FLAME SPREADING TEST IN HONG KONG AND NEW ALTERNATIVES

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ABSTRACT

The existing bench scale test BS 476: Part 7 for evaluating flame spread over materials used in Hong Kong is regarded as inadequate. A new assessing strategy on flame spread over construction and lining materials is recommended to be developed. BS 476: Part 7 together with other five standard flame spread tests are reviewed. The ISO 9705 full scale burning test is identified as a good choice. However, such test requires much resources and time. Alternatives like the Reduced Model Box (RMB) test and the Single Burning Item (SBI) test might be considered by the Authority. Results from SBI and BS 476: Part 7 are compared.

Keywords: flame spreading tests, BS 476: Part 7, ISO 9705 full-scale burning test, Single Burning Item test

1. INTRODUCTION

Flame spread plays a significant role in fire growth. It controls the expanding rate of the burning area. Rapid flame spread over materials would cause high heat release rate and smoke production rate. This might give a short time to flashover and affect the available safe egress time for occupants.

As reviewed [1], specifications of flame spread over materials in the local prescriptive fire codes issued by the Fire Services Department [2] and the Buildings Department [3-5] are inadequate. There are only detailed requirements on the fire resistance period of compartmentation constructions. Restrictions on flame spread over materials are not clearly described. Only the old bench-scale test, BS 476: Part 7 [6] on the surface spread of flame was specified in the Fire Services Installation (FSI) code [2]. This test was designed basically for assessing building materials, but not for building assemblies. Specifying a new testing strategy should be considered especially when developing the performance-based fire codes and to cope with the use of new building materials. BS 476: Part 7 and other five standard tests [6-12] on flame spread were reviewed [1,13]. The ISO 9705 full-scale burning test [10] was recommended to the local government [14]. New intermediate scale tests such as the Reduced Model Box (RMB) test [11] and the Single Burning Item (SBI) test [12] are possible alternatives worthwhile to be considered.

2. THE LOCAL STANDARD TEST – BS 476: PART 7

In the local fire codes [2-5], BS 476: Part 7 is the only test specified by the Fire Services Department on flame spread over materials. This test was introduced by the British Standards Institution in 1945. The development of this test was initiated by some disastrous fires caused by rapid flame spread along wall linings. It was designed to simulate a corridor situation with a fire at one end [15]. A vertically oriented specimen of length 885 mm and height 270 mm (0.24 m^2) is mounted at right angle to a 900 mm by 900 mm radiation panel. The external radiant heat flux is set at a steep gradient from 32.5 kWm^{-2} to 5 kWm^{-2} across the specimen surface. This might cause more rapid flame spread over the part of the specimen close to the radiant panel and slower spread over the surface away from it. Materials are evaluated for 10 minutes and are classified based on the extent of flame spread as shown in Table 1. In the FSI code, it is specified that all linings used for acoustic and thermal insulation or decoration purposes in ductings, concealed locations and protected means of escape in basements, commercial buildings and domestic buildings, etc. shall be of Class 1 or 2; or the materials shall be brought up to that standard by applying an approved fire retardant product. Similar specifications on combustibles used as false ceilings, partitions and wall furnishings are also included in the Karaoke Establishments Ordinance [16] and the requirements for application of license for registered premises and karaoke issued by the Licensing Authority, Home Affairs Department [17] and Food and Environmental Hygiene Department [18].

The scale of this test is too small in relative to the full-scale installation. It is difficult to use this test to assess full-scale effects such as structural performance and thermostructural failures of materials in real fires. The maximum thickness of specimens is 50 mm. This gives some constraints on the testing of sandwich panels and composite materials. As surveyed [19], sandwich panels composed of two chipboard panels and insulating materials are commonly used for internal partitioning in the local industry. Those panels should be tested in the full assembly as the heat transfer might be very different from that for individual components. However, the limited thickness of the testing apparatus might not allow that. Even when the assembly can be fitted in the specimen holder, ignition of the exposed insulating materials in cutting edges of the panels would affect the overall flame spread results.

