Smoke Release by Some Indian Woods and Wood Substitutes

Rakesh Kumar [1], *A. Aravind Kumar* [2] *and Bhawna* [3]

Abstract

This article presents the study of smoke release by some Indian woods and wood substitutes. These woods and wood substitutes are used in buildings as lining materials and furniture. The study will help to prepare fire retardant coating for interior lining materials, so the material will release nil/low smoke during fire after application of coating. Some tests were performed on Kail wood, Deodar wood, plywood, and fibre board to determine smoke release properties of these woods and boards. The SOD was determined using smoke density chamber as per ASTM E–662 which measures the amount of smoke released by a specimen in the burning (F–mode) or smoldering mode (NF mode). In smoldering mode, only radiation through a furnace of 2.5 W/cm^2 was applied to the specimen surface. In flaming mode, radiation and fire from a burner were given to the specimen surface. The sample which represents the material was tested when it starts to smolder and again when a flame source was applied on the surface of specimen. The smoke density was between 0 (no smoke generated) to 800 as per standard ASTM E–662. The above said woods were tested as per standard in two modes, that is, NF and F-modes. The SOD was calculated for the above said materials to measure the amount of smoke release by materials.

Keywords : **ASTM E–662, combustion, flaming, smoldering, smoke density, SOD, wood, wood substitute**

NOMENCLATURE

PMT	Photomultiplier tube	*GRG*	Glass Reinforced Gypsum
ASTM	American Society for Testing and Materials	*MDF*	Medium Density Fiberboard (MDF)
MDFB	Medium Density Fibre Board	*EPS*	Expanded Polystyrene Insulation
BMB	Bamboo Mat Board	*SOD*	Specific Optical Density
PPB	Pre-lamented Particle Board	*SD*	Smoke Density
MP	Marine Plywood	*NF Mode*	Non-Flaming Mode
RMP	Red Mud Plastic	*F Mode*	Flaming Mode

I. INTRODUCTION

Determination of smoke release by material is very essential in the context of fire. For protection from fire it is essential to make out the "reaction to fire" properties of materials used in buildings. Smoke released by materials during fire is one of the essential/vital properties to be measured. Dense smoke release by materials hampers the

Manuscript Received : September 10, 2021; Revised : October 6, 2021; Accepted : October 7, 2021. Date of Publication : November 5, 2021.

[1] R. Kumar, *Technical Officer* ; Email : solankirgdr@gmail.com ; ORCID iD : https://orcid.org/0000-0003-2214-3590
[2] A. A. Kumar, *Sr. Scientist* ; Email : aravindkumar@cbri.res.in ; ORCID iD : https://orcid.org/0000-0001-6321-2658
[3] Bhawna, *Technical Assistant*; Email : bhawna@cbri.res.in ; ORCID iD : https://orcid.org/0000-0002-5214-9478
[1,2,3] Fire Research Division, CSIR-Central Building Research Institute, Roorkee, Haridwar District, Uttarakhand -247 667, India.

DOI : https://doi.org/10.17010/ijce/2021/v4i2/166724

visibility of human beings during actual fire conditions, so it becomes difficult to breathe and escape from fire area. To escape, it is essential that one can view the escape route clearly. As per standard, the escape time from fire for human beings is 4 minutes. Ansari, Singh, Kumar, and Tyagi [1] determined the CO and CO_2 released by wood and wood substitutes (Kail wood, Deodar wood, RMP Sheet, MDF/EPS/MDF Composite Panel, GRG Board Ferro– cement board) using smoke chamber as per ASTM E–662. Rajulu, Nandanwar, and Kiran [2] determined SD of wood based panel which includes plywood, MDF, BMB, PPB, and MP grade using smoke chamber as per ASTM D 2843–70. Strykowski [3] attempted to answer the question whether in the conditions of technique and technology advancement in a more and more global world, wood is a substitute for many raw materials or a raw material substituted for. The latter can be to some extent indicated by wood being pushed out of the markets that can be observed in the EU and other countries. In the research on th effect of fire retardant painting product on SOD of burning natural wood specimens [4], Olimat, Awad, and Al-Ghathian determined the effect of SOD of burning natural wood samples on fire retardant painted on products. In model development of imaginative wood substitutes for the economical development of the Thai wood replacement industry [5], the author considered a model for imaginative wood substitutes for the defendable growth of the Thai wood substitution industry. In spectral study of the SOD in NF mode [6], the author considered only two materials, that is, wood and PMMA (Polymethyl Metacrylate), and measured the transmittance and SOD in NF condition using ASTM E–662. The tests for the SD for the above said wood and wood substitute were performed using the ASTM E–662 [7].

