Survey of Movable Fire Load in Japanese Dwellings

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ABSTRACT

A survey of the movable fire load in dwellings has been conducted for apartment houses in the metropolitan area around Tokyo. Goods and furniture that are likely to be encountered were listed in advance with their figures, and the volume of goods that were stored in the containers was also asked. Collected data were converted to equivalent timber weight. The result suggests that the average movable fire load in a dwelling unit is about 34 kg/m^2, with a standard deviation of 11.7 kg/m^2. There seems to be a tendency for the total movable fire load to increase with the floor area; the total fire load is also likely to increase to some extent with the length of life in that dwelling unit; most heavily loaded spaces in total weight are bedrooms, with the average of about 400 kg; common storage spaces adjoining the corridor or the washroom are most heavily loaded per unit floor area, although they are usually narrow.

KEYWORDS: Apartment houses, combustibles, dwellings, fire load, movable goods, questionnaire survey.

INTRODUCTION

One of the key factors that determine the size of a fire in a building is the quantity of combustibles in it. The actual volume of combustibles in each fire compartmentation must be known to assume the maximum possible fire size in that space. It is a prerequisite for fire safety design of buildings. Combustibles in a building consist of: 1) fixed fire load such as backings of walls, ceilings, floors, partitions, and their finishing materials that enclose the space, and 2) movable fire load that is brought in after the construction is finished, i.e. various kinds of furniture and containers, stored goods in them such as documents, books and magazines, clothes, carpets, curtains and draperies, and so on.

Fixed fire load is generally known during the building design process, and it is relatively easy to correctly define like structural dead load. In contrast, movable fire load is less clear to estimate. As for dwellings, variety of movable fire load has been changing with quickly changing pattern of life. There exist different opinions whether the movable fire load has recently increased or not. Popularity among dwellings of steel furniture may have contributed to a reduction of fire load in dwellings. On the other hand, better living conditions might have introduced more and more combustibles in dwellings. Besides, the amount of movable combustibles in a dwelling unit is quite variable depending on the way of life, and their distribution is varied according to the purpose of the space. It is also expected that there will be frequent changes of the contents with time.

A survey of the movable fire load in offices and in some commercial buildings has been done recently (Ref. 1, 2). As for dwellings, however, no

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precise data were available from the viewpoint of fire load, excepting an old indirect survey (Ref. 3). Here, the results of a new survey on the fire load in dwellings are reported.

PROCEDURES OF THE SURVEY

Basic Considerations for the Survey

It is very difficult to directly measure the number and quantity of goods and furniture in dwellings. Existing data on movable combustibles in offices and commercial buildings are generally collected through direct observation/inspection on the spot by researchers or professionals. This is however not always possible for dwellings due to privacy of the residents. A previous study on the fire load in dwellings done more than ten years ago (Ref. 3) used the data obtained by a survey conducted by another research group on the way of life in apartment units of the Japan Housing Corporation (now the Housing and Urban Development Corporation), also done under contract of the Corporation (Ref. 4). The result of the original survey, i.e., a list of goods and furniture in dwelling units with their numbers, was used to estimate both fixed and movable fire load based on various assumptions.

For the present study, therefore, a set of questionnaire forms was distributed to the dwellings, and the actual work to fill out the forms was handed to the dwellers themselves. They observed their goods and furniture, and the contents. The result was later converted to equivalent timber weight as the fire load. A good estimate of the amount of movable combustibles is thus obtained. To get more reliable data for the purpose of the survey, a method was developed that will give enough information on the content of goods stored inside furniture and in various types of containers.

Selection of Dwellings

Dwellings surveyed were apartment units. Blocks of flats were selected from a vast number of stocks supplied by the Housing and Urban Development Corporation (HUDC) for rented units. Self-owned units were chosen from ones constructed and supplied by a private construction company. The selection was done through a stratified quasi-random sampling, in consideration of the size of the dwelling units and differences of regional characteristics in the metropolitan area around Tokyo. Block of flats that were the subjects of the previous study in 1974 (Ref. 3) were also included this time. It should be pointed out that the dwelling units surveyed at that time do not correspond to the ones investigated during the present survey.

