FIRE RATING PROCEDURE IN JAPAN

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Abstract
Background of "Fire Rating" for the building materials and construction are described with some linked big fires. The concept of the fire rating is almost the same as ones in foreign countries and also the testing procedures are almost the same. Number of big fires occurred have decreased drastically after the consensus of importance and demands for fire rated building materials have been recognized widely in Japan. The testing procedure on the fire rating for fire resisted building structure played also important roles in the establish of fire safety buildings.

Key Words: fire rating, building material, JIS A1304

1. History of Big Fires and Background of Rating in Japan

The Japanese traditional house is a wooden construction with a wide open space and openings which is suited to the high temperature and moist climate. This style of houses have been continued for more than 1,000 years. Consequently, frequent big fires took place in Edo city and produced big employments without establishing any effective plan for fire proof districts. Japan had the remarkable progress in an industrial fields until 1930s, although, the traditional house design and life style have been little changed.

The biggest city fire in these period was "Kanto Earthquake Disaster". This earthquake happened on September 1st., 1923, and the fires in urban area continued for 3 days. 407,992 houses burnt down only in Tokyo area and which was 64% of houses existed.

4 years back from the disaster, 1928, Urban Building Code was promulgated. However, noncombustible material of those days were limited to cement mortar, plaster, and clay. The history of noncombustible dry materials in Japan began with the importation of cement excelsior board, gypsum board, and asbestos cement sheet as the reconstruction material for this disaster. After the disaster, the government decided to make an article ordering the fire protection must be given to the special buildings (schools, auditorium, theater, inn, assembly houses, warehouse, hospital, etc). But the fire protection recommenced was rather simple as just assemble or put on an noncombustible materials on the main structure and exterior panels. These protection procedures were established on the experiments and not on theoretical research. A few research on the fire resistance tests had carried out in Tokyo University using a small furnace (about 2 square meters). In 1942, articles on the fire protection for district from fire development ordering fire resistant performance on the exterior panels, fire tight doors, and so on to buildings.

On March 10th, 1945, there was a big air raid in Tokyo area. This air raid marked tre–

mendous achievement unrivaled in world war history. 268,358 houses were burnt down, and 83,793 peoples were killed by one air raid. However, even after the world war II, we had several big city fires until 1960s.

Table 1 Some Big Fires in Japan

Period	Numbers of Big Fires	Burnt down Houses by Big Fires
1945 - 49	13	12,235
1950 - 54	6	13,284
1955 - 59	9	9,837
1960 - 64	5	2,592
1965 - 70	3	1,149
1971 - 91	1*	1,774

* occurred in 1976

Experience of these big fire distastes indicated the importance of fire resistance performance for building materials and protection methods. In 1950, the detailed classification on the fire resistance performance to building materials and testing methods were established.

2. Building Standard Law of Japan

2-1. Designation of fire protection districts

To carry out maintain secure fire resistance, Japanese Government provides the "Building Standards Law" saying,

> Article 1. The purpose of this Law of to safeguard the life, health, and property of people by providing minimum standards concerning the site, structure, equipment, and use of buildings, and thereby to contribute to the furtherance of the public welfare.

Based on this concept, urban area is divided into two fire protection districts, as shown in Table 2, by their fire risk, and building materials or construction systems which to be used in each district are regulated by this code.

Table 2 District Classification

District	shall be fire proof building	shall be quasi-fire proof building
Fire Protection	exceed 3 stories or 100 m^2 total floor area	Every other buildings, excluding single story and total floor area does not exceeds 50 m^2
Quasi-Fire Protection	exceed 4 stories or 1,500 m^2 total area	exceed 3 stories or 500 - 1,500m^2 total floor area external walls of wooden small buildings shall be fire preventive construction

In fire protection districts or quasi-fire protection district, roof of building which are not of fire proof construction shall be made of or covered with noncombustible materials.

2-2. Designation of Materials and Construction

2-2-(a). Classification of fire protection materials

Fire protection materials are classified into following 3 rates with some typical ones.

(1) Non Combustible Materials

Concrete, Brick, Roof tile,, Asbestos Slate, Steel, Aluminum, Mortar, and Other Building Materials of which performance having noncombustibility as speculated by Cabinet Order

(2) Quasi-Noncombustible Materials

Cement Excelsior Board, Gypsum Board, and Other Building Materials designated by Ministry of Construction

(3) Fire Retardant Material

Fire Retardant Plywood, Fire Retardant Fiber Board, Fire Retardant Plastic Board, and Other Building Materials designated by the Ministry of Construction

2-2-(b). Classification of Constructions and Buildings

(1) Fireproof Construction

Reinforced Concrete, Brick Construction etc. having fireproof property as specified by Cabinet Order. Principal parts of fireproof building should be built by fireproof construction.

