EVALUATION OF THE FIRE PERFORMANCE INDICES OF SOME BUILDING MATERIALS

S. A. Anjorin & J. D. Abiwo
Mechanical Engineering Department, Federal University of Technology Akure
P.M.B. 704, Akure, **NIGERIA**

ABSTRACT

Many buildings have been destroyed by fire and lots of properties lost to outbreak of fire in both residential and industrials buildings. These occurred because of the lack of knowledge of the fire propagation index of building materials used in constructing the buildings. Fire performance indices provide a measure in comparative terms of the contribution of a material to the build-up of heat and potential fire spread. In this study, fire performance indices of selected building materials, tested against a non-combustible material (9.5 mm plasterboard) were calculated. The fire performance indices (I) for Asbestos (Nigerite) ceiling Board, Asbestos (Imperial) Ceiling Board, Mansonia Hard Wood (*Mansonia altissima),* Omo Soft Wood *(Cordia platythyrsa*), Ikere clay Brick and Glass were 60.1, 58.3, 30.7, 42.1, 4.8 and 5.5 respectively. The application of ammonium phosphate coating to *Mansonia altissima* and *Cordia platythyrsa* reduced their fire performance indices by 48.5% and 52.0% respectively.

Keywords: Fire, performance, propagation, indices, noncombustible, coatings.

1.0 INTRODUCTION

Fire properties of building materials must be known so as to safeguard life and property. Fire properties are expressed as fire resistance levels, or in terms of early hazard or combustibility properties (Ellis, 2002). Airapetov (1986) defined building materials as "natural and man-made products used as structural elements and for furnishing purpose and special purpose types such as heat insulating, acoustical, scaling, water-proofing and roofing materials". They are combination of items such as sand, cement, wood, glass etc. to form interconnected components that serve definite predetermined functions.

With the development of fire testing, it has become apparent that many properties of materials can contribute significantly to the growth and progress of fire in its early stages in a building. Some of the relevant factors are ignitability, combustibility, surface spread of flame, smoke emission and rate of heat release of a material when subjected to fire. The fire propagation test has been developed in order that account can be taken in the grading of materials of the amount and the rate of heat evolved by such materials when subjected to a fire situation.

Combustion is a series of very rapid chemical reactions between a fuel and oxygen (usually from the air), releasing heat and light; whilst ignition is the process of initiating combustion or catching fire. Ignition is of two types. These are pilot ignition and spontaneous ignition.
Common building materials include stone, brick, cast iron, steel, glass, wood, aluminium, asbestos, ceramic tiles, twisted bar and plywood Materials are classified according to their purpose and field of application. Most common classifications, according to Folorunso (2006), were of both natural and man-made materials such as wood, natural stone, ceramics, metals, natural and synthetic polymers and composite.

Properties of building materials include: Physical Properties **(**Feldsman, 1975) Chemical Properties (Wahab *et al*, 1990) and Mechanical Properties (Olusanya, 1998). Physical properties are structural and mass characteristics such as density, porosity, void ratio etc. Chemical properties include acid resistance, alkali resistance and resistance to the simultaneous action of several corrosive agents whilst mechanical properties include various kinds of strength hardness, elasticity, brittleness, ductility, yield creep, and abrasion resistance. These properties were extensively discussed by Shields and Silcock (1987). Fire properties of building materials also include the fire resistance of the material, flammability, combustibility, ignitability, surface spread of flame, fire propagation and potential for smoke obscuration (Ellis, 2002; Onwuka, 1989). An extensive study was carried out on fire resistance properties of different materials: Timber (Dunn, 2002); Ceramic Tiles (Singer and Singer, 1971**);** Asbestos (Lin and Wade, 2002**)**; Plywood (Standard Australia 1997); Floor Material and Coverings (Abrams *et al*, 1985); Wall and Ceiling Linings (Abrams *et al*, 1985).

Studies were carried out on the ignitability of timber and wood based materials based on the classification resulting from the ignitability by the test laid down in BS476: Part 5: 1979 (Fisher and Rogowski (1976); Kokkala *et al*., (1993). Wiskstron (1990) observed that timber and wood-based materials produce more smoke under smouldering conditions than when flaming freely. Investigation was carried out on room-fire growth (McCaffrey *et.al.*, (1981); Phillip and Kasem, 1985).

