A Survey of Fire Loads in Elementary Schools and High Schools

GEORGE HADJISOPHOCLEOUS* AND ZHENGRONG CHEN

Department of Civil and Environmental Engineering
Carleton University, Ottawa, Ontario, Canada

ABSTRACT: This article presents a fire load survey of schools in Ottawa, Canada. The survey was conducted from February 2009 to May 2009. Four elementary schools and three high schools with a total floor area of $6313.0\,m^2$ were surveyed. In the elementary schools, three types of rooms were surveyed: classrooms, computer rooms, and libraries. In the high schools, five types of rooms: classrooms, computer rooms, science rooms, art rooms, and libraries were surveyed. The floor area, window area, and percentage of floor area covered by furnishings are also provided. The results show that the mean fire load density for classrooms in the elementary schools is $397.5\,MJ/m^2$, which is about twice that in the surveyed high schools. The mean value of total fire load density for all the surveyed rooms in elementary schools is $426.3\,MJ/m^2$ and that for high schools is $313.7\,MJ/m^2$.

KEY WORDS: fire load survey, schools, fire load density, performance-based design.

INTRODUCTION

IN STRUCTURAL DESIGN, engineers need to know the loads on the structure. Similarly, in performance-based fire safety design, fire protection engineers or designers need to know fire loads and their composition in order to select proper design fires, which is a fundamental step of performance-based design. Improper selection of fire loads and design fires could lead to an improper fire safety design. Fire loads also correlate with fire severity [1,2], due to the contribution of the fuels that can burn in a compartment in case of fire. However, the difference between fire loads and the loads in structural engineering is that fire severity not only depends on fire loads, but also depends on the dimensions of rooms and their openings, and the distribution of combustible items in the room.

*Author to whom correspondence should be addressed. E-mail: ghadjiso@connect.carleton.ca

Historically, fire loads for various different building categories were obtained through field surveys [1]. The most surveyed building category is office buildings, which has been done by different authors [3–7] in different countries at different times. Some reports of fire load surveys in residential buildings can be found in [8–10], for shopping malls in [11], and for motels and hotels in [12]. This article presents a fire load survey in a rarely surveyed building category, elementary and high schools. The survey was conducted in Ottawa, Canada, from February 2009 to May 2009. Four elementary schools and three high schools with a total floor area of $6313.0\,\text{m}^2$, including 35 classrooms, 11 computer rooms, 10 science rooms, 4 art rooms, and 7 libraries, were surveyed. The floor area, window area, and percentage of floor area covered by furnishings were also recorded in the survey and presented in this article.

SURVEY METHODOLOGY

The fire load in a compartment represents the heat energy that can be generated by all combustibles in the compartment in case of a fire. The fire load can be divided into a fixed fire load and a moveable fire load, which is similar to 'dead loads' and 'live loads' in structural engineering. The fixed fire load consists of all combustible materials in or on the walls, floor, and ceiling, such as doors and window frames. The moveable fire load consists of all other combustible items that are brought into the compartment, such as desks and bookshelves. From the literature, some other terms used for the fixed fire load are 'permanent fire load' and 'nonmovable combustible items', and the terms used for the moveable fire load are 'variable fire load' and 'moveable combustible items'.

The fire load density is normally defined as the fire load per unit floor area of a compartment. The total fire load density in a compartment can be calculated using the following equation [modified from 6,13]:

$$q''_f = \frac{Q}{A_f} = \frac{1}{A_f} \sum k_i \, m_i \, h_{c_i}, \tag{1}$$

where
  $q''_f =$ total fire load density in a compartment (MJ/m^2),
  $Q =$ total fire load in a compartment (MJ),
  $A_f =$ floor area of the compartment (m^2),
  $k_i =$ proportion of content or building component i that can burn,
  $m_i =$ mass of item i (kg),
  $h_{ci} =$ calorific value of item i (MJ/kg).

Table 1. Calorific value of different materials.

Items	H_c	Unit	Reference
Wood	18.6	MJ/kg	[6]
Plastic	22.1	MJ/kg	[14]
Textile	18.8	MJ/kg	[14]
Paper	17	MJ/kg	[6,14]
Leather	19	MJ/kg	[6,14]
Carpet (wool)	23	MJ/kg	[14]
Carpet (PU)	36	MJ/kg	Calculated from [15]

The goal of the fire load survey is to determine the mass of each item m_i, the proportion that can burn k_i, their calorific values h_{ci}, and floor area A_f. For determining the mass of each item, either the weighing technique or inventory technique, or a combination of the two can be used during a survey. In this survey, the inventory technique was mainly used and some sample items were weighed on site, such as chairs, student desks, and plastic bins. Combustibles in metal file cabinets and metal drawers were not counted in the fire loads. As the types of combustibles were identified through the survey, their calorific values were derived from the literature, as shown in Table 1.