To obtain approval of fireproof construction, materials should be proceed fire proofing test of JIS A1304 (Method of fire resistance test for structural parts of building). Heating temperature curve of this standard almost resembles the foreign standards such as ASTM E119, BS476, and DIN 4102. Duration of withstand the heating is shown in Table 3.

Table 3 Duration Required for the Construction Parts

Parts of buildings \ Stories of buildings				Uppermost story and second to fourth stories from the uppermost story	Fifth to fourteenth stories from the uppermost story	Fifteenth or more stories from the uppermost story
Walls	Partition walls			1 hour	2 hours	2 hours
Walls	External walls	Bearing walls		1 hour	2 hours	2 hours
Walls	External walls	Walls other than bearing walls	Portions liable to catch fire	1 hour	1 hour	1 hour
Walls	External walls	Walls other than bearing walls	Portions other than those liable to catch fire	30 minutes	30 minutes	30 minutes
Columns				1 hour	2 hours	3 hours
Floors				1 hour	2 hours	2 hours
Beams				1 hour	2 hours	3 hours
Roofs					30 minutes	

1) For those buildings whose above-roof parts are excluded from the determination of number of stories and basement levels under Article 2 paragraph 1 item (8), the uppermost story mentioned in this table shall be the story which is immediately below the above-roof parts concerned.

2) The above-roof parts mentioned in the preceding item shall comply with the same provisions of fire-resistance duration as those for the uppermost story specified in this table.

3) In counting the number of stories with respect to this table, all basement levels, notwithstanding the provisions of Article 2 paragraph 1 item (8), shall be included.

Specimen should not generates significant cracks, reinforcement or steel temperature should not over the temperatures as shown in Table 4 during heating time, and should be safe against to regulated impacting test after heating.

Table 4 Allowable Temperature (°C)

Construction	Temperature Application	Column, Beam	Floor bearing wall
Reinforced Concrete	maximum	500	550
Prestressed Concrete	maximum	400	450
Steel	maximum average	450 350	500 400

Common materials used for the fire protection of steel structure and their average thickness are shown in Table 5.

Table 5 Fire Protection Materials

Material	thickness for fire resistance(mm)		
	1 hour	2hours	3hours
Concrete	30	50	60
Sprayed Rockwool (Dry)	35	50	65
Sprayed Rockwool (Wet)	30	40	50
Sprayed Asbestos	25	40	55
Vermiculite Plaster	25	40	55
Vermiculite Mortar	25	40	55
Calcium silicate Bd.	25	40	55

The competition between companies, which deal with fire protection materials and protection methods, focus on the less thickness of protection materials and easy application. Recently, wet application method such as spraying and troweling are decreased because which needs more human power and generate more dust than board application. Accordingly, application methods using boards, panels, and sheets have been developing and which rush on the market with developments of new materials and new application methods. Typical details of fire protection method are shown in Figure 1 and 2.

Figure 3 shows prototype section of 2 hours fire protection party wall. Gypsum or calcium silicate boards are commonly used as finishing material for these wall. This is because of their high fire resistance, softness for sound absorption properties and low price.

In case of gypsum board, mainly non-combustible gypsum board are applied to 2 hours fire protection wall. It is not a plane gypsum board but contains few portion of glass fiber and vermiculite. Vermiculite expands by heating and compensate shrinkage of gypsum board caused by loose of hydrated water.

Since water hose spreading test is not adopted in Japan, gypsum board has a great privilege in the fire protection tests. Furthermore, recently bent down channel shape gypsum board were approved to use as stud of the wall so this wall has been free from restriction of steel stud temperature. Minimum gypsum board thickness for 2 hours fire protection is reduced to about 36 mm – 42 mm, today.

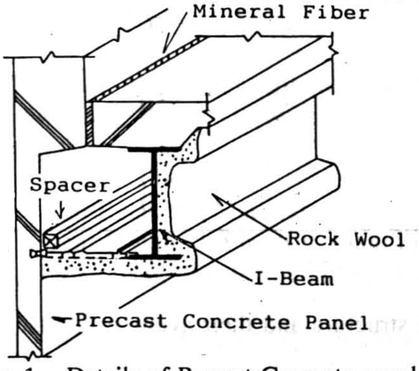

Figure 1 Details of Precast Concrete panel and Rock Wool Composite Fire Protection.