II. OBJECTIVE OF THE STUDY

The main purpose of the study was to determine the smoke released by some Indian woods by calculating the specific optical density, so the comparison can be made regarding the smoke production by materials during fire conditions.

The specific purpose was to:

(i) To prepare a fire retardant coating for wood and wood substitutes.

(ii) To prepare a coating which will prevent the materials from releasing dense smoke and flame during actual fire conditions.

(iii) To prepare coating which itself releases less or no toxic smoke.

III. APPARATUS FOR SMOKE DENSITY TEST

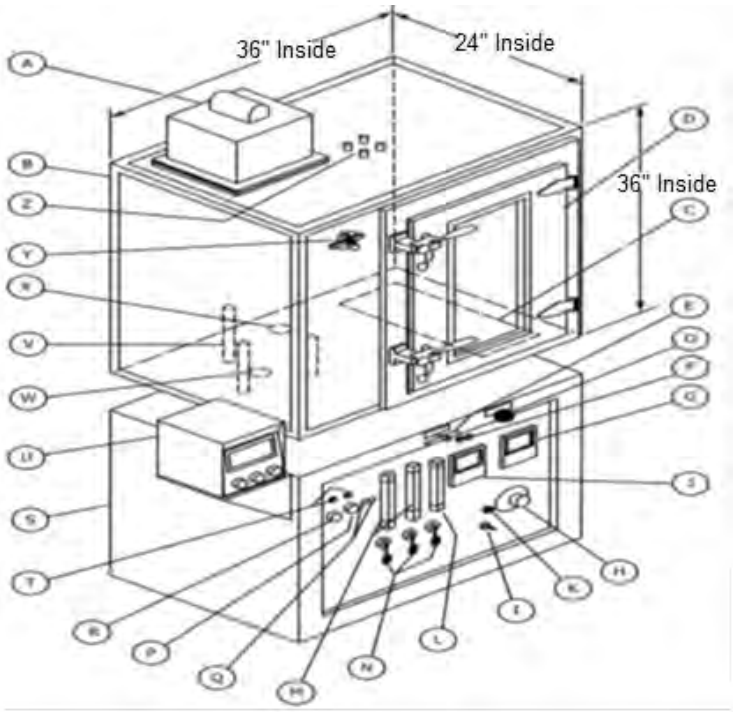
The apparatus for Smoke Density test as per internationally accepted standard ASTM E–662 was used to determine the smoke release by some Indian wood and wood substitutes (Fig. 1).

IV. METHODOLOGY

This test chamber consists of an electrical furnace as a radiant heat source fitted into an insulated pottery cylindrical pipe to give radiation upto 2.5 W/cm^2. The 75 x 75 mm^2 sample was placed into a holder which uncovers the specimen's area upto 65.1 x 65.1 mm^2. The heat radiation was given to specimen through heating furnace, that is, the NF mode of the test. For the flaming mode, a six–tube small burner was used to give flame on the specimen's surface at across the lower edge. The flame was given along with the specified radiation level from the furnace, added upto the flaming burning contact. The test samples were exposed to the F and NF modes within a sealed chamber. A PMT was used to measure the light. A light bulb (source of incandescent light) was used for vertical light path of one meter. This path was used to calculate the varied light communication as smoke collected in the chamber. The light transmittance capacities were used to work out the SOD of the smoke released by materials at the time phase to arrive at the greatest value. The Beer–Lambert law was used to calculate SOD using percentage transmittance of light.

