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Study on Residential Fire Load in the Yangtze River Delta

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Abstract. Fire load survey is an important step in residential fire risk assessment. There are certain differences in residential fire loads in different regions. In order to improve the basic fire data in the Yangtze River Delta, we mainly investigated the residential fire loads in Zhejiang Province. In this survey, the residential fire loads were divided into 7 categories according to the characteristics of combustibles in the room. The measurements include mass method, single item method, size method and area method, etc. The survey data were analyzed by SPSS and residential fire loads were obtained as: 355.75MJ/m² for living room, 612.28MJ/m² for bedroom, 658.64MJ/m² for kitchen, 542.66MJ/m² for study and 219.64MJ/m² for bathroom. The statistical analysis shows that the distribution characteristics of residential fire loads are closely related to room use. The fire loads of bedroom and kitchen are basically normal distribution and other rooms are not obvious.

1. Introduction

According to the national fire statistics of Fire Rescue Bureau of China, the number of deaths caused by residential fires in 2016 accounted for 80.2% of the total deaths and residential fires have been a problem that threatens the lives of people. Fire risk assessment is one of the important means to effectively prevent residential fires, so it is necessary to accurately grasp the basic data of residential fire load to make a scientific fire evaluation.

Fire load is a parameter to measure the amount of combustibles contained in a building and it is measured by the total calorific value generated when all combustibles in the building are burned. The distribution of fire loads is often uneven, so fire load density is generally used to describe the distribution of fire loads in the building. Fire load density is defined as the calorific value, which could be released per square metre of floor area of the building and its calculation formula is as follows.

$$q = \frac{\sum Q}{A} \quad (1)$$

q = fire load density (MJ/m²)

$\sum Q$ = total calorific value of combustible material (MJ)

A = floor area (m²)

Residential fire loads are affected by the natural conditions, socio-economics, living customs, cultural level, building technology, building type and building materials, etc. With the in-depth study and extensive application of fire risk assessment, it is more and more important to establish the fire load database suitable for China. So it is necessary to conduct fire load survey in different regions of China to enrich and improve the basic fire data.



The scholars have conducted some investigations on the residential fire loads and obtained some relevant data. Li Tian investigated the movable fire loads of bedrooms in Henan Province and obtained the average fire load density of 520.26MJ/m². Wang Jinping conducted fire load survey on ordinary houses in Beijing and obtained the average fire load density of 1197.17 MJ/m². Chow WK investigated the old high-rise residential buildings in Hong Kong and found that the fire load density in this kind of buildings was generally higher than 1135 MJ/m² as stipulated by Hong Kong local codes. However, the investigations of residential fire load in the Yangtze River Delta are not enough.

2. Survey method and process

The survey is mainly for residential buildings in Zhejiang Province. The survey area is about 5,300 square meters with a total of 385 rooms. The survey sorts the residence into living room, bedroom, kitchen, study, bathroom and storage room, etc. According to the properties of the items in the rooms, the fire loads are assorted into several categories, such as furniture, electrical appliances, decoration, clothes and bedding. The survey methods include mass method, single item method, size method and area method, etc. For example the clothes are easy to weigh, so the fire load values of clothes are measured by mass method which means the clothes weight is multiplied by the unit mass calorific value. The materials of large items such as wardrobes, TV sets, and sofas are more complex and they are difficult to weigh, so the fire load values of large items are calculated by multiplying the number of items by the calorific value of the single item. Books' fire load values are calculated by multiplying the total thickness by the calorific value per unit thickness. The unit thickness calorific values of 16 open format and 32 open format books are about 735 MJ/m and 420 MJ/m respectively. Interior decoration such as wooden floors, ceilings and wallpapers are calculated by multiplying the decoration area by the calorific value per unit area. The statistics on residential fire load density are shown in Table 1.

Table 1. Statistics on residential fire load density characteristics.

Rooms	Numbers	Minimum (MJ/m ²)	Maximum (MJ/m ²)	Mean (MJ/m ²)	Standard deviation
Living room	52	149.96	862.46	373.41	177.66
Bedroom	116	112.16	1475.19	624.98	250.55
Kitchen	44	155.10	1734.75	635.19	326.58
Study	21	254.76	3495.03	749.76	782.46
Bathroom	74	21.02	804.93	252.71	163.26
Storage room	24	44.11	1594.81	388.82	357.15
Other space	54	6.67	766.13	190.45	167.32
Total rooms	385	6.67	1734.75	421.49	193.27

3. Data processing and analysis

3.1. Analysis of residential fire load density characteristics

The fire load density box diagram of various rooms can be obtained by using SPSS to analyze the survey data of Table 1. It can be seen from Figure 1 that there are some fire load density outliers in the rooms. After the outliers are removed, Table 2 and Figure 2 can be obtained by using SPSS to recalculate the residential fire load density characteristics.

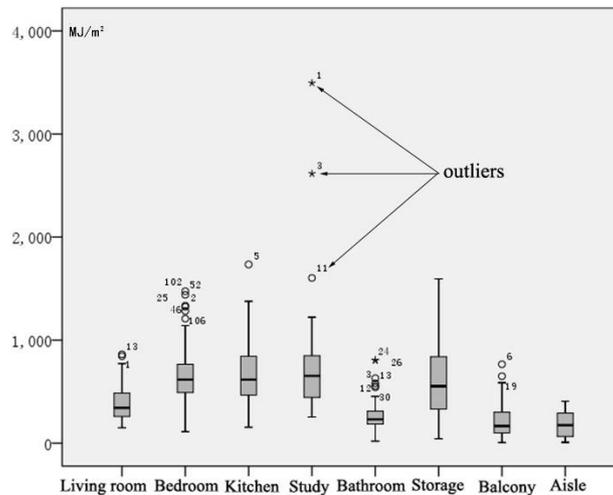


Figure 1. Fire load density box diagram of various rooms

Table 2. Statistics on residential fire load density characteristics after removing the outliers.

Rooms	Numbers	Minimum (MJ/m ²)	Maximum (MJ/m ²)	Mean (MJ/m ²)	Standard deviation
Living room	48	149.96	709.07	355.75	136.99
Bedroom	107	171.69	1055.19	612.28	179.97
Kitchen	43	155.10	1377.00	658.64	291.18
Study	16	254.76	848.43	542.66	172.24
Bathroom	60	47.82	393.96	219.64	72.92
Storage room	24	44.11	1594.81	606.21	364.83
Other space	50	6.67	413.86	171.74	111.16
Total rooms	348	6.67	1594.81	419.29	163.56

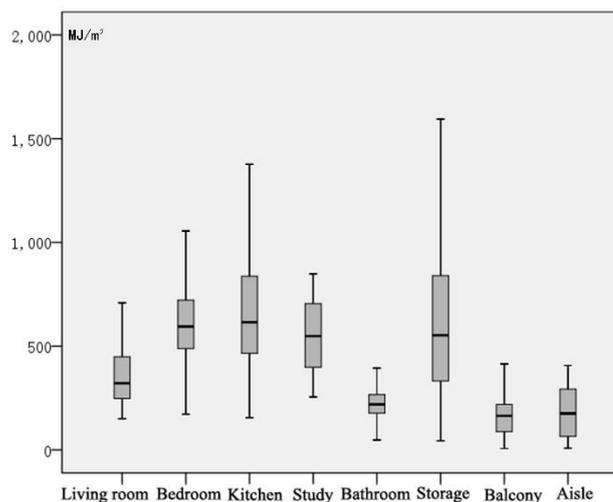


Figure 2. Fire load density box diagram of various rooms after removing the outliers

It can be seen from Table 2 and Figure 2 that the fire load density of storage room and kitchen is higher and the variation range is larger, mainly because the two types of room store a lot of debris. The reason for the higher average fire load density of bedroom and study is that there are more combustibles and they are susceptible to different living habits, resulting in a greater change in the fire load density.

3.2. Relationship between fire load density and room use

Using SPSS to plot fire load density histograms can further understand the relationship between fire load density and room use. (Figure 3-7)

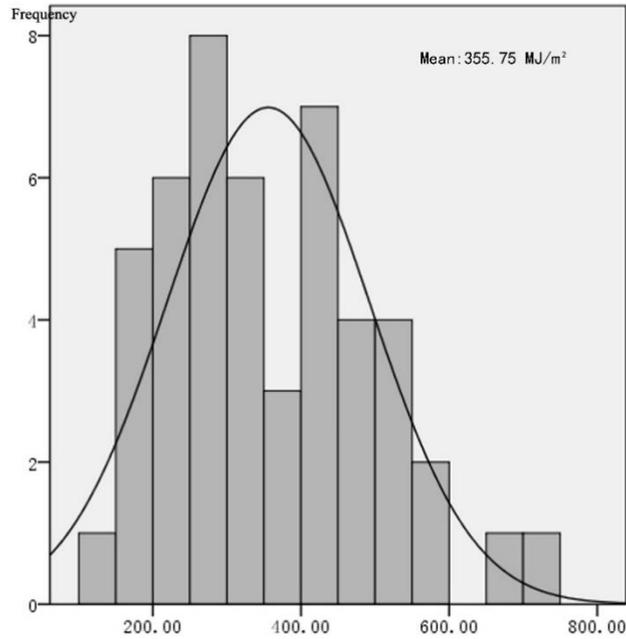


Figure 3. Living room fire load density histogram

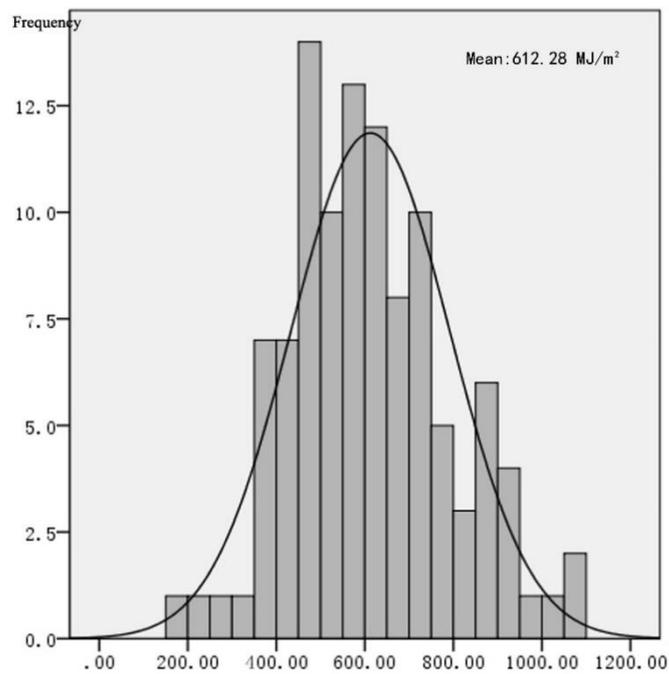


Figure 4. Bedroom fire load density histogram

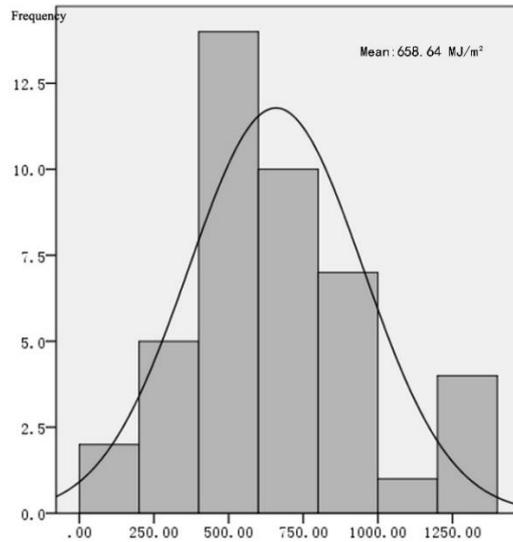


Figure 5. Kitchen fire load density histogram

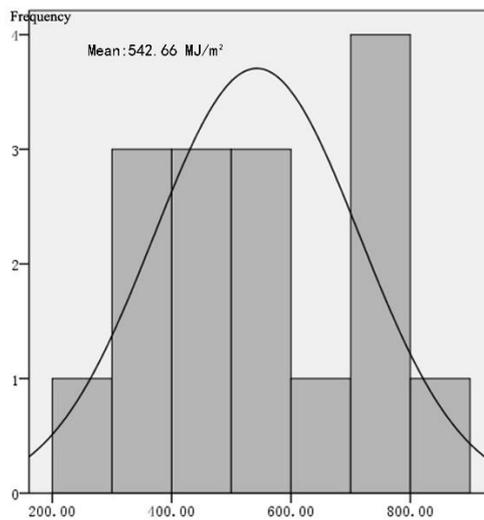


Figure 6. Study fire load density histogram

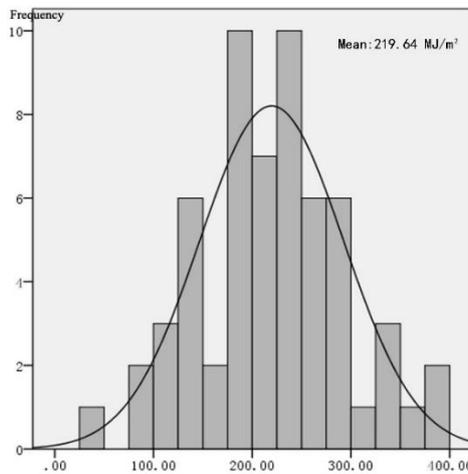


Figure 7. Bathroom fire load density histogram

It can be seen from Figure 3-7 that the fire loads of bedroom and kitchen are basically normal distribution and other rooms are not obvious. The fire load density of living room is mainly distributed at 200-500MJ/m² with an average value of 355.75MJ/m². The fire load density of bedroom is mainly distributed at 400-700MJ/m² with an average value of 612.28MJ/m². The fire load density of kitchen is mainly distributed at 400-1000MJ/m² with an average value of 658.64 MJ/m². The fire load density of study is mainly distributed at 300-800MJ/m² with an average value of 542.66MJ/m². The fire load density of bathroom is mainly distributed at 200-300MJ/m² with an average value of 219.64MJ/m². According to the data distribution, the fire load density is greatly affected by room use and there is a correlation between the two.

3.3. Relationship between fire load density and room areas

According to the room area data obtained from the survey, the rooms are divided into several intervals by floor area and the characteristic values of fire load density are respectively counted. (Table 3) Drawing a map of relationship between room area intervals and fire load density can further understand the trends.(Figure 8-12)

Table 3. Residential fire load density characteristics based on area intervals

Rooms	Area intervals(m ²)	Numbers	Minimum (MJ/m ²)	Maximum (MJ/m ²)	Mean (MJ/m ²)	Standard deviation
Living room	A<20	11	149.9	862.4	437.0	181.7
	20≤A<30	28	179.9	844.4	400.1	178.9
	30≤A<40	9	172.9	709.0	347.4	162.0
	A≥40	4	193.5	500.8	290.8	124.5
Bed-room	A<10	5	772.7	1334	1009	203.0
	10≤A<15	44	112.1	1324	699.9	233.1
	15≤A<20	42	237.4	1439	620.0	203.3
Kitchen	A≥20	25	171.6	1475	563.0	280.5
	A<10	7	452.0	1734	967.2	419.5
	10≤A<15	10	388.4	1031	647.5	218.9
Study	15≤A<20	9	518.2	1213	796.2	215.3
	A≥20	18	155.1	1377	535.7	286.7
	A<10	5	513.1	3495	1695	1167
Bath-room	10≤A<15	13	311.7	1603	696.5	352.6
	A≥15	3	254.7	589.4	429.1	137.0
	A<5	28	47.82	804.9	358.0	212.5
Bath-room	5≤A<10	41	21.02	542.2	222.9	86.70
	A≥10	5	29.70	381.8	197.4	114.5

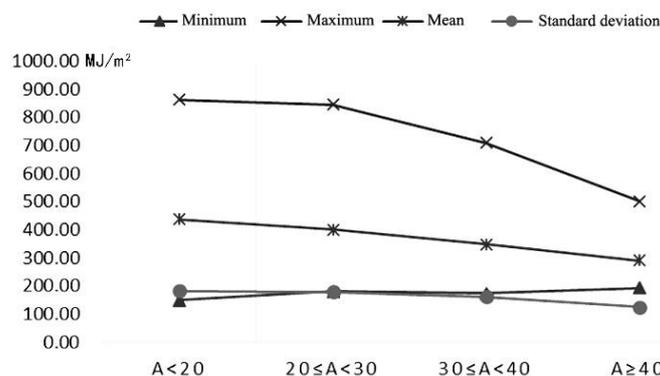


Figure 8. Relationship between living room areas and fire load density

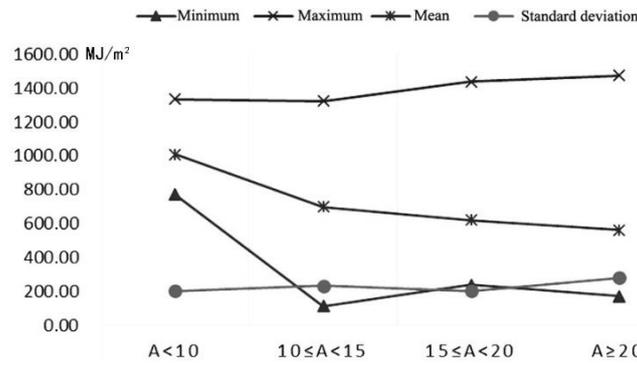


Figure 9. Relationship between bedroom areas and fire load density

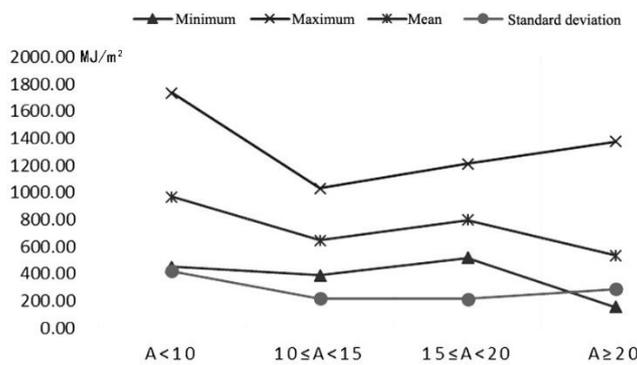


Figure 10. Relationship between kitchen areas and fire load density

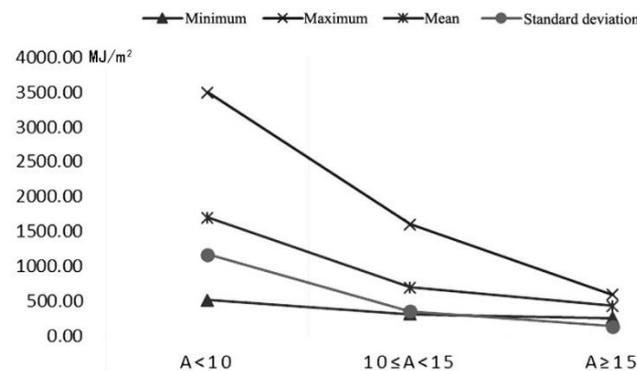


Figure 11. Relationship between study areas and fire load density

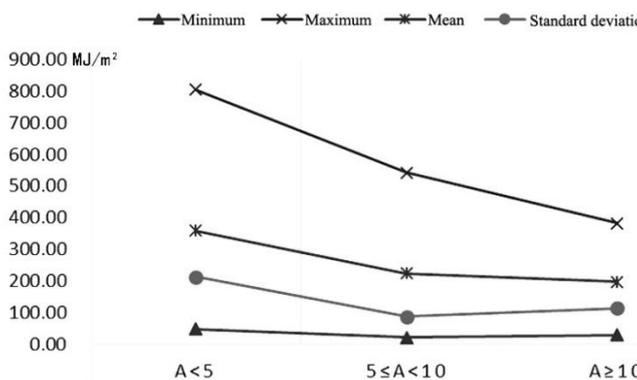


Figure 12. Relationship between bathroom areas and fire load density

It can be seen from Figure 8-12 that the characteristic values of residential fire load density decrease with the increase of room areas. The relationship between individual data changes and room areas of bedroom and kitchen is not obvious, mainly because the fire loads of these two types of room are relatively large and the impact on room areas is relatively small.

4. Conclusion

The main conclusions of this survey can be drawn.

(1) SPSS can be used to eliminate the outliers in the survey to ensure the reliability of the survey data.

(2) The mean values of fire load density of various rooms are as follows: living room with 355.75MJ/m², bedroom with 612.28MJ/m², kitchen with 658.64MJ/m², study with 542.66MJ/m², bathroom with 219.64MJ/m².

(3) The fire loads of bedroom and kitchen are basically normal distribution and other rooms are not obvious.

(4) The characteristics of fire load density are closely related to room use.

(5) The characteristic values of residential fire load density decrease with the increase of room areas.

Acknowledgments

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