SURVEY SCOPE AND SCHOOL INFORMATION

The fire load survey was conducted in four elementary schools and three high schools in Canada's capital city, Ottawa. The survey focused on students' study areas in the school. In the elementary schools, the survey was conducted in three types of rooms: classrooms, computer rooms, and libraries. In high schools, the survey was conducted in five types of rooms: classrooms, computer room, science rooms, art rooms, and libraries. Other types of rooms in schools, such as gymnasiums, teacher's offices, storage rooms, mechanical rooms, and toilets, were not included in this study.

For the elementary schools, two relatively new schools with building ages of 5 and 15 years and two old schools with building ages over 100 years were selected for the survey. One of the two old schools was renovated, where wooden floors were replaced by concrete floors plus vinyl tile, and wooden doors were replaced by metal doors. The buildings of three surveyed elementary schools are three stories, and the building of the other school is two stories. An average of five classrooms for each school, all computer rooms (one school had no computer room), and all libraries in the four elementary schools with a total floor area of 2272.6 m² were surveyed.

In the surveyed high schools, the building of the relatively new school (10 years old) was three stories high. The other two schools were four-story

Table 2. *Surveyed room types and building characteristics.*

Surveyed schools	Number of surveyed room types					Surveyed building	
	Classrooms	Computer rooms	Science rooms	Art rooms	Libraries	Stories	Age
Elementary schools							
School-1	5	1	–	–	1	2	5
School-2	6	1	–	–	1	3	15
School-3	4	–	–	–	1	3	100+
School-4	5	1	–	–	1	3	100+
Sum	20	3	0	0	4		
High schools							
School-5	5	2	4	1	1	3	10
School-6	3	3	3	2	1	4	80
School-7	7	3	3	1	1	4	100+
Sum	15	8	10	4	3		
All schools	35	11	10	4	7		

buildings with a building age of 80 years and 100+ years, respectively. Both old schools were renovated and the wooden floor and doors were replaced. A total of 15 classrooms, 8 computer rooms, 10 science rooms, all art rooms, and all libraries in the three high schools with a total floor area of 4040.4 m^2 were surveyed. Table 2 presents the number of surveyed room types, building stories and ages for the surveyed elementary schools and high schools.

Because schools were surveyed either before school hours or after school hours, students' bags were not considered in this survey. These would need to be added to the fuel package to get the total fire load density.

FLOOR AREA

In the four surveyed elementary schools, a total of 20 classrooms, 3 computer rooms, and 4 libraries with a total floor area of 2272.6 m^2 were surveyed. The 20 surveyed classrooms have a mean floor area of 76.8 m^2, including two samples having the minimum floor area of 21.8 m^2 and five samples above 100.0 m^2. The three surveyed computer rooms have a mean floor area of 73.9 m^2, which is close to the mean value for classrooms, but the standard deviation of 13.6 m^2 for computer rooms is much lower than that of 22.5 m^2 for classrooms. The computer rooms in elementary schools are normally renovated from regular classrooms with relatively larger floor areas, a feature that was found even in the two surveyed new schools. The 4 surveyed libraries in elementary schools have a mean floor area of 128.9 m^2, and three of them are the largest rooms in those schools with floor areas

**Table 3.** *Characteristics of floor area in different room types.*

		Floor area of surveyed rooms (m^2)			
Surveyed rooms	Samples	Minimum	Maximum	Mean	Standard deviation
Elementary schools					
Classrooms	20	21.8	104.2	76.8	22.5
Computer rooms	3	58.9	85.3	73.9	13.6
Libraries	4	87.8	185.5	128.9	44.1
All elementary schools	27	21.8	185.5	84.2	31.2
High schools					
Classrooms	15	60.3	74.0	69.6	4.2
Computer rooms	8	53.4	107.0	82.6	18.9
Science rooms	10	86.4	122.0	104.7	10.6
Art rooms	4	97.6	135.7	116.2	17.4
Libraries	3	195.6	400.8	274.6	110.4
All high schools	40	53.4	400.8	101.0	59.5
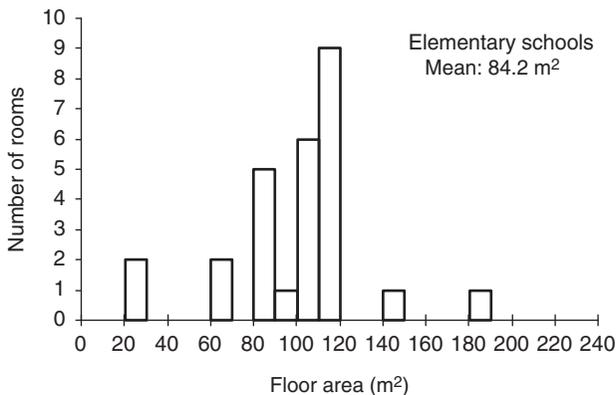
Figure 1. *Floor area distribution for all surveyed rooms in elementary schools.*