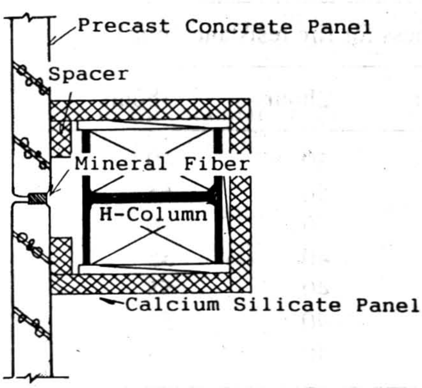

Figure 2 Details of Precast Concrete Panel and Calcium Silicate Panel Composite Fire Protection.

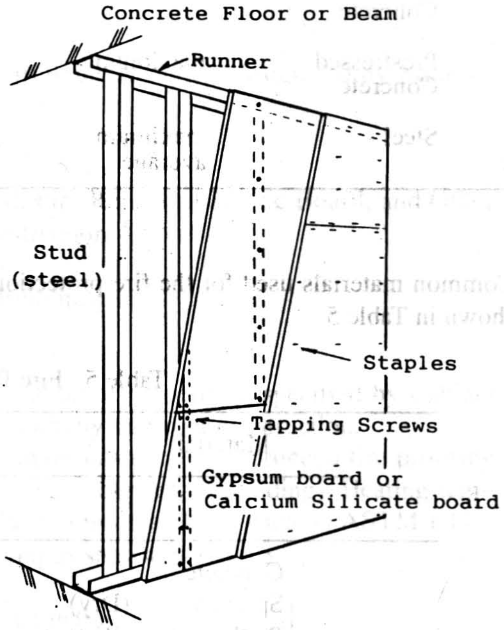

Figure 3 Details of Two–Ply Application of Party–Wall Fire–Protected.

Calcium silicate boards are produced by wet machine or pouring into form. Properties of this board are depend on specific gravity, quality of fiber and contents. Commonly, specific gravity of 0.9 – 1.2 boards, are used for fire protection wall.

A point should take prudence in this construction is joint between top of the wall and ceiling or beam. Fire test is applied to wall itself but not test to the joint. Especially, in a case of corrugated deck plate used to floor slab, should be fill up perfectly the gap between top of wall and corrugates. It is not only important for shut fire but also for sound insulation from the next door.

Building Standard law provides another regulation of sound insulation value for separation party wall of detached house. Fire will not occurs so frequently, but sound penetration is a daily problem of condominium resident. Party wall should provides sound insulation as well as fire safe, and the regulated sound transmission loss is not less than 40 dB at a sound frequency of 500 Hz. According to this regulation, thickness of surface material or weight of party wall will be determined by sound transmission rather than fire protection. Careless small holes without repairmen passed through the party wall will spoil every quantities of party wall.

2-2-(c). Fire Preventive Construction

This construction is used to quasi-fireproof building. Building Standard Law shows metal lath with mortar finish as an example.

Regulation for the thickness of mortar finish differs by material used to wall studs or floor joint, 1.5 cm or more for the made by noncombustible materials, and 2 cm or more for made by wood. Several definite Fire Preventive Construction are regulated in this law, and another construction shall be designated by Minister of Construction after the testing of preventive properties. Testing method for fire preventive construction is regulated by JIS A1302 and JIS A1301 class II heating curve.

2-2-(d). Designation procedure of Noncombustible, Quasi-Noncombustible and Fire Retardant Materials

Testing methods are provided by JIS A1321, whereas Ministry of Construction provides individual designation procedure for these materials as their notification. Surface test is common procedure to all tests. Three pieces of 22 cm x 22 cm specimen shall be tested under regulated temperature by furnace and generated smoke is gathered to smoke chamber as is shown Figure 4. Judgment Standard of test result is shown in Table 6.

Table 6 Judgment Standard for Results

	Noncombustible	Quasi-noncombustible	Fire Retardant
heating time (min)	10	10	6
total temperature time·area over standard value	0	≤ 100	350
smoke generation coefficient (CA)	30	< 60	< 120
surface melting		No melting Required	
depth of Crack		thickness/10	
flame remaining time after heating (sec)		30	

Furthermore, designation of noncombustible materials depends on the results of noncombustibility test using the furnace shown in Figure 5. Testing method on noncombustibility almost resembles ISO 1182, but main foreign standards such as ASTM, DIN, ULC-CAN regulate another type of test apparatus.

Specimen (40mm x 40mm x 50mm thick) is set into the furnace and is exposed to the controlled temperature of 750°C. Judgment of the noncombustible test is given depending on whether the furnace temperature exceed 50°C from 750°C or not during the heating time of 20 min.