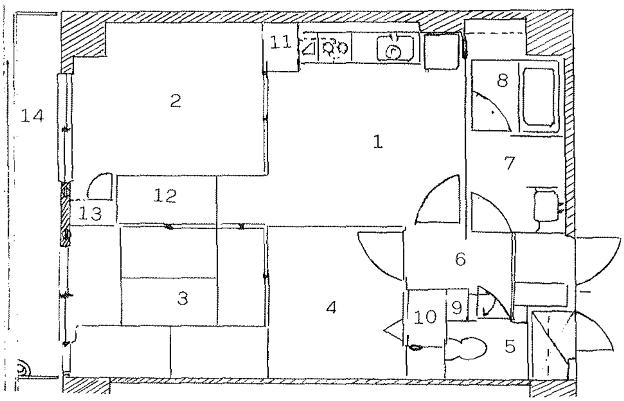
At first, the dwellers were contacted and asked of their willingness to cooperate for the survey. When the consent was obtained, they were sent a set of questionnaire forms with a 1/50 floor plan and a detailed instruction on how to fill out the forms.

Method of the Survey

In the floor plan, each space enclosed by a floor, a ceiling, walls and openings is given a separate number irrespective of whether it is a room or a storage. The dwellers were expected to list up everything in the space, both furniture and goods. Purpose of the space was roughly divided into three, livable room space, storage connected to it, and outdoor storage. Small built-in cupboards and the like were treated as independent storage spaces. A separate questionnaire form was provided for each space that was given a different identification number in the plan.

Standard furniture and goods commonly found in dwellings were originally listed in the questionnaire forms, and an explanatory sheet with their figures was also distributed to the dwellers. A sample of floor plan is shown in FIG. 1, and a partial extract of the questionnaire form is given in TABLE 1. Some of the figures in the explanatory sheet are given in FIG. 2. They had only to tick the name of furniture or goods if they had. They were asked to additionally write in goods and furniture not listed.

Dimensions needed to calculate the fire load were also asked of the dwellers to measure and write in. Information on numbers and materials was also requested. For typical goods and furniture, no dimensional measurement was required as it was easy to estimate. Materials were selected among wood, metal or others. In the case of other materials, they were also asked to specify what. For goods or furniture that are nearly made of incombusti-



1. Living/Dining
2. Bedroom A.
3. Tatami matted room
4. Bedroom B.
5. Toilet
6. Corridor
7. Washing room
8. Bathroom
9. Storage A.
10. Storage B.
11. Storage C.
12. Storage D.
13. Storage E.
14. Balcony

FIGURE 1. Sample of floor plan of a dwelling.

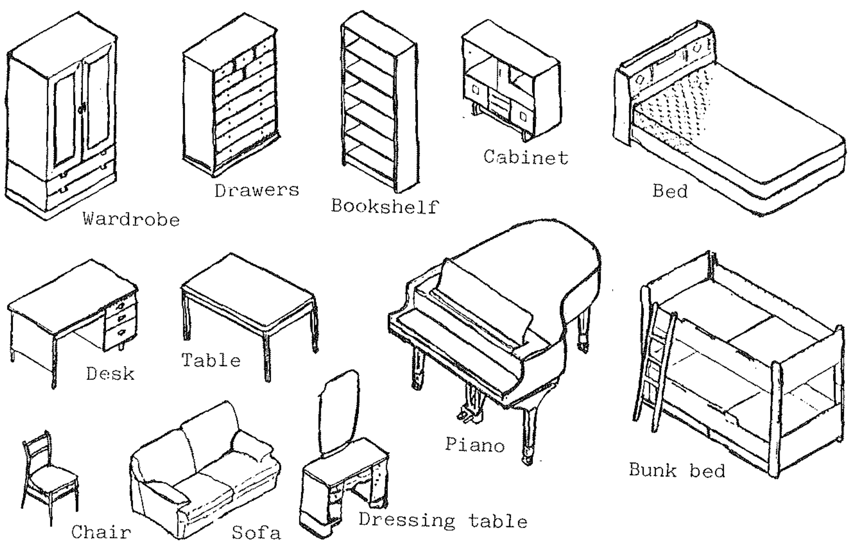


FIGURE 2. Explanatory figures of furniture and goods in dwellings.

ble materials, they were advised not to write in. Additional information was collected on the approximate amount of goods in the storage. It was also given by observation of the dwellers. Type of goods inside containers was also asked.