above $100.0\,m^2$. The other library in one of the old schools is similar to the regular classroom with a floor area of $87.8\,m^2$.

Table 3 presents the floor areas in different room types for elementary schools and high schools. Figure 1 and Figure 2 provide the frequency distribution of floor area for all surveyed rooms in elementary schools and high schools, respectively.

In the three surveyed high schools, a total of 15 classrooms, 8 computer rooms, 10 science rooms, 4 art rooms, and 3 libraries with a total floor area of $4040.4\,m^2$ were surveyed. The 15 surveyed classrooms have a mean floor area of $69.6\,m^2$, and the 8 surveyed computer rooms have a mean floor
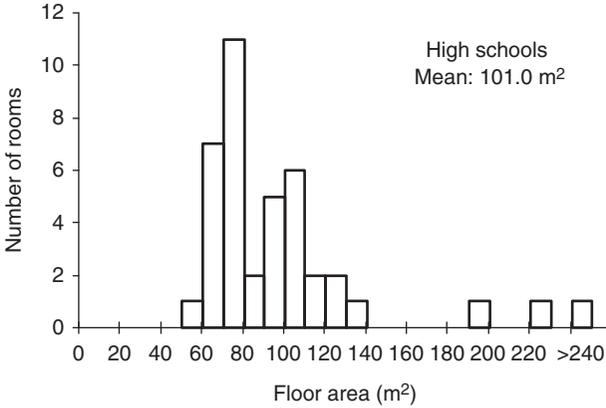
Figure 2. *Floor area distribution for all surveyed rooms in high schools.*

area of $82.6\,\text{m}^2$. The standard deviation for classrooms in high schools is $4.2\,\text{m}^2$, which is very low and much lower than that in elementary schools. The standard deviation for computer rooms in high schools is $18.9\,\text{m}^2$, which is close to that in elementary schools.

The 10 surveyed science rooms in high schools have a mean floor area of $104.7\,\text{m}^2$ and the 4 surveyed art rooms in high schools have a mean floor area of $116.2\,\text{m}^2$. Both of them are about $22\text{--}34\,\text{m}^2$ larger than the mean floor area for computer rooms in high schools and much larger than that for classrooms in high schools. The standard deviation for science rooms and art rooms are $10.6\,\text{m}^2$ and $17.4\,\text{m}^2$.

The three surveyed libraries in high schools have a mean floor area of $274.6\,\text{m}^2$ with a minimum value of $195.6\,\text{m}^2$ and a maximum value of $400.8\,\text{m}^2$. All of the three libraries in high schools have a larger floor area than those in elementary schools.

AREA OF WINDOWS

The window areas of the surveyed rooms were measured and recorded on site. Windows considered include windows towards the exterior, an atrium or a corridor, and glass windows on, above, or beside the doors. All of the glass window areas in a room were added together, and counted as the area of windows for that room. The characteristics of window areas in different room types for elementary schools and high schools are presented in Table 4.

In the surveyed elementary schools, the 20 surveyed classrooms have a mean window area of $13.8\,\text{m}^2$ with a minimum value of $7.0\,\text{m}^2$, a maximum value of $23.4\,\text{m}^2$, and a standard deviation of $5.1\,\text{m}^2$. The three surveyed

Table 4. Characteristics of window area in different room types.