Beer–Lambert law : $SOD = G \log_{10} 100/T$
T = % transmittance as read from the light sensor,
G = V/AL = 132 (constant),

Where,
V = chamber's volume (m^3),
A = exposed region of specimen (m^2),
L = light path's length through the smoke (m).



A - PMT housing
B - Main Chamber
C - Blow-out plate
D - Door and window
E - Control for Exhaust vent
F - Radiometer production port
G - Temperature meter
H - Transformer
I - On/Off switch for Furnace switch
J - Voltmeter
K - Holder for Fuse
L - Flow meter for Radiometer air
M - Flow meter for Gas and air
N - Shutoff valves
O - Mover knob (Sample)
P - Switch (Light source)
Q - Voltage jacks for Light bulb
R - Line switch
S - Cabinet base
T - Lamps
U - PMT
V - Rods for optical system
W - Window for optical system
X - Smoke release vent
Y - Input vent
Z - Access ports

Fig. 1. Apparatus for Smoke Density Test

V. SOD OF SMOKE

The SD evaluation of material was determined in order to find out whether it will or will not add directly to smoke production. Measurement was made of the decreasing of a light ray by smoke collected within a sealed chamber because of NF (pyrolytic) decay and burning combustion. The test specimens of Kail wood and Deodar wood, plywood, and fiber board were The (2) (ii) exposed to F and NF modes within a sealed chamber. The dimension of specimens representing the material were as follows: 75mm (L) x 75mm (W), and of normal thickness not exceeding 50mm. The following observations were made:

(i) The measurement of percent transmittance from the beginning at an interval of 0.5 minutes was the duration of the evaluation.

(ii) The mass before and after the experiments for each specimen and relating to the behaviour of the specimen during the experiment was recorded.

(iii) The occurrence of any flame on the surface of specimen and duration of such flame were recorded.

(iv) Observations were made for sagging, shrinkage, melting, collapse etc.

VI. RESULT AND DISCUSSION

The results obtained during experimental investigation for release of smoke from wood and wood substitutes are summarized in the following table:

The SOD in woods (Table I) and wood substitutes (Table II) was found as follows :

TABLE I.
SOD IN WOOD

Name of wood	Flaming mode	Non-Flaming Mode
1. Kail Wood	228	329
2. Deodar Wood	248	319

TABLE II.
SOD IN WOOD SUBSTITUTES

Name of wood	Flaming mode	Non–Flaming Mode
1. Ply Wood	080	181
2. Fibre Board	218	318