A method for the classification of the surface spread of flame for materials was presented in BS476: Part 7: 1. This was based on the rate and extent of travel of a flame front across 885mm long test panel exposed at one end to a radiant heating panel and a pilot flame. Shield and Silcock, (1987), discussed the various methods of measuring fire properties of building materials as detailed in the British Standard 476: Non-combustibility test for materials, Methods of test for ignitability, Fire propagation test for materials, Surface spread of flame test for materials, Methods for assessing the heat emission of building materials and Test methods and criteria for the fire resistance of elements of building construction. The surface spread of flame test was devised to determine the burning characteristics of materials by considering the flame spread over their surfaces based on BS476: part 7:1971 (Shields and Silcock, 1987). Tewarson (1994) investigated the flammability parameters associated with the ignition, combustion and fire propagation processes and their usefulness for the development of fire resistant materials. Babrauskas and Krasny (1985) presented a systematic review of engineering data on the major aspects of upholstered furniture flammability.

2.0 METHODOLOGY

The test compares the time-temperature curve of a standard material (12.5 mm plasterboard) with that of the specimen under consideration based on BS 476: Part 6. The thicknesses of the specimens were measured by a vernier cliper before being cut into appropriate sizes The specimens tested were 3.5 mm Asbestos (Nigerite) ceiling board, 2.4 mm Asbestos (imperial) ceiling board, 36.3 mm Ikere clay bricks, 36.5 mm Omo hard wood, 23.5 mm Danta hard wood and 8.0 mm Glass. The materials were inserted into a Muffle furnace for 20 minutes and their temperatures were measured, using a Type S thermocouple, at prescribed intervals of 0.5min for 3 minutes, 1 minute interval from 4 to 10 minutes and at 2 minutes from 12 to 20 minutes. The materials were eventually removed from the furnace by means of tongs. A stop watch was used to take note of time intervals during the experiment. By calculating the difference between the temperature rise obtained with the specimen tested and that with non-combustible material (9.5 mm plasterboard) used as standard, related to time, the performance indices or fire propagation indices for the tested specimen were calculated using the following performance indices:

ISSN 2056-5860

$$i_1 = \sum_{1/2}^{3} \frac{\theta_s - \theta_c}{10t} \; for\ 1/2\ minute\ interval \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$$i_2 = \sum_{4}^{10} \frac{\theta_s - \theta_c}{10t} \; for\ 1\ minute\ interval \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

$$i_3 = \sum_{12}^{20} \frac{\theta_s - \theta_c}{10t} \; for\ 2\ minutes\ interval \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

$$I = \underbrace{\sum_{1/2}^{3} \frac{\theta_s - \theta_c}{10t}}_{i_1} + \underbrace{\sum_{4}^{10} \frac{\theta_s - \theta_c}{10t}}_{i_2} + \underbrace{\sum_{12}^{20} \frac{\theta_s - \theta_c}{10t}}_{i_3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

θ_s = Temperature rise recorded for material at time t.
θ_c = Temperature rise recorded for the non-combustible standard at time t.
t = time in minutes from the beginning of the test
I = the Index of performance
i_1,i_2,i_3 = sub-indices for the three time components

The fire propagation test, a performance index, I was calculated which provided a measure in comparative term of the contribution of the materials to the build-up of heat and potential fire spread.

3.0 RESULTS AND DISCUSSION

The test results are given as an index of performance (I), which is based on three sub-indices (i_1,i_2,i_3). Table 1 gives the Fire Performance Indices and Sub-Indices for the Different Materials Tested**.**

Table 1: Fire performance indices and sub-indices for the materials tested

Material	i_1	i_2	i_3	I
Asbestos (Nigerite) Ceiling Board	20.2	25.0	14.9	60.1
Asbestos (Imperial) Ceiling Board	18.2	27.2	12.9	58.3
Mansonia (*Mansonia altissima)* Hardwood	9.7	13.4	7.6	30.7
Omo *(Cordia platythyrsa*) Softwood	19.1	17.0	6.0	42.1
Ikere clay Brick	1.7	2.0	1.1	4.8
Glass	2.2	2.3	1.0	5.5
Omo *(Cordia platythyrsa*) Softwood coated with Ammonium phosphate	5.2	9.0	6.0	20.2
Mansonia (*Mansonia altissima)* Hardwood Coated with Ammonium phosphate	4.6	7.5	3.7	15.8

The Asbestos (Nigerite) ceiling board cracked before 20 minutes at 20°C, while the Asbestos (Imperial) ceiling board did not. The Hardwood specimens started producing smoke before the expiration of the 20minutes that was slated for the experiment. This was an indication that wood could catch fire easily. *Mansonia altissima* and *Cordia platythyrsa*, being combustible building materials were treated with a fire retardant, ammonium phosphate. This brought a reduction in fire performance indices of *Mansonia altissima* and *Cordia platythyrsa* by 48.5% and 52.0% respectively whilst the sub-indices (i_1) were reduced by 39.5% and 18.8% respectively for the two materials. The glass material tested during the experiment for the slated 20 minutes of the experiment had cracks but was not shattered during the experiment. Ikere clay brick did not produce smoke during the 20 minutes slated time for the experiment. This showed that the brick material was non-combustible. Although, it could contribute to heat build-up thus leading to fire growth in buildings.