| Surveyed rooms	Samples	Window area of surveyed rooms (m²)			
		Minimum	**Maximum**	**Mean**	**Standard deviation**
Elementary schools					
Classrooms	20	7.0	23.4	13.8	5.1
Computer rooms	3	8.2	25.6	14.2	9.9
Libraries	4	20.3	94.0	43.7	33.9
All elementary schools	27	7.0	94.0	18.3	16.6
High schools					
Classrooms	15	5.7	13.8	9.1	2.6
Computer rooms	8	8.6	18.6	13.2	3.1
Science rooms	10	3.5	20.0	11.4	5.7
Art rooms	4	9.6	24.1	18.0	6.5
Libraries	3	15.5	65.1	35.6	26.1
All high schools	40	3.5	65.1	13.4	9.9

computer rooms have a mean window area of $14.2\,m^2$ with a minimum value of $8.2\,m^2$, a maximum value of $25.6\,m^2$, and a standard deviation of $9.9\,m^2$. The two sets of data for classrooms and computer rooms in elementary schools are quite close. The four surveyed libraries in elementary schools have a mean window area of $43.7\,m^2$, and one of them, the new school with a building age of 5 years, has a very large window area of $94.0\,m^2$. The standard deviation of window areas for libraries in elementary schools is $33.9\,m^2$. Figure 3 shows the frequency distribution of window areas for all surveyed rooms in elementary schools.

In the surveyed high schools, the 15 surveyed classrooms have a mean window area of $9.1\,m^2$, and the 8 surveyed computer rooms have a mean window area of $13.2\,m^2$. The surveyed science rooms in high schools have a mean window area of $11.4\,m^2$, which is slightly lower than that for computer rooms and slightly higher than that for classrooms in high schools. The surveyed art rooms in high schools have a mean window area of $18.0\,m^2$. The standard deviations for classrooms, computer rooms, science rooms, and art rooms are 2.6, 3.1, 5.7, and $6.5\,m^2$, respectively.

The three surveyed libraries in high schools have a mean window area of $35.6\,m^2$ with a minimum value of $15.5\,m^2$ and a maximum value of $65.1\,m^2$. All of these three values for libraries in high schools are lower than those in elementary schools. The reason is the largest window area surveyed in the new elementary school. The standard deviation of window areas for libraries in high schools is $26.1\,m^2$, which is lower than that in elementary schools. Figure 4 shows the frequency distribution of window areas for all surveyed rooms in high schools.
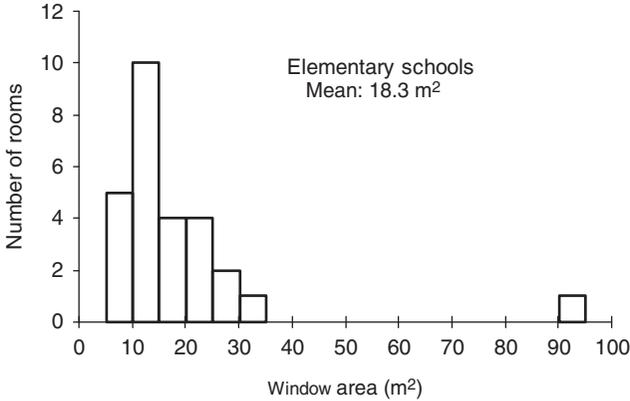
Figure 3. *Window area distribution for all surveyed rooms in elementary schools.*
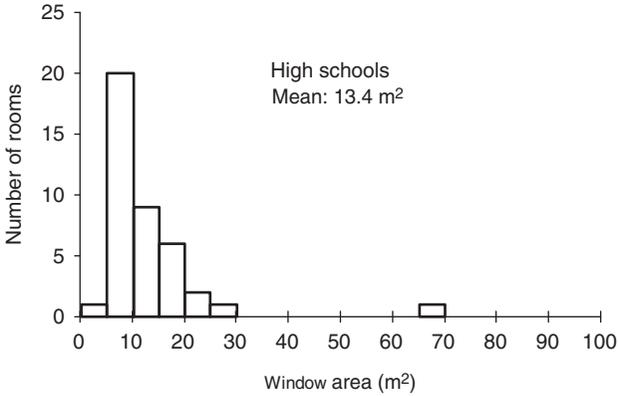
**Figure 4.** *Window area distribution for all surveyed rooms in high schools.*

PERCENTAGE OF FLOOR AREA COVERED BY FURNISHINGS

The percentage of floor area covered by furnishings in a surveyed room was derived by measuring the maximum horizontal occupied area of furniture, electronics, and other movable objects, including metal file cabinets, chairs, and plastic bins and baskets that are not above or under other furniture. The carpets and rugs were not considered. Table 5 provides the percentage of floor area covered by furnishings in different room types for elementary schools and high schools.

All of the surveyed room types can be divided into three groups in terms of the mean values of the percentage of floor coverage by furnishings. The first group with higher mean values of percentage of floor coverage can

Table 5. Percentage of floor coverage by furnishings in different room types.