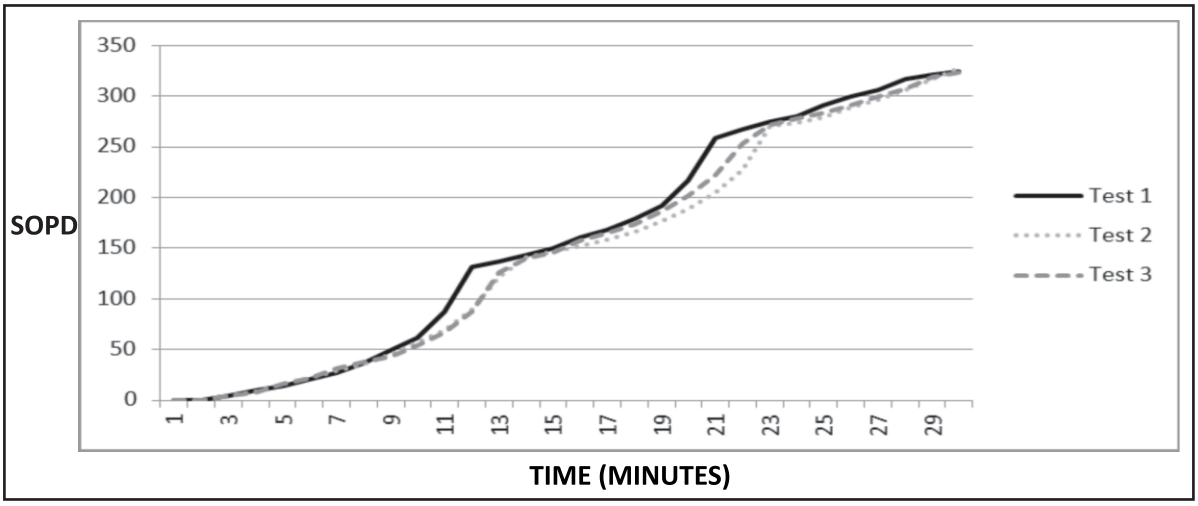


Fig. 2. Fiber Board (NF Mode)

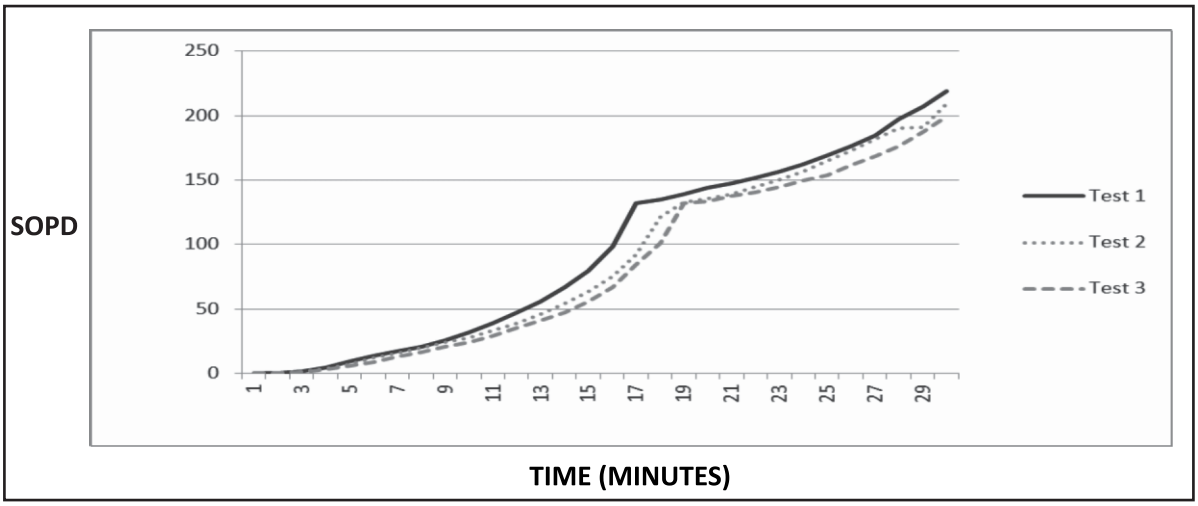


Fig. 3. Fiber Board (Flaming Mode)