TABLE 1. Survey sheet of movable combustibles in the space No. ( ).

Kind of combustibles	Dimensions/Quantity	Materials	Stored volume inside
Wardrobes/Drawers	Width/Depth/Height	W/M/Other	Full 3/4 1/2 or less
Wardrobes	___ x ___ x ___ (cm)		
Drawers	___ x ___ x ___		
etc.			
Shelves			
Bookshelves	___ x ___ x ___		
Cupboard	___ x ___ x ___		
Record cabinet	___ x ___ x ___		
etc.			
Desks/Tables			
Study desk	( )	Do not write in if it is virtually incombustible (as made of metals).	
Dining table for 4	( )		
etc.			
Chairs/Sofas			
Dining chair	( )	Do not write in if it is virtually incombustible.	
Sofas	( )		
etc.			
Beds			
Single bed	( )		Not applicable
Bunk bed	( )		Not applicable
etc.			
Various fabric goods			
Beddings	( ) for adults ( ) for children		Not applicable
Blankets	( )		Not applicable
Sitting cushions	( )		Not applicable
Carpets	width ___ cm, depth ___ cm		Not applicable
Curtains/Draperies	width ___ cm, height ___ cm		Not applicable
etc.			
Others			
Dressing table	( )	Do not write in if it is virtually incombustible (as made of metals).	
Piano	( )		
Box containers	( )		
etc.			
Others not elsewhere classifiable (in approximate weight).	1. Almost nothing. 2. 50 kg or less. 3. 50-100 kg. 4. 100-200 kg. 5. 200 kg or over.	Note that a standard corrugated paper box is about 10 kg.	

Estimation of Weight

Collected data on movable goods inside dwelling units had to be converted to equivalent fire load. As for the conversion, three basic methods were used. First, there are goods whose weight can be calculated from their dimensions. Second, there are goods that have several standard sizes and several weights, like desks. For these, the weight is known only by identifying the type. Third, there are goods that are almost a single variety from the viewpoint of weight, like dining chairs. Necessary data on standard weight estimation were collected by a survey at retail stores.

The combustibles are usually made from a combination of various materials that it is the custom to represent them by equivalent timber weight as fire load. This was done using information on the material of goods and furniture. As for metals, the container itself was treated as incombustible, and only the contents were counted. For wooden goods, the calculated weight was directly used. For plastics, the calculated weight was multiplied by two taking into consideration of polyethylene, although some types of plastics like polyvinyl chloride have the factor of nearly unity. This is done to avoid underestimation of the total fire load.

RESULTS

The first step request letters questioning whether the dwellers are willing to cooperate for the survey were distributed about 1,000 in total. Favorable replies were between 6 to 20 % among various housing blocks, averaging about 12 %. The return rate was worse for the HUDC housing, and it was decided to ask for more participation in some of the housing blocks of the HUDC. The return rate at the second stage of the survey was good, and 216 sets of questionnaire forms were returned. For the present study,

TABLE 2. Movable fire load in dwelling units.

Name of housing scheme	Number of units	Average total fire load kg	Average floor area m^2	Unit fire load kg/m^2	S.D. kg/m^2	CY*
HUDC Housing						
Jindai	65	1714.9	43.3	39.5	12.5	'65
Oojima	47	1764.7	51.8	34.2	11.8	'70
Toyogaoka	15	2041.1	67.9	29.9	8.8	'76
Kaitori	9	1967.8	54.0	36.4	10.5	'79
Apartment houses supplied by a private construction company						
Tsunashima	12	1888.1	56.2	33.5	11.4	'79
Itabashi	16	2055.5	62.2	32.6	10.1	'80
Minami-machida	23	2564.3	93.6	27.3	6.7	'82
Higashi-shinagawa	13	1600.6	56.9	28.1	10.2	'83
Ooguchi	14	1520.4	54.9	27.6	6.8	'84
Total	214	1866.1	56.5	33.9	11.7	

*CY: Year of construction completion.

TABLE 3. Movable fire load in respective spaces within dwelling units.

Purpose of the space	Number	Average total fire load kg	Average floor area m^2	Unit fire load kg/m^2	S.D. kg/m^2
Living Room	74	305.5	8.4	36.3	25.2
Dining Room	13	278.7	8.4	33.1	16.5
Kitchen	54	147.8	5.4	28.4	20.2
L/D	42	414.4	16.7	26.7	13.8
D/K	75	326.4	10.6	31.2	12.7
L/D/K	86	370.5	12.1	30.9	14.6
L+Main Bedroom	46	290.7	8.1	36.4	19.4
L+Wife's Bedroom	20	391.2	8.1	48.4	26.7
Main Bedroom	86	351.1	8.8	39.8	19.1
Bedroom for Male	25	449.1	7.9	57.3	25.2
Bedroom for Female	27	444.4	8.0	58.1	32.4
Children's (12-18)	53	414.0	7.6	54.8	22.0
Children's (-11)	37	375.9	7.9	48.0	17.2
Master's room	42	381.7	7.8	50.9	48.8
Family Bedroom	39	279.2	8.5	33.5	16.1
Study Room	29	455.8	8.2	56.7	25.0
Other Room	144	441.2	7.6	58.1	40.5
Bathroom	59	19.7	2.3	8.9	7.4
Toilet	125	11.6	1.1	11.5	14.5
Washroom	123	55.3	3.1	18.6	34.0
Entrance, Corridor	179	76.6	4.2	23.7	46.7
Corridor, Stairs	7	80.1	4.0	29.7	45.4
Storage					
Living Room	61	69.6	1.2	64.9	42.6
L/D	2	290.6	0.6	518.9	280.2
L/D/K	4	58.9	1.3	66.8	49.3
L+Main Bedroom	44	76.4	1.2	65.3	55.2
L+Wife's Bedroom	14	84.3	1.3	65.8	32.8
Main Bedroom	87	76.8	1.4	58.7	41.5
Male Bedroom	21	62.5	1.3	48.6	28.6
Female Bedroom	21	47.7	1.2	40.1	29.5
Children's(12-18)	46	76.9	1.3	63.4	40.5
Children's(-11)	27	92.1	1.3	83.9	67.3
Master's Room	40	77.2	1.4	59.5	39.7
Family Bedroom	38	88.7	1.4	69.7	60.1
Study	21	85.3	1.3	81.4	63.9
Other Room	113	72.1	1.3	60.2	48.2
Washroom	31	59.1	0.4	142.0	123.8
Entr. ,Corridor	110	65.9	0.6	132.2	109.4
Corridor, Stairs	5	121.6	1.3	93.4	27.5
Balcony	139	58.8	5.7	11.5	10.3
External Storage	71	59.3	0.5	113.5	69.4
Total	2283	179.5	4.8	48.5	57.3

214 housing units with 2723 room spaces were used for statistical analysis of characteristics of the dwelling units, because two samples were quite irregular from the viewpoint of stored goods and their volume in dwellings. The result of the total movable fire load in dwelling units is in TABLE 2.

The average fire load in different types of spaces is given in TABLE 3. In calculating the data in this table, spaces without combustibles were excluded from the analysis to avoid underestimation of probable movable fire load in various spaces in dwellings.

DISCUSSION

Fire Load in Dwelling Units

There were very few existing data on the movable fire load in dwelling units because it had rarely been the subject of fire safety design. The report on the fire load in apartment units of Japan Housing Corporation (Ref. 3) suggested an average of 17.5 kg/m^2. TABLE 2 shows the result of the present survey on the fire load in dwelling units, whose average is 33.9 kg/m^2. The scatter diagram in FIG. 3 shows a general tendency for the total fire load to increase with the floor area. It is however to be noted that the movable fire load per unit floor area was larger if the floor area was smaller. There does not seem to exist a significant difference among different localities in Tokyo.

It seems that the total movable fire load gradually increases with time after the dwellers have settled down in the dwelling units. In TABLE 2, the housing blocks are listed in the order of the construction year, and it is in good agreement with the decreasing order of the average fire load per floor area. This is perhaps the dwellers rather store goods within the unit than to throw them away even if they are no longer needed. At least, there is a tendency for the total goods to increase rapidly at the early years of the occupancy because Japanese housings are sold or let unfurnished.

The scatter diagram for Jindai housing, the same one that was under study in Ref. 3, is given in FIG. 4. The present result with an average

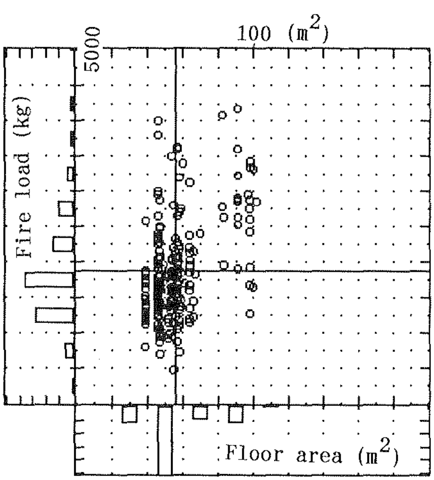


FIGURE 3. Scatter diagram of total movable fire load in dwelling units.

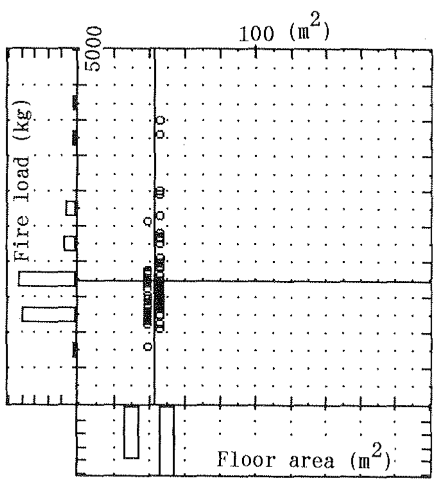


FIGURE 4. Scatter diagram of total fire load in Jindai housing.

movable fire load of 39.5 kg/m^2 is more than doubled compared to the previous study. The housing was nearly 10 years old when the first survey was conducted. One possible explanation is that the movable fire load in the dwelling units has increased considerably in the last 10 to 15 years. Another possibility is that the 1974 report is inadequate in the sense that the survey was not original and therefore it overlooked a lot of furniture and goods that should have been counted as the movable fire load.

A survey by the authors on the movable fire load in detached houses in 1985 (Ref. 4) suggested an average fire load of about 20 kg/m^2 (FIG. 5). The houses were however constructed only in the previous year as the sample was collected from the most recent building permit of the local government. It is therefore probable that the furniture and goods will sharply increase in several years after the initiation of life in the house. Another possible reason is that the floor area in the detached houses surveyed is quite large with an average of about 122 m^2. It is more than twice of the dwellings of the present study. The averaged total movable fire load for detached houses is 2448 kg, which is also larger than that of apartment units in all, but very similar to the average of Minami-machida with 2564 kg which has the floor area of 94 m^2. A likely explanation one can draw from the comparison is that there is a standard maximum value of the movable fire load in a dwelling for a family, which is around 2500 kg.

Fire Load in Various Spaces in a Dwelling Unit

During the fire safety design stage, fire load is treated as a uniform value for most of the spaces within buildings. Actually, fire load per unit floor area varies depending on the purpose of the spaces. Since present study not only used the floor plan but also asked the daily use of rooms, purpose of the spaces is clearly known. TABLE 3 shows the relationship between the room purpose and the fire load per unit floor area. It is evident that rooms and their adjoining storage spaces are quite different in the unit fire load. The data clearly show that the unit fire load in bedrooms is very large. It varies according to the users of the space: main

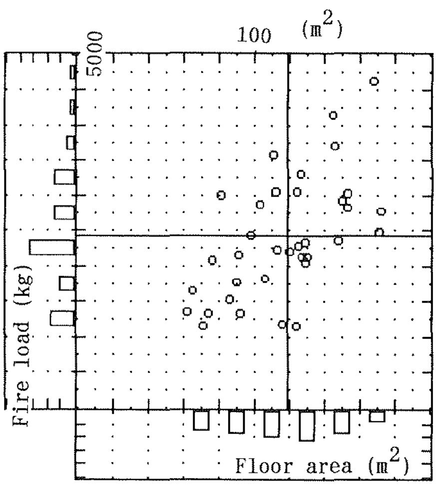


FIGURE 5. Scatter diagram of movable fire load in detached houses.

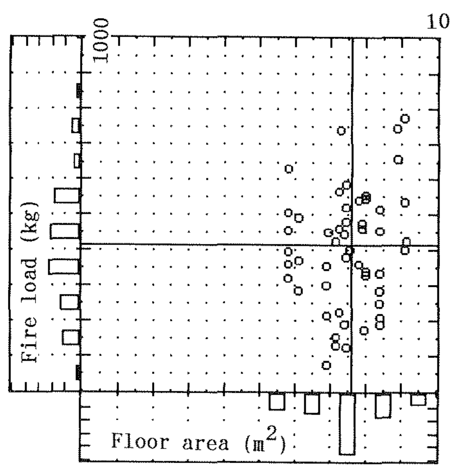


FIGURE 6. Scatter diagram of movable fire load in children's (12-18) bedroom.

bedrooms are less heavily loaded with combustibles than other bedrooms, but most bedrooms have the unit fire load of about 55 kg/m^2. The scatter diagram of fire load density and the floor area for children's bedroom is given in FIG. 6, and the scatter diagram of living room, in FIG. 7. The fire load in living rooms is about a third less than bed rooms, as the comparison between FIG. 6 and FIG. 7 shows. A typical scatter diagram of the storage spaces is given in FIG. 8. Although the storage spaces are narrow, they usually have the average load of 60 kg/m^2 or more.

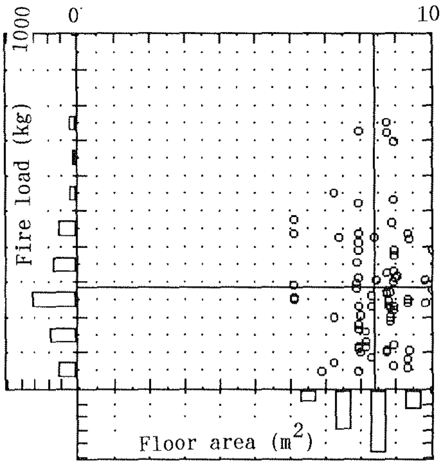


FIGURE 7. Scatter diagram of movable fire load in the living room.

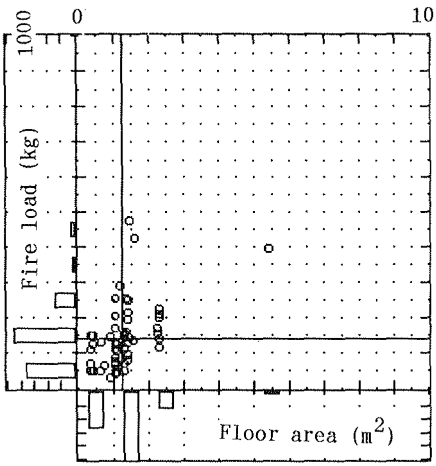


FIGURE 8. Scatter diagram of movable fire load in the living room storage.

Fire Load Characteristics in Heavily Loaded Dwelling Units

The characteristic of the two dwelling units excluded from the statistical treatment of the total movable fire load in TABLE 2 is discussed here. There are five dwelling units among the samples, two of which are loaded more than 5000 kg (these were excluded ones), three others more than 4000 kg. Typical feature is that they have several bookshelves reaching near the ceiling in some of the rooms. In one dwelling unit, the dweller also introduced some handmade shelves, which were also heavily loaded. It is quite difficult to predict such happenings, but perhaps the designer should bear in mind that it might occur in some of the dwelling units (if not all). It can perhaps occur if the dwelling is occupied by three or more adults, as in the case when the children have grown up. It is also likely to occur if they live very long in that dwelling.

CONCLUSION

A questionnaire survey on the movable fire load in the dwelling units of apartment houses has revealed that the average movable fire load is about 2000 to 2500 kg in total, or 34 kg/m^2 in respect of the floor area. Relationships between the total fire load, the floor area, the number of the family member, and the length of life in the dwelling have been suggested. It was also pointed out that each space in a dwelling can be loaded more depending on various conditions.

ACKNOWLEDGMENTS

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