Surveyed rooms	Samples	Percentage of floor coverage (%)			
		Minimum	Maximum	Mean	Standard deviation
Elementary schools					
Classrooms	20	22.3	42.6	32.8	5.3
Computer rooms	3	33.6	45.4	41.2	6.6
Libraries	4	21.8	36.2	28.0	6.0
All elementary schools	27	21.8	45.4	33.0	6.3
High schools					
Classrooms	15	24.6	32.5	27.8	2.2
Computer rooms	8	32.8	48.6	40.4	5.0
Science rooms	10	31.4	42.5	38.3	3.9
Art rooms	4	37.8	44.5	40.8	2.8
Libraries	3	18.3	36.7	26.0	9.5
All high schools	40	18.3	48.6	34.1	7.2
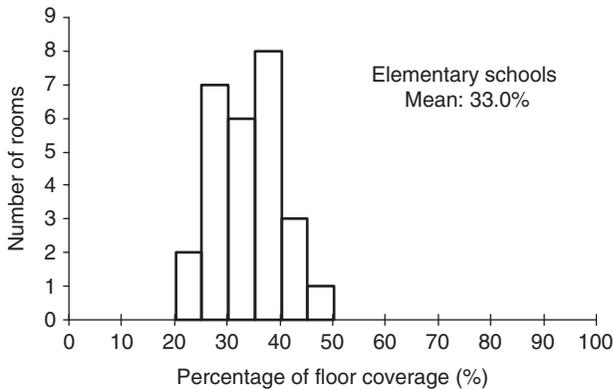
Figure 5. *Distribution of floor covering for all surveyed rooms in elementary schools.*

be found in 4 room types. They are the surveyed computer rooms in both elementary schools and high schools, and science rooms and art rooms in high schools with the mean values from 38% to 41%. The second group is the classrooms in elementary schools with a mean value of 32.8%. The other three room types, classrooms in high schools, and libraries in both elementary schools and high schools consist of the third group with lower percentage of floor coverage from 26–28%. All of the standard deviations are within 10%. Figure 5 and Figure 6 present the frequency distribution of the percentage of floor area covered by furnishings for all surveyed rooms in elementary schools and high schools, respectively.
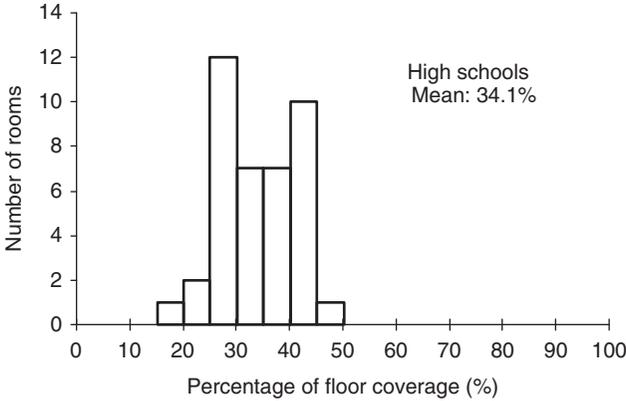
Figure 6. *Distribution of floor covering for all surveyed rooms in high schools.*

From the literature, the mean values of percentage of floor coverage was about 27% for offices, and could be as high as 33% for special function offices, such as drawing offices and machine rooms [4]. Except for hotel living rooms having a mean value of 28.4%, and bedrooms with 2 beds in suite hotels having a mean value of 47.1%, all other types of guest rooms in motels and hotels have an average percentage of floor coverage in the range from 33% to 35% and from 38% to 42% [12].

FIRE LOAD DENSITY

Total fire load density includes fixed fire load density and moveable fire load density. The major impact on the fixed fire load density could be the building age, but no direct correlation was found with age since many old schools may have been renovated more than once. The renovation of old buildings was also noticed in the fire load survey of historic buildings [16]. Among all of the surveyed schools, only one elementary school with a building age of 100+ years had wooden floors. Some of the old schools have replaced the wooden doors with metal doors. In the surveyed schools, the moveable fire load density was higher than the fixed fire load density. The room use has a major impact on the total fire load density or moveable fire load density. This was also found in previous fire load surveys in office buildings and residential buildings [5,6,9].

Table 6 presents the moveable and total fire load density in different room types in the surveyed schools. The values of moveable and total fire load density are not only influenced by the room use, such as classrooms and computer rooms, but are also related to the type of school, such as elementary school and high school. It was also found in motels and hotels

Table 6. Moveable/Total fire load density in different room types.