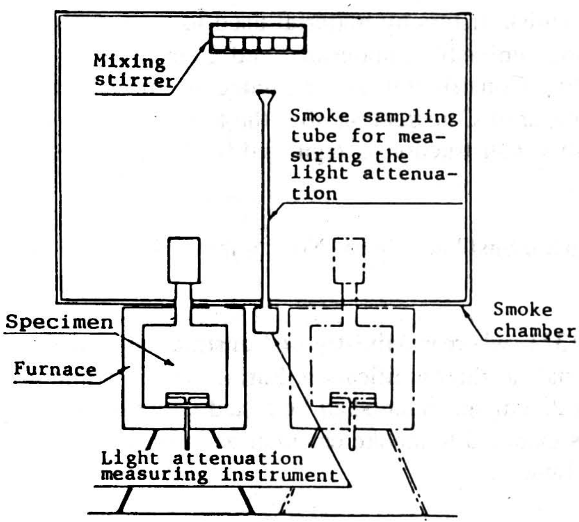

Figure 4 Surface Test.

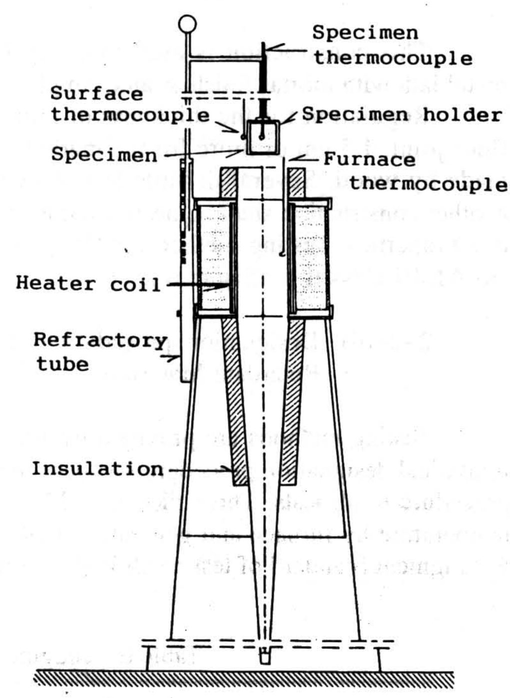

Figure 5 Noncombustibility Test.

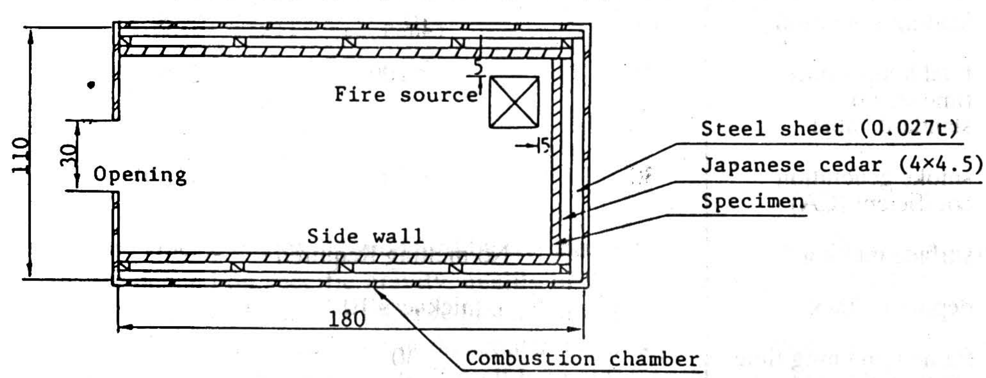

Figure 6 Construction and Arrangement of Combustion Chamber and Specimen.

It is necessary to carry out the toxicity test and the box test for the certification of quasi-noncombustible material for new building materials which contains plastic. Gas toxicity generated from the specimen is compared with the gas from standard combustible material (wood) using 8 mice. Model box test shall be conducted on specimens which interia finished combustion chamber by testing materials with the burning test which regulated wood crib fire source. Figure 6 shows plan view of the box test. The judgment of the box test depending upon the maximum and total value of heat release from each of the two box specimens whether exceed the regulated values or not.

3. Concluding Remarks

Japanese fire testing system is not so different from the ones of foreign countries. Changes in life style and housing needs new materials and new methods for fire proofing so that the rating and testing method of the fire retarding, resisting, and proofing for those materials and methods have to be develope including smoke/gas generation performance.

Appendix A

Introduction of the Center for Fire Science and Technology

The Center was established in April, 1991 as one of celebrations of the 100th anniversary of the Science University of Tokyo. Members of the organization are consist of 12 professors including science and engineering faculty (who joins to the research project as demands), and 3 researchers (full time).