The classification system only provides an arbitrary comparison between materials. No physical or chemical properties of the materials are determined. The results can hardly be taken for further uses like mathematical modelling. A new testing strategy should be proposed.

3. REVIEW ON FLAME SPREAD TESTS

Standard tests including ASTM E1321 [7], ASTM E84 [8], NFPA 255 [9], ISO 9705 [10], RMB [11] and EN 13823 (SBI) [12] on flame spread were reviewed with BS476: Part 7. No significant correlations between testing results was found [1]. Materials passing one test do not necessarily fulfill the requirements in the others.

- ASTM E1321

ASTM E1321 is also referred to as the Lateral Ignition and Flame Spread Test or LIFT. This test is focused on the fire spread over wall materials. Materials are tested under normal oxygen conditions in lateral flame spread under an opposed flow. It is a bench scale test with a specimen of length 800 mm and height 155 mm (0.12 m^2) subjected to an external heat flux from a radiant panel. The radiant heat flux shall be set based on the minimum heat flux for ignition to be determined in the ignition test for individual materials. The results from this test include the minimum temperature and heat flux for ignition and flame spread and other flame spread parameters. Those data are useful for mathematical modelling and simulation for full-scale test results.

- ASTM E84/ NFPA 255

ASTM E84/ NFPA 255 is a relative large scale test. This test is specified in the US Building Codes [20-22] and the Life Safety Code [23]. It was designed to simulate the growth stage of a fire when interior finishes are ignited and consumed. Materials are tested in the ceiling position of a large rectangular tunnel-shaped fire chamber of width 451 mm, depth 305 mm and length 7620 mm. The maximum specimen size is 7320 mm long, 514 mm wide (3.34 m^2) and 100 mm thick. Two gas burners located at the fire end of the tunnel provide a large flame coverage over the specimen. Materials are assessed for 10 minutes. The flame spread distances with time are recorded for determining the Flame Spread Index for classification of materials. This provides a relative ranking and comparison between materials.

- ISO 9705

ISO 9705 is a full scale burning test. The contribution of a surface product to fire growth is evaluated with a specific ignition source. Materials are lined up, according to their actual installation methods, on the ceiling and three walls of a room of length 3600 mm, width 2400 mm and height 2400 mm. The maximum testing size is 31.68 m^2. A door of width 800 mm and 2000 mm high is opened. A gas burner of 170 mm by 170 mm is located at the rear wall corner to provide a heat output of 100 kW (comparable to a basket fire) for 10 minutes. If no flashover is reached, the heat output shall be stepped up to 300 kW (comparable to a small upholstered furniture) for a further 10 minutes. The test should be terminated at flashover for safety reasons. Smoke, combustion products and gases coming out from the door are collected by a hood and extracted through an exhaust

Table 1: Classification of flame spread under BS 476: Part 7 [6]

Class	Spread of flame / mm			
	At 1.5 min.		Final	
	Limit	Limit for one specimen in sample	Limit	Limit for one specimen in sample
Class 1	165	165 + 25	165	165 + 25
Class 2	215	215 + 25	455	455 + 45
Class 3	265	265 + 25	710	710 + 75
Class 4	Exceeding the limits for Class 3			

duct to a duct section for further data analysis. Major testing results include heat release rate which indicates the fire size, time to flashover, smoke production rate and gases concentrations. No classification system was specified in the standard and there have been proposed systems in the literature [e.g. 24-26]. This test is adopted in the US High Speed Craft Code [27] and was proposed as one of the fire tests to be considered for assessing materials in Australia [28]. ISO 9705 was recommended to the local government [14]. However, there are concerns to specify this test as the regulatory tool. Much resources including cost, time, equipment and technical support are required for this test. This might not be suitable for product development, quality control and on selection of materials. Large production of smoke, soot and possible toxic gases might create environmental problems. Installation of smoke treatment plant and developing a facility in a remote area might be possible solutions but that might increase the cost and transportation time.