Surveyed rooms	Moveable fire load density (MJ/m^2)				Total fire load density (MJ/m^2)			
	Min.	Max.	Mean	SD*	Min.	Max.	Mean	SD*
Elementary schools								
Classrooms	174.4	483.3	303.9	79.5	253.9	541.9	397.5	87.1
Computer rooms	172.8	233.7	211.4	33.6	233.5	506.5	331.5	151.9
Libraries	357.1	684.6	545.8	157.8	386.8	944.7	641.1	244.0
All elementary schools	172.8	684.6	329.5	129.9	233.5	944.7	426.3	151.5
High schools								
Classrooms	70.3	340.3	137.2	70.0	117.2	413.6	192.6	84.0
Computer rooms	136.6	348.2	201.0	71.9	178.9	391.2	241.1	71.3
Science rooms	269.9	461.8	336.0	63.8	314.9	487.4	379.5	57.2
Art rooms	368.3	595.9	490.7	93.5	401.4	622.5	544.4	101.1
Libraries	431.7	653.7	537.8	111.3	471.0	714.5	586.2	122.3
All high schools	70.3	653.7	265.1	155.9	117.2	714.5	313.7	157.3

*SD – standard deviation.

that the same type of guest rooms, such as bedrooms with two beds, had different fire load densities depending on the type of motels, standard hotels, luxury hotels, and suite hotels [12].

The mean values of moveable and total fire load density for classrooms in elementary schools are 303.9 and 397.5 MJ/m^2, respectively, which are about two times higher than those in high schools where the corresponding values are 137.2 MJ/m^2 and 192.6 MJ/m^2. The Swedish data [13] also show that the average values of variable fire load density (moveable fire load density) in schools are 295 MJ/m^2 for junior level, 340 MJ/m^2 for middle level, and 215 MJ/m^2 for senior level. Both the data derived from this survey and the previous Swedish data illustrate that teachers in elementary schools or junior/middle level schools may like and/or need to bring more teaching aid items and personal items into the classrooms than their colleagues in high schools or senior level schools.

Computer rooms have nearly the same mean values of moveable fire load density in elementary schools and high schools, with values of 211.4 and 201.0 MJ/m^2, respectively. The mean value of total fire load density for computer rooms in elementary schools is higher than that in high schools, due to the higher fixed fire loads in elementary schools. Science rooms and art rooms were only found and surveyed in high schools. Both room types have higher mean values of moveable and total fire load density than the computer rooms in elementary schools and high schools. It is interesting to note that the mean values of moveable and total fire load density for science rooms of 336.0 and 379.5 MJ/m^2, respectively, are close

to those for classrooms in elementary schools. The mean values of moveable and total fire load density for art rooms are 490.7 and 544.4 MJ/m^2, respectively, which are about 155–165 MJ/m^2 higher than those for science rooms.

In the surveyed science rooms, no chemicals were found, but either a specific storage room or several small rooms beside the science rooms were used to store chemicals in the surveyed schools. Storage rooms were not included in this survey, because they were found to be always closed. In all of the four surveyed art rooms, there was a corner having a highly concentrated fire load with many combustible items, such as painting boards and drawing paper, which needs to be addressed in a fire safety design. This may result in a growing fire reaching flashover faster than if the combustibles were equally distributed over the room. No previous data on fire load density for computer rooms, science rooms, and art rooms has been found.

Similar to computer rooms, libraries in elementary schools and high schools have nearly the same mean values of moveable fire load density at about 540 MJ/m^2. The mean value of total fire load density in elementary schools is higher than that in high schools. The maximum total fire load density is 944.7 MJ/m^2, which was found in the old elementary school with a wooden floor. These values are lower than the published data for libraries, e.g., a mean total fire load density of 1750 MJ/m^2 from [13]. The reason could be that less wood is now used than before, such as metal components used in some of the bookshelves, metal carts for books, and desks and chairs with metal frames. Another reason could be that libraries may have fewer books than before, due to the use of computers and the internet. Some libraries, especially in high schools, have a corner space for computers, which could have been the space for bookshelves before. It was also noted that the new 5-year-old elementary school building had a larger floor area but fewer books than other school libraries. The librarian mentioned that more books will be accumulated with time.

