (Table 1). This is mainly because the coating swells up on heating and forms an effective insulation layer over the surface of the substrate, thereby protecting it against heat and hence lower levels of smoke are observed.

## CONCLUSION

A large number of materials have been studied for their smoke generation characteristic, using the NBS smoke density chamber, at the CBRI, Roorkee with a view to compile data on Indian materials which was not available hitherto, but is of great use to the architects, engineers, designers etc. Fire retardant coatings employed are found to be effective in reducing the smoke generation from wood and wood based materials to a considerable extent. Inorganic fillers used in plastics (Bauxite in RMP sheet) suppresses smoke mainly because they reduce the net amount of the polymer available for combustion and hence the smoke generation is reduced.

## REFERENCES


1. ASTM E 176-81 Standard Terminology Relating to Fire Standards, American Society for Testing and Materials, Philadelphia, 1981.
2. Gaskill J.R., J. Fire and [illegible] 4,2[illegible] (1973).
3. Jurgen Troitsch, International Plastics Flammability Handbook, Hanser Publisher, Munich 1987.
4. ASTM E 662-83 Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials, American Society for Testing and Materials, Philadelphia, 1983.
5. Gross D., Loftus J.J. and Robertson A.F., Method for Measuring smoke from Burning Materials, Symposium on Fire Test Methods: Restraints and Smoke, ASTM STP 422, American Society for Testing and Materials, Philadelphia, 1966, pp 166-204.
6. Rarig F.J and Bartosic A.J., Evaluation of XP 2 Smoke Density Chamber, ibid., pp 106-124.
7. ASTM D 2843-77 Standard Test Method for Density of Smoke from the Burning or Decomposition of Plastics, American

Society for Testing and Materials, Philadelphia, 1977.

8. Saxena N.K., Sharma Sunil K. and Gupta D.R., Fire Protection of Wood based products by Coatings, J. Indian Academy of Wood Science, Communicated.

**TABLE 1**

**SMOKE GENERATION CHARACTERISTICS OF FIRE RETARDANT INTUMESCENT COATINGS**

| Materials | Application rate of FR Coatings $M^2$ / 1t. | Max. Specific Optical * Density of Smoke $D_m$ |
|---|---|---|
| Deodar Wood | 0.0 | 338.40 |
| | 2.5 | 39.20 |
| Plywood | 0.0 | 176.70 |
| | 2.5 | 37.60 |
| Particle Board | 0.0 | 415.20 |
| | 2.5 | 40.50 |
| Fibre Insulation Board | 0.0 | 308.20 |
| | 1.8 | 38.80 |

* data pertains to Non Flaming Exposure only

**TABLE 2**

**SMOKE GENERATION CHARACTERISTICS OF BUILDING MATERIALS**

| **Materials** | **Thickness** | **Max. Specific** | **Optical Density, $D_m$** |
|---|---|---|---|
| | **mm** | **Non-Flaming** | **Flaming** |
| Kail Wood | 12 | 328.5 | 278.0 |
| Plywood | 3 | 176.7 | 74.2 |
| Particle Board | 12 | 415.2 | 261.5 |
| Wood Wool Board | 25 | 26.0 | 20.0 |
| Laminate (s) | 1.6 to 3 | 34.0 to 67.0 | 48.0 to 198.0 |
| Composites * | 25 | 472.0 | 450.0 |
| Core of composites * | 25 | 136.0 | 210.0 |
| GRP Sheet | 1 | 20.0 | 73.0 |
| PMMA Sheet | 3 | 75.0 | 191.0 |
| PVC Profile | 1 | 393.5 | 585.0 |
| Phenolic Rigid Foam | 25 | 5.0 | 7.5 |
| Polyisocyanurate Foam | 50 | 11.0 | 58.5 |
| RMP Sheet | 1.6 | 223.2 | 342.0 |

* Results relate to the same material