4.0 CONCLUSION

The higher the value of the index (I) of a material the greater the material's contribution to fire growth. However the test results relate only to the behavior of the test specimens of the products under the particular condition of the test. Variation in the thickness of the materials could have effect on the index, I. The application of ammonium phosphate coating to *Mansonia altissima* and *Cordia platythyrsa* reduced their fire performance indices significantly. The order of fire resistance in a descending order are: Ikere clay Brick, Glass, *Mansonia altissima*, *Cordia platythyrsa*, Asbestos (Imperial) Ceiling Board and Asbestos (Nigerite) ceiling Board repectively, judging from the values of their fire performance indices. The fire resistance of Glass can be increased by reinforcing it with steel wires. Heavy sections of *Mansonia altissima* and *Cordia platythyrsa* would assist in boosting their resistance to fire.

ISSN 2056-5860

REFERENCES

Abraham, M.S., M.V. D'Souza, P. Higginson, W.S. Meters, J.G. Quintiere, W.J. Parker, R.F, Robins, J. A. White, J. (1985)**:** Review of ASTM Test for Surface Burning Characteristics of Building Material (E84)(An ASTM white paper). *Journal of Testing and Evaluation*, Vol. 13, No. 2. pp. 89 – 114.

Airapetov, D. (1986). Architectural materials Science. *Mir Publisher*, Moscow.

Babrauskas V. and Krasny J. F. (1985). Fire behaviour of upholstered furniture *Final Report National Bureau of Standards*, Washington DC.

Dunn, A. (2002). Performance of Timber in Buildings during Bush Fire. (DA NSW) *Australian Timber Design*. University Press, Cambridge.

Ellis, P. (2002). The Adequacy of the Australian Standards AS359 – 1999 Statement to the Select Committee of the NSW Parliament on Bush Fire. CSIRO, Forestry and Forest Products, Kingston Act.

Feldsman, E. B. (1975). Building Design for Maintenance. McGraw-Hill Book Company, N.Y.

Fisher, R.W. and Rogowski (1976). Result of Surface Spread of Flame Test on Building Products. *Building Research Establishment Report*. London.

Folorunso, C.O. (2006). Maintenance Reduction through Climatic Complaint Building Material Utilization. *Journal of Land use and Development Studies*, Vol. 2, No1.

Kokkala, M.A., Thomas, P. H. and Karisson B. (1993). Rate of Heat Release and Ignitability Indices for Surface Linings. *Fire and Materials*, Vol. 17 Pp. 209 – 216.

Lin, L. and Wade, C. (2002). Experimental fire test of Tests of Two-Way concrete stabs. *Fire Engineering Research Report* 02/12. University of Canterbury, Christchurch.

McCaffrey, B.J., Quintrene, J. G. and Harklevoad, M. F. (1981). Estimating Room Temperatures and the Likelihood of Flashover using Fire Test Data Correlations, *Fire Technology*, Vol. 17, Pp. 98 – 119.

Olusanya, S. O. (1998). Benefits of Effective Building Maintenance Habit. *Journal of Building Science and Management*, Lagos. Vol. X111 (2).2.

Onwuka, F.E. (1989). Maintenance in Building and Construction Works. *Journal of Nigeria Institute of Quantity Surveyor*, Lagos. Vol. 3(1): 3.

Philips, D. and Kasen, M.A. (1985). Upholstered Furniture Fires in Canada. *Consumer and Corporate Affairs Canada*, L10127 – F3284/85. Ottawa, p.29.

Shield, T .J. and Silcock G.W.H. (1987). Building and Fire. Longman Singapore Publisher (PTL) Ltd.

Singer, F. and Singer, S.S. (1971). Industrial Ceramics. Chapman and Hall Ltd London.

Standards Australia (SA) (1997). AS1530 Part 4. Methods for Fire Tests on Building Materials, Components and Structures – Fire Resistance Tests of Elements of Building Construction.

Tewarson, A. (1994). Flamability Parameters of Materials: Ignition, Combustion and Fire Propagation Journal of Fire Sciences 12 (4) 329 – 356 1994.

Wahab, K., Adedokun, L. A. and Onibokun, A. G. (1990): Urban Housing in Nigeria. *Nigerian Institute of Social and Economic Research* (NISER), Ibadan.

Wickstron, U. (1990). The Future of European Testing. *Flame Retardants Conference*, Elsevier London.