Figure 7 presents the mean values and 95th percentile values[1] of the total fire load density in different school room types. The two highest 95th percentile values of total fire load density are 910.7 and 700.3 MJ/m^2, both of which were found in libraries, one for elementary schools and one for high schools, respectively. The two lowest 95th percentile values of total fire load density are 358.8 and 373.4 MJ/m^2, both of which were found in high schools, with one for computer rooms and one for classrooms. The other 95th percentile values of total fire load density from higher to lower are 620.4, 541.0, 481.3, and 456.5 MJ/m^2 for art rooms in high schools,

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[1]95th percentile means that there is a 95% chance that the actual fire load is the same or less than this value.

classrooms in elementary schools, computer rooms in elementary schools, and science rooms in high schools, respectively.

Table 7 provides the total fire load density in terms of different combustibles and different schools and room types. Except for the libraries
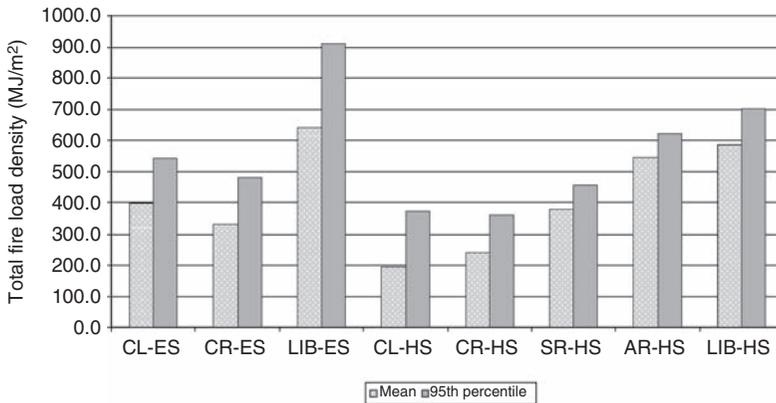

Figure 7. *Total fire load density in different school room types*.*
* ES: elementary schools; HS: high schools; CL: classrooms; CR: computer rooms; LIB: libraries; SR: science rooms; AR: art rooms. (The color version of this figure is available online.)

Table 7. Total fire load density in different combustibles and different room types.

Categories		Wood (MJ/m²)	Plastic (MJ/m²)	Textile (MJ/m²)	Paper (MJ/m²)	LR* (MJ/m²)	Total (MJ/m²)
CL-ES*	Mean	275.8	48.9	4.0	67.8	0.99	397.5
	% Contribution	69.4	12.3	1.0	17.1	0.25	100.0
CR-ES	Mean	246.1	70.1	1.7	13.0	0.56	331.5
	% Contribution	74.2	21.2	0.5	3.9	0.17	100.0
LIB-ES	Mean	265.9	13.4	18.7	342.8	0.33	641.1
	% Contribution	41.5	2.1	2.9	53.5	0.05	100.0
CL-HS	Mean	111.3	40.5	0.9	39.8	0.08	192.6
	% Contribution	57.8	21.0	0.5	20.7	0.04	100.0
CR-HS	Mean	164.3	68.2	0.6	7.9	0.06	241.1
	% Contribution	68.2	28.3	0.2	3.3	0.03	100.0
SR-HS	Mean	302.1	36.0	0.2	41.1	0.02	379.5
	% Contribution	79.6	9.5	0.1	10.8	0.00	100.0
AR-HS	Mean	418.7	49.3	1.4	75.0	0.03	544.4
	% Contribution	76.9	9.1	0.3	13.8	0.01	100.0
LIB-HS	Mean	186.9	9.5	24.5	365.2	0.00	586.2
	% Contribution	31.9	1.6	4.2	62.3	0.00	100.0

*ES: elementary schools; HS: high schools; CL: classrooms; CR: computer rooms; LIB: libraries; SR: science rooms; AR: art rooms; LR: leather and rubber.
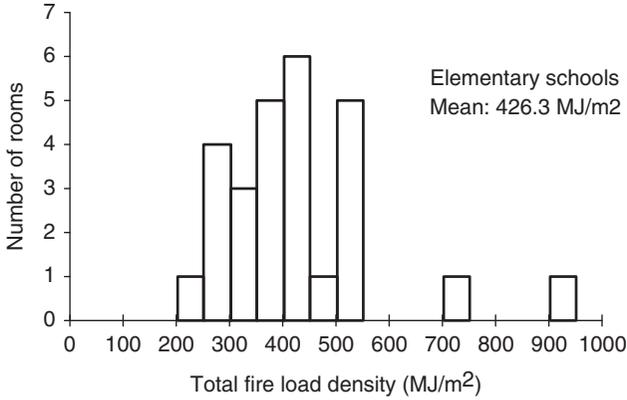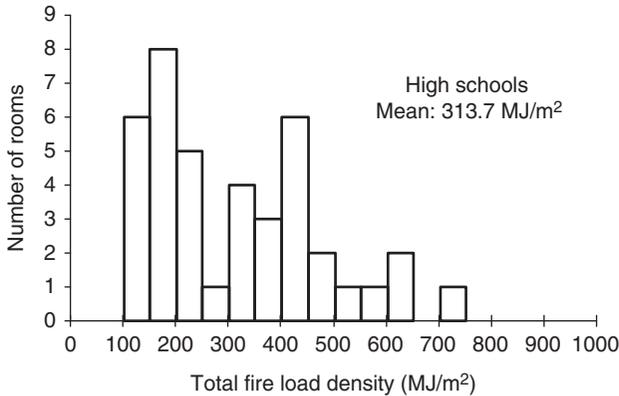
Figure 8. *Distribution of total fire load density for all surveyed rooms in elementary schools.*

in elementary schools and high schools, wood provides the highest contribution to the total fire load density in all of the other surveyed rooms. In all of the surveyed libraries, wood also provides a high contribution to the total fire load density, but the highest contribution is from paper at 53.5% for elementary schools and 62.3% for high schools. The surveyed computer rooms have the highest contribution of plastic to the total fire load density with values of 28.3% for high schools and 21.2% for elementary schools. The classrooms in high schools also have a high contribution of plastic at 21.0%, due to the lower percentage of wooden furniture used in the high school classrooms than that in elementary school classrooms. Textile, leather, and rubber have a lower contribution to the total fire load density at values below 5% for all of the surveyed rooms.

The frequency distribution of total fire load density for all surveyed rooms in elementary schools and high schools is presented in Figure 8 and Figure 9. In the surveyed elementary schools, more samples have fire load density between 350 and 450 MJ/m^2 and between 500 and 550 MJ/m^2. In the surveyed high schools, the samples are concentrated in two areas: one between 100 and 250 MJ/m^2 and the other between 400 and 450 MJ/m^2. The frequency of total fire load density in elementary schools shows a normal distribution and the frequency of total fire load density in high schools is close to a log-normal distribution.

CONCLUSIONS

This article presents the results of a fire load survey, conducted in four elementary schools and three high schools in Canada's capital city, Ottawa. The survey also includes the floor area, window area and percentage of floor

Figure 9. *Distribution of total fire load density for all surveyed rooms in high schools.*

area covered by furnishings, because of their impact on fire severity. Based on this survey and data analysis, some conclusions can be drawn and listed as follows:

(1) The mean floor area for all surveyed rooms in elementary schools is $84.2\,m^2$ and in high schools, $101.0\,m^2$. The mean floor areas for libraries, art rooms, and science rooms are above $100.0\,m^2$, and those for computer rooms and classrooms are in a range from 70 to 83 m^2. The average size of classrooms in elementary schools is larger than that in high schools.

(2) The classrooms, computer rooms, and science rooms have mean values of window area in the range of $9–14\,m^2$, and the average window area for art rooms is a little larger, at $18.0\,m^2$. Libraries have the largest window areas, with a mean value of $43.7\,m^2$ for elementary schools and $35.6\,m^2$ for high schools.

(3) The mean percentage of floor area covered by furnishings is nearly the same for elementary schools and high schools, with values of 33.0% and 34.1%, respectively.

(4) The average value of the total fire load density for all the surveyed rooms in elementary schools is $426.3\,MJ/m^2$, and that for high schools is $313.7\,MJ/m^2$. The standard deviations are 151.5 and $157.3\,MJ/m^2$, respectively. Libraries have the highest mean values and 95th percentile values of total fire load density, and other room types from higher value to lower value are art rooms in high schools, classrooms in elementary schools, computer rooms in elementary schools, science rooms in high schools, and computer rooms and classrooms in high schools.

(5) Wood provides the highest contribution to the total fire load density in most of the surveyed rooms, except for libraries, where paper has the highest contribution, above 50%, and wood has the second highest

contribution from 32% to 42%. The surveyed computer rooms and classrooms in high schools have the highest contribution of plastic to the total fire load density. Textile, leather, and rubber have a lower contribution to the total fire load density at values below 5% for all of the surveyed rooms.

(6) The frequency of total fire load density in elementary schools shows a normal distribution, and the frequency of total fire load density in high schools shows a log-normal distribution.

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