

## RESEARCH ARTICLE

# Fire Loads Calculation in The School Library: A Case Study

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**ABSTRACT** - A combustible material is one of fire hazard where the number of combustible materials or fire load could affect the heat release and fire severity in enclosure. A library is a facility where books and information sources are kept. People can reach them more easily for a variety of reasons such as knowledge. As the library is full of combustible materials such as books, the probability of fires happening there is high. The awareness of the danger of fire caused by fire load is low because most people think that the occurrence of fire in the school library is low. Therefore, this research objectives aim to identify the types of fire loads that are present in the library and to determine what type of fire load has the highest contribution to fire hazard. The determinations of fire load were conducted by using combination of fire load survey method, weighing and inventory method. In this study, the paper is higher than other combustible material that is 27705.6 MJ and the total of fire load density of the library is 234211.9 MJ/m<sup>2</sup> that is fall under high class of fire. Result from fire load survey can help to determine the sufficient requirements of fire suppression in school library as well as fire fighters' intervention strategy. Furthermore, this study contributes to fire risk assessment towards life safety, property, and environmental damage thus improving the fire safety measures and preparedness in educational settings.

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## 1. INTRODUCTION

Educational institutions are growing rapidly in recent decades in the world, which brings challenges to fire protection in view of high occupant load and high fire load. Schools are high-risk type of facilities in fire emergencies. This requires implementing safety measures, including administrative and operational efforts to minimize the occurrence of fire accidents for example by implementing a fire safety management in school facilities [1]. In order to improve learning outcomes in educational setting, the learning space design has become part of the factors that is significantly influence the academic achievements, however it should be in line with the health and safety concern. In addition, Chao et al., [2] discovered that the physical environment of learning spaces can have impacts on student safety and health. According to a statistics of fire accidents, there is a significant number of fatalities and injuries worldwide that were contributed by a fire occurred in schools. The factors that contribute to these cases are the large number of users and the availability of different type of combustible such as wood furniture, papers, class decoration and chemicals used in science laboratories [3]. A fire load survey is the direct method of gathering related data that can be used as a basis for the design fire in fire risk assessment. In addition, a suitable and reasonable design fire should be based on the fire load of the structures under consideration for the adequateness of fire safety system, and the features of the fire load rely significantly on occupancy and building uses [4]. There is a large volume of published studies describing the role of total energy released by the combustion of all combustible materials in the enclosure, which is known as the fire load, expressed in MJ unit. This study offered a result on fire load and fire load density for the school library which is rarely discussed to estimate the potential severity of a fire and implement control measures to minimize losses and damage. With this result calculation of fire load, firefighters and other safety professional will use the fire load calculation results to assess the potential severity of a fire in a particular area. This fire load can also be used to design a fire emergency structure that is adequate for any building or area.

## 2. METHODS AND MATERIAL

### 2.1 Qualitative Method and Descriptive Method

Various techniques for estimating the weight of each combustible object are employed, including weighing, inventory assessment, a combination of weighing and inventory, as well as previous journal and website analyses [4]. The following are the data survey methods:

- Combination Method - Mass is obtained by opting for both the weighing method and the inventory method.
- Weighing Method - Direct weighing method is a simple way to obtain the weight of the items. This method applies to movable materials while for fixed combustibles, this method is impractical.

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- c) Inventory Method - inventory method is used by measuring the object's dimensions, and then calculating the weight by multiplying the measured volume by the corresponding density. This method is useful for items that cannot be weighed.
- d) Website review technique - for the combustible weight that cannot be measured by inventory and direct method, the weight of the items is taken from the website according to the type and size of the items.

This study uses a quantitative method where the data were collected from journals and articles to achieve the objective of this study. The articles and journals were used as reference material to do the calculation for estimating the fire load. In addition, a descriptive method such as the inventory and observation method, were also utilized in calculating the fire load. A school library for secondary school was selected for this study where the building consists of student section, books section, and library staff office. The total area of the library is 125535.57 square meters (m<sup>2</sup>). The materials that presented in this library are books, journal, steel racks and reading table. All the materials that present in the library were calculated to find the fire load.

## 2.2 Fire load and Fire Load Density

The total amount of heat energy (MJ) that can be released during complete combustion is known as the fire load (FL) in a compartment, and it is frequently stated as the energy density per square meter of floor space (MJ/m<sup>2</sup>). Fire load density (FLD) measures a fire's severity by how likely it is to spread to an entire building or area within a given amount of time.

$$\text{Fire Load, FL} = \text{Sum of all combustible mass (kg)} \times \text{calorific value of combustible} \left( \frac{\text{MJ}}{\text{kg}} \right) \quad (1)$$

$$\text{Fire Load Density, FLD} = \frac{\text{Sum of all combustible mass (kg)} \times \text{calorific value of combustible} \left( \frac{\text{MJ}}{\text{kg}} \right)}{\text{Floor are of compartment (m}^2\text{)}} \quad (2)$$

Fire load calculated by using weighing method is based on measured weight of combustible material multiply with its corresponding calorific value as shown in Equation 1. Weights of items can be obtained by directly weighted the items or pre-weighted items. The calorific value of different items and materials are presented in Table 1. Fire loads were calculated from the masses of the items with their corresponding calorific value as similar as weighting method. Meanwhile, to calculate the fire load density (MJ/m<sup>2</sup>) in Equation 2, the area in the library were measured. Fire loads divided into two categories: fixed fire load and movable fire load. Cabinet, wall, ceiling, and floor are classified under fixed fire load while books and other reading materials considered as moveable fire load.

Table 1. Calorific value

Materials	Paper	Wood	Plastic	Computer	Printer	Steel	Leather (sofa)
Calorific value (MJ/kg)	13.5	14.4	40	491.67	145.90	6.58	15.7
Calorific value (Kcal/kg)	3244.4	3439.4	9553.8	117512.2	34871.5	1574.0	3749.9

## 3. RESULTS AND DISCUSSION

### 3.1 Types of Fire Load

The main source of fire threat is the fire load. There are several types of fire load materials that are present in the library such as wood, steel, paper, plastic, computer, printer, and leather. According to Figure 1, the paper has the highest fire load and the leather which is sofa has very low fire load in the library. Because paper is the highest, so in the event of a fire, paper will be the first to burn and it can cause a fire to occur quickly and can also increase the severity of building damage. The library consists of a variety of combustible materials such as fire load and fire load surveys to obtain information on the fire load or fire load density of a certain type of building. The fire load itself can represent the total energy content present in the compartment. Fire loads and densities were analyzed to determine the need for firefighting equipment.