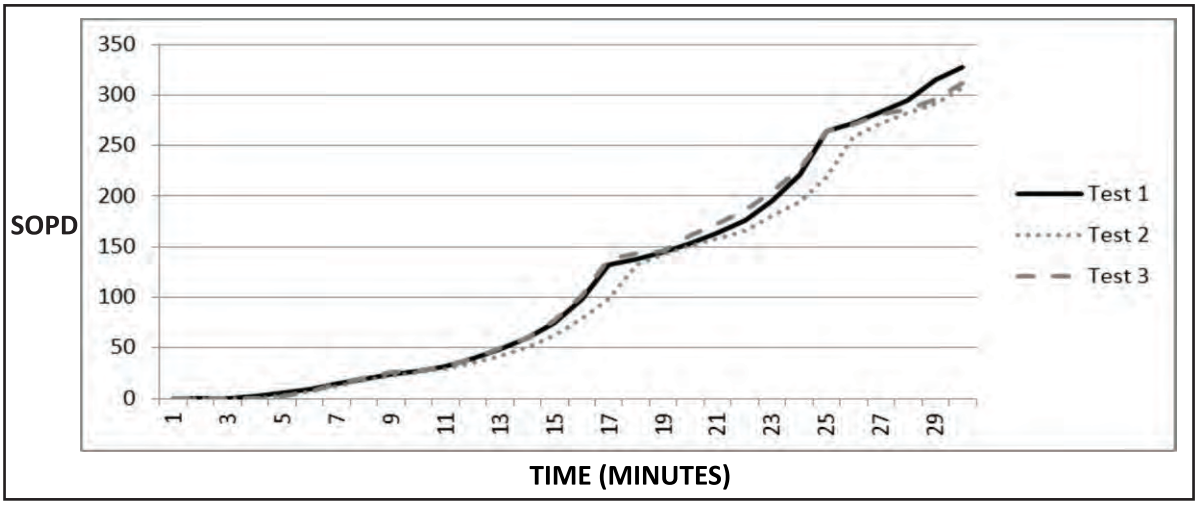


Fig. 4. Kail Wood (NF Mode)

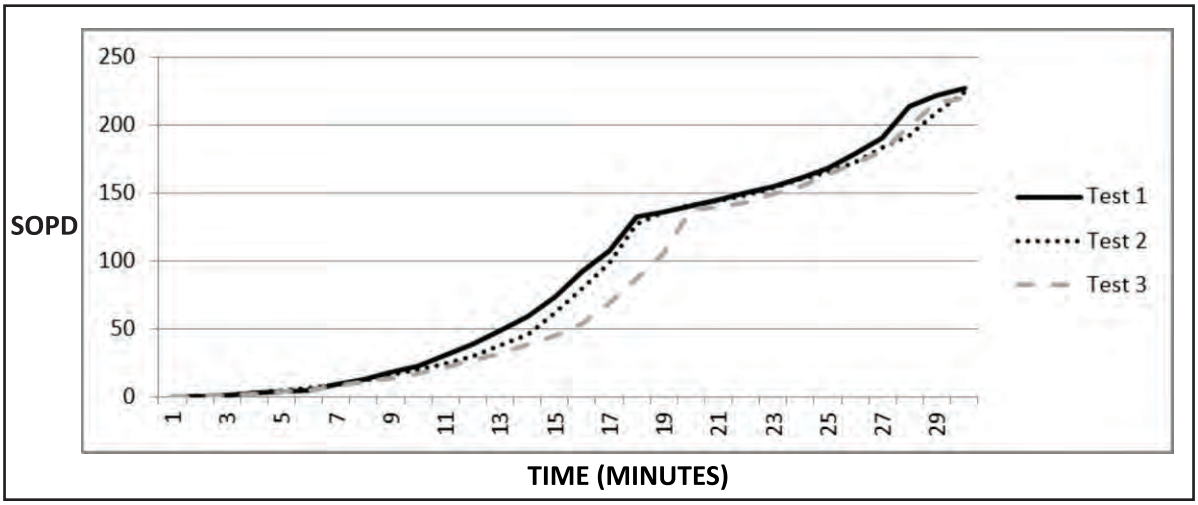


Fig. 5. Kail Wood (Flaming Mode)