Brief Introduction of Some Results from Research Work

1) Smoke Filling Test in a Full Scale Compartment

In order to investigate the human behavior linking with smoke filling in a compartment of the department fire (Nagasaki-Ya, 15 peoples were killed by smoke/gas), full scale smoke filling tests were carried out in the same building. A hundred sheets of curtain hanged and the other same amount of curtain piled on the shelves were used as a fire source, and smoke filling rate was estimated of about 2 cm/sec. Figure A-1 shows the time variation of smoke filling in 800 m^2 estimated from two witnesses. Both filling rate were almost same so that we could evaluate the heat release rate in the initial stage of the fire. Based on the heat release rate estimated, smoke development, which was driven by heat from a fire source, in the building through the unclosed doors was estimated using the two-zone model.

2) Fire Retardance Mechanism for Ethylene Copolymers given by Magnesium Hydroxide

The fire retardance mechanism of magnesium hydroxide for ethylene copolymers were studied experimentally, using low density polyethylene (LDPE), ethylene-ethylacrylate copolymers (EEA) and ethylene-vinylacetate copolymers (EVAc). This study was carried out utilizing a high radiant furnace, thermogravimetry-differential scanning calorimeter-gas chromatography (TG-DSC-GC) and infrared spectroscopy (IR). The results show that magnesium hydroxide have little fire retardance on polyethylene and on ethylene-vinylacetate copolymers, but have remarkable fire retardance on ethylene-ethylacrylate copolymers. The differences of the fire retardance effects in these polymer-$Mg(OH)_2$ systems are due to the thermal stability of char layer formed on the polymer surface. And the char formation is due to certain intermolecular reaction forming cross-linking in the system, as shown in Figure A-2. In the case of ethylacrylate copolymers system, particularly, magnesium hydroxide reacts with ethylacrylate groups resulting the cross-linkings among the polymer chains, and both these reactions and char formation enhance the thermal stability against the burning propagation into the material. The dehydration of magnesium hydroxide gives also important effects for fire retardancy which is given by endothermic effect as well as dilution in gas phase.

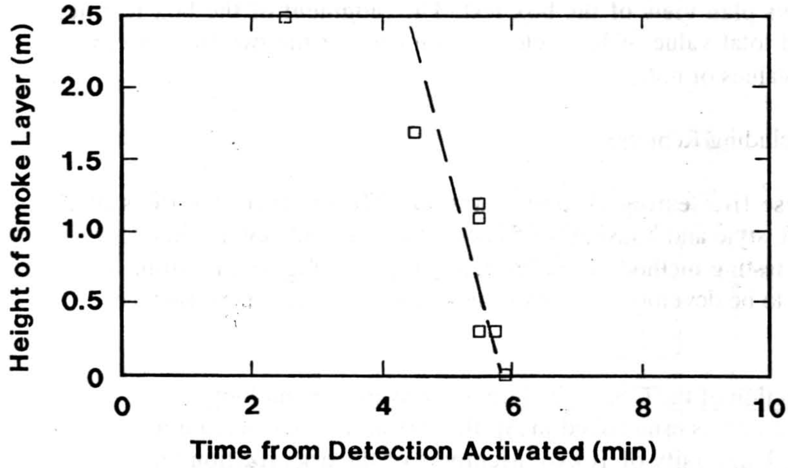

Fig. A-1 Time variation of smoke layer height estimated from two witness who survived in the department store fire.

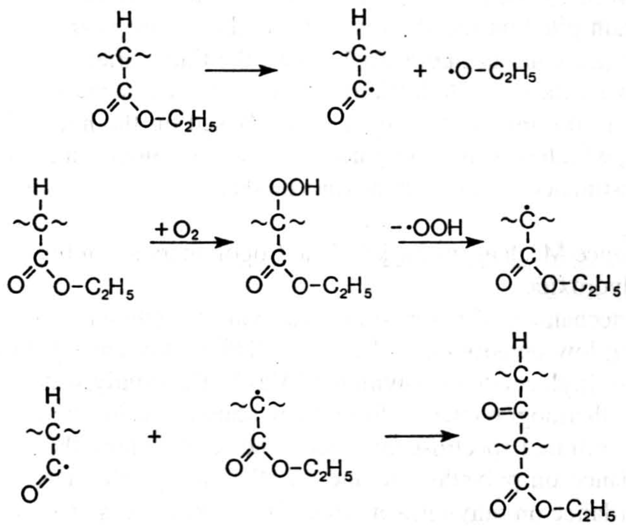

Fig. A-2 Scheme of the cross linking formed by intermolecular reaction with $Mg(OH)_2$ in EEA system.