- RMB

Intermediate tests were developed. Those are possible alternatives to ISO 9705. Examples include RMB and SBI. RMB was established in early 1980's as a one-third scaled model of ISO 9705 to reduce the total testing cost and for collection of postflashover data. Materials are lined on the walls and ceiling of a small room of length 1680 mm, width 840 mm and height 840 mm, with a doorway of width 300 mm and height 1680 mm. The maximum specimen size is 4.94 m^2. A wood crib, later proposed to be replaced by a 170 mm by 170 mm 40 kW gas burner [29], is located at the rear wall as ignition source. A hood is mounted outside the doorway for collection of combustion products. Materials are evaluated for 15 minutes. Measurements are similar to ISO 9705. This test was specified in the Japanese Regulation [11] and the classifying parameters used in Japan include the total heat release and peak heat release rate.

- SBI

SBI simulates a fire originating from a single burning item in the corner of a room and growing within that room to flashover. This scenario was taken by various fire regulators as representing the major fire hazard [30]. Materials are mounted according to end-use conditions on two specimen holders, 1000 mm wide by 1500 mm high and 500 mm wide by 1500 mm high (total 2.25 m^2), forming a corner configuration. A triangular 30 kW gas burner is located at the corner. This setup is located in a room of length 3000 mm, width 3000 mm and height 2400 mm to prevent air draft around the specimen and escape of effluents. The normal testing period is 20 minutes. Air is supplied throughout the test at the bottom of the room and combustion products are extracted through a hood and exhaust duct at the top of the room for further analysis of the oxygen consumption, heat release rate, smoke production rate and gases concentrations. Materials are classified into Classes A2, B, C and D based on the total heat release in the first 600 s of exposure period, THR_{600s} two indices derived from the heat release rate, i.e. FIGRA index, and smoke production rate, i.e. SMOGRA index, the extent of lateral flame spread and falling debris and particles. Classes A2 and B are materials with practically no flame spread and THR_{600s} less than 7.5 MJ. Class C are materials with very limited flame spread, limited heat release rate and THR_{600s} less than 15 MJ. Class D materials are with limited flame spread, heat release rate and THR_{600s} higher than 15 MJ. SBI is one of the harmonized tests approved by the European Committee for Standardization (CEN) and adopted by the CEN members.

The UK Building Regulations [31] will soon be revised to specify this test to replace the existing BS 476: Part 7 on testing of flame spread. An attempt was made [32] to compare the results from the two tests. Tests were carried out on wood, paint, wallboards, wallcoverings, cellular plastics and plastics to represent a wide range of common building materials. The comparison of the classifications from the two tests is shown in Table 2. The SBI results included the Euroclasses defined from the heat release rate, extent of lateral flame spread, smoke production and falling of flaming droplets. The BS Classes were given based on the flame spread distance only and no measurements on smoke and flaming particles are included. A poor correlation was obtained. 47 out of 52 (90%) materials were classified as Class 1 in the BS standard. Those included materials of Class A2, B, C and D in SBI. The correlation is better for single elements and materials with low flame spread like mineral wool, paint and wallboards. Materials are classified as low hazard in both tests. However, in testing of assemblies, a large difference is shown. For example, gravure printed contract grade paper backed vinyl wallcovering was classified as Class D in SBI, considered as high hazard, but Class 1 – material with little flame spread in BS 476: Part 7. This shows that materials passing BS 476: Part 7 might have higher flame spread rate in larger scale tests and in real fires. SBI is a better test to reflect the flame spread behaviours of assemblies and in distinguishing materials with different treatments. When compared with the SBI, BS 476: Part 7 tends to under-estimate the flame spreading rate.