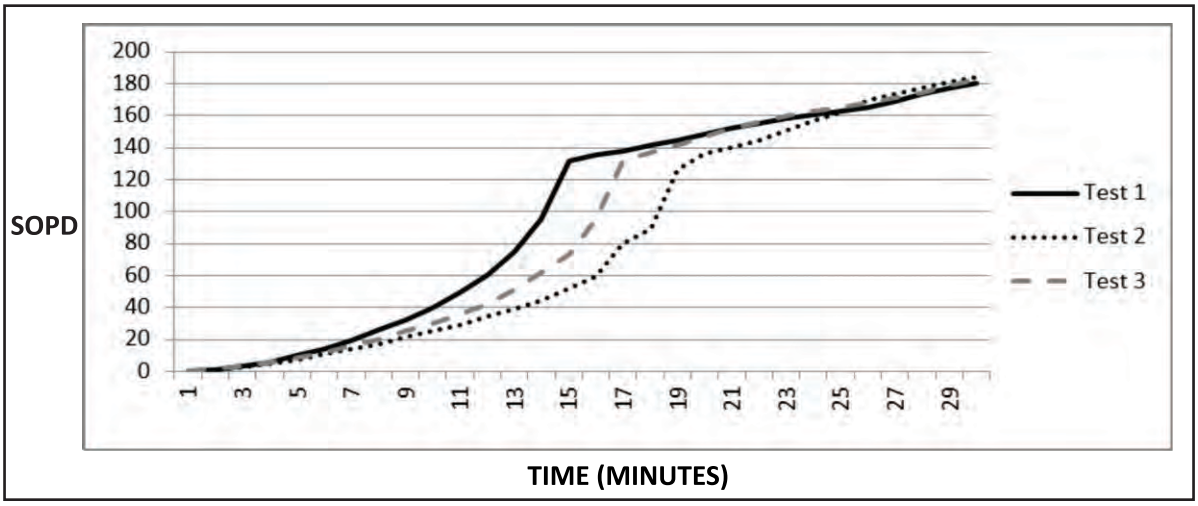


Fig. 6. Plywood (NF Mode)

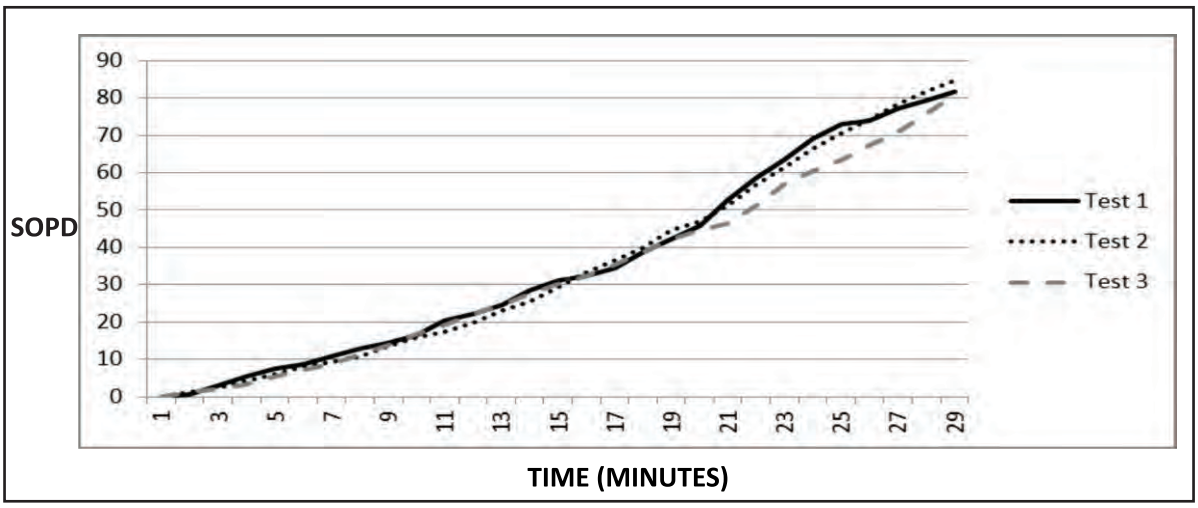


Fig. 7. Plywood (Flaming Mode)

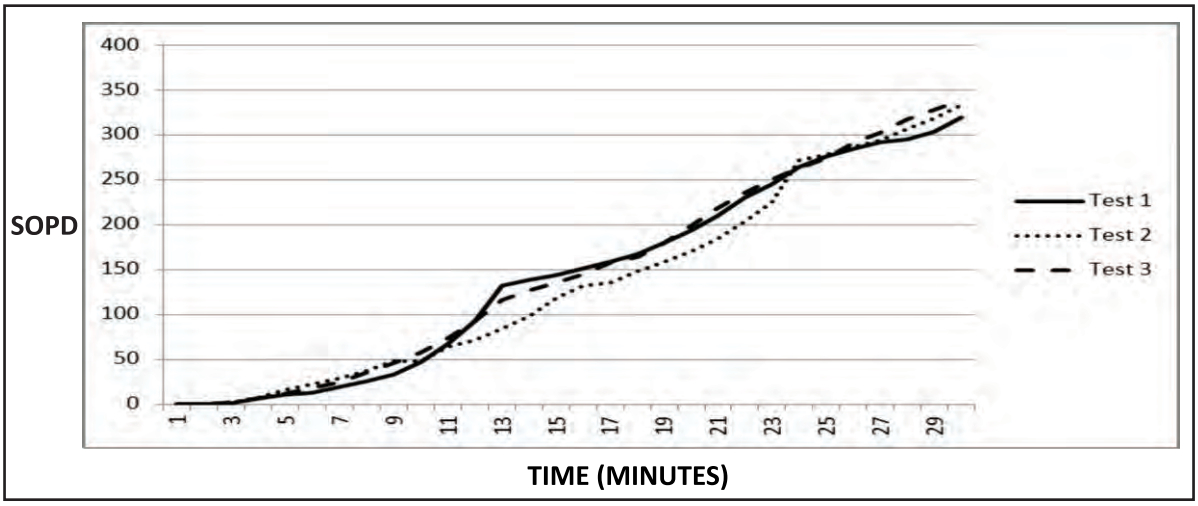


Fig. 8. Deodar Wood (NF Mode)

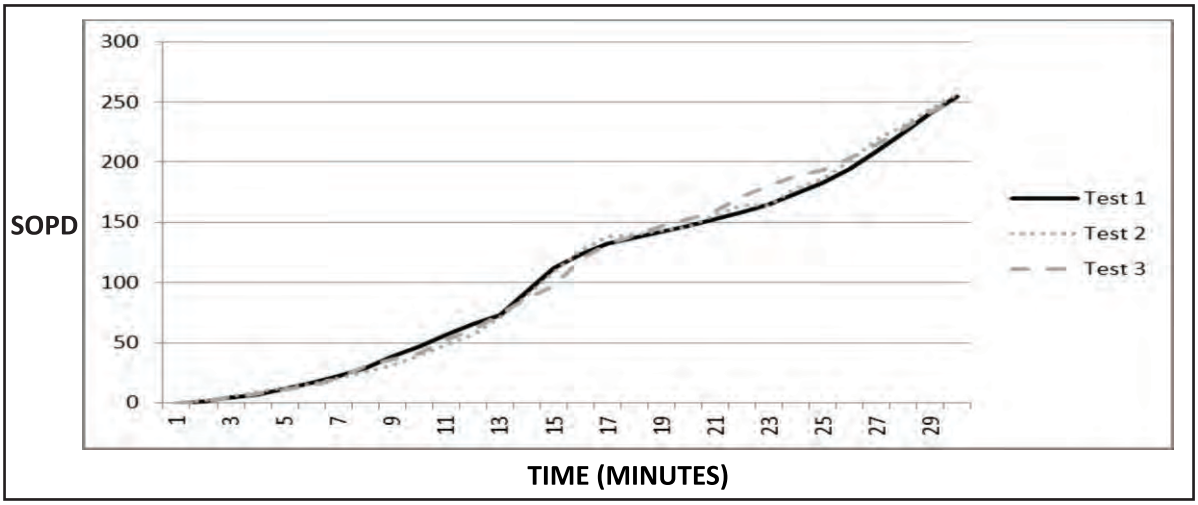


Fig. 9. Deodar Wood (Flaming Mode)

The smoke release by wood substitute was less than the smoke release by wood in both modes, that is, F and NF modes. The best among these woods and wood substitutes in terms of smoke release was plywood which released less smoke than other woods. Smoke generated by Kail wood was much more than other wood and wood substitutes.

VII. CONCLUSION

The studies were carried out on smoke generation/release by some Indian woods and wood substitutes. These woods are utilized in building interiors, vital for all times safety purpose. As less smoke releasing products are safe for all time safety, therefore, plywood, a substitute of wood is often utilized in buildings. Fiber board also released less smoke than other woods and is safe as compared to wood for making a correct choice. Using data generated in these studies may serve as a useful guide in the selection of fireside safe materials/products.

AUTHORS' CONTRIBUTION

Rakesh Kumar, Dr. A.Aravind, Miss. Bhawna conceived the idea to study the smoke released by some Indian woods and wood substitutes. The work was carried out jointly by Rakesh Kumar, Dr.A.Aravind, Miss. Bhawna at "Reaction to fire" characteristics of building materials lab. of CSIR-CBRI Roorkee.

CONFLICT OF INTEREST

The authors certify that we have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter, or materials discussed in this manuscript.

FUNDING ACKNOWLEDGEMENT

The authors received no financial support for the research, authorship, and/or for the publication of this article.

REFERENCES

[1] Ansari A. A., M. P. Singh, R. Kumar, and N. S. Tyagi, "Hazared assessment of combustion products generated by wood and wood substitutes," *Fire Engineer,* vol. 36, no. 3, pp. 13-16, 2011. [Online]. Available; https://www.indianjournals.com/ijor.aspx?target=ijor:fe&volume=36&issue=3&article=003

[2] K. V. Rajulu, A. Nandanwar, and M. C. Kiran, "Evaluation of smoke density on combustion of wood based panel products," *Int. J. of Materials and Chemistry*, vol. 2, no. 5, pp. 225-228, 2012. [Online]. Available: https://doi.org/10.5923/j.ijmc.20120205.07

[3] W. Strykowski, "Wood-a substitute or a raw material substituted for," *Ann. of Warsaw University of Life Sciences- SGGW, Forestry and Wood Technol.*, no. 84, 2013, pp. 194-200.

[4] A. N. Olimat, A. S. Awad, and F. M. Al-Ghathian, "Effect of fire retardant painting product on smoke optical density of burning natural wood samples," *Int. J. of Energy and Power Eng.,* vol. 11, no. 9, pp. 1028-1037, 2017. [Online]. Available: https://doi.org/10.5281/zenodo.1340364

[5] T. Anuntaruttana and T. Roopsing, "Model development of innovative wood substitutes for the sustainable growth of the Thai wood substitution industry," *J. of Open Innovation: Technol., Market, and Complexity,* vol. 6, no. 1, pp. 1-12, 2020. [Online]. Available: https://doi.org/10.3390/joitmc6010017

[6] J. Tissot, M. Talbaut, J. Yon, A. Coppalle, and A. Bescond, "Spectral study of the smoke optical density in non-flaming condition," *Procedia Eng.*, vol. 62, pp. 821-828, 2013. [Online]. Available: https://doi.org/10.1016/j.proeng.2013.08.131

[7] *Standard test method for specific optical density of smoke generated by solid materials*, ASTM E662-19, 2008. [Online]. Available: https://www.astm.org/DATABASE.CART/HISTORICAL/E662-19.htm

About the Authors

Rakesh Kumar, AMIE is Technical Officer and fire researcher with the Department of Fire Research Engineering, CSIR-Central Building Research Institute, Uttrakhand. He is an Associate member of the institution of Engineers India (Kolkata). His expertise is in the areas of building engineering, machine design, material research, fire retardance, passive fire protection, and fire safety evaluation of buildings etc.

Aravind Kumar A. is working as Senior Scientist with Fire Research Engineering group of CSIR-Central Building Research Institute, Uttarakhand. He received his Ph.D. in Chemical Engineering from Andhra University, Visakhapatnam, India in 2011. His research is focused on modeling ignition, flame spread, and fire growth on solids, thermal degradation of solids, under-ventilated fire and development of performance-based codes for fire safety engineering and design of active fire protection system for buildings.

Bhawna holds Diploma in Mechanical Engineering and is working as Technical Assistant with Fire Research Engineering Group of CSIR-CBRI Roorkee, Uttrakhand. Her expertise is in the areas of building research, engineering drawings, material research, and fire resistance testing etc.