Table 2: Comparison of SBI and BS 476: Part 7 results [32]

Product description	Class		Product description	Class	
	SBI	BS476: Part 7		SBI	BS476: Part 7
Wood			*Wallcoverings*		
FR MDF	B	1	Gravure printed simplex wallpaper	B	1
Birch plywood B/BB, WBP Grade, FR0	B	1	Gravure printed vinyl wallpaper	B	1
Birch plywood B/BB, WBP Grade, FR1	B	1	Screen printed foamed PVC on peelable Backing paper	B	1
European redwood TGV Boarding, FR0	B	1			
European redwood TGV Boarding, FR1	B	1	Fabric backed vinyl wallcovering	B	1
FR MDF	C	1	Duplex embossed wallcovering	B	1
FR MDF	C	1	Gravure printed contract grade paper backed vinyl wallcovering	D	1
FR MDF	C	1			
Birch plywood B/BB, WBP Grade, FR2	C	3	*Cellular plastics*		
European redwood TGV Boarding, FR2	C	3	Flexible melamine foam	B	1
Wallboards			0.55 mm thick steel faced phenolic foam (cold store panel)	B	1
Ordinary gypsum wallboard	A2	1			
Fire resistant gypsum wallboard	A2	1	0.4 mm steel faced composite panel with PIR core	B	1
Sound resistant gypsum wallboard	A2	1			
Moisture resistant gypsum wallboard	A2	1	0.4 mm steel faced PUR foam	B	1
Calcium silicate board	A2	1	9 mm plasterboard faced XPS	B	1
Cememt particle board	A2	1	Unfaced phenolic foam	B	2
Wallboard type 5 (Extra durability)	B	1	25 micron Al foil/Gf tissue faced phenolic foam	C	1
Mineral wool			Unfaced PIR block foam	C	1
High density unfaced glass wool slab	A2	1	PIR foam with 38 micron Al foil facing	D	1
Low density unfaced glass wool slab	A2	1	*Plastics*		
Aluminium foil faced medium density glasswool slab	A2	1	FR high pressure decorative laminate faced composite panel	B	1
High density mineral wool with glass reinforced aluminium foil facing	A2	1	FR high pressure decorative laminate	B	1
			Standard polycarbonate multiwall sheet	B	1
High density mineral wool with glass tissue facing	A2	1	Glass re-inforced plastic	B	1
			PVC waste pipe	B	1
High density mineral wool with two coat decorative render	A2	1	Co-extruded cellular PVC-U cladding system	C	1
			Co-extruded cellular PVC-U cladding system	C	2
Paint					
Mineral based passive barrier (Encapsulent)	A2	1			
Silicate based mineral paint (for Masonry)	A2	1			
Anti Graffiti system	B	1			
Intumescent basecoat + Acrylic eggshell	B	1			
20% water thinned acrylic eggshell + Acrylic eggshell	B	1			
Halogen free fire retardant surface coating	B	1			

4. CONCLUSION

The local government still sticks to the old prescriptive bench scale test BS 476: Part 7 on testing of flame spread over materials. Those specifications should be updated. Standard tests of different scales including ASTM E1321, ASTM E84, NFPA 255, ISO 9705, RMB and SBI were reviewed. The testing scenarios and results are distinct. The ISO 9705 is considered as a suitable testing method. However, it requires much resources and is relatively time consuming to carry out. Intermediate scale tests like RMB and SBI can be possible alternatives to ISO 9705. Those smaller scale tests allow testing of materials in their end-use conditions and similar measurements to ISO 9705, including heat release rate, can be made. SBI will be specified as the national scheme in the UK to replace BS 476: Part 7 to assess flame spreading properties of materials. Testing results of SBI and BS 476: Part 7 were compared and the correlation was found to be poor. SBI is more suitable in testing of assemblies and to distinguish materials with different treatments. This is a good alternative to ISO 9705 to be considered by the local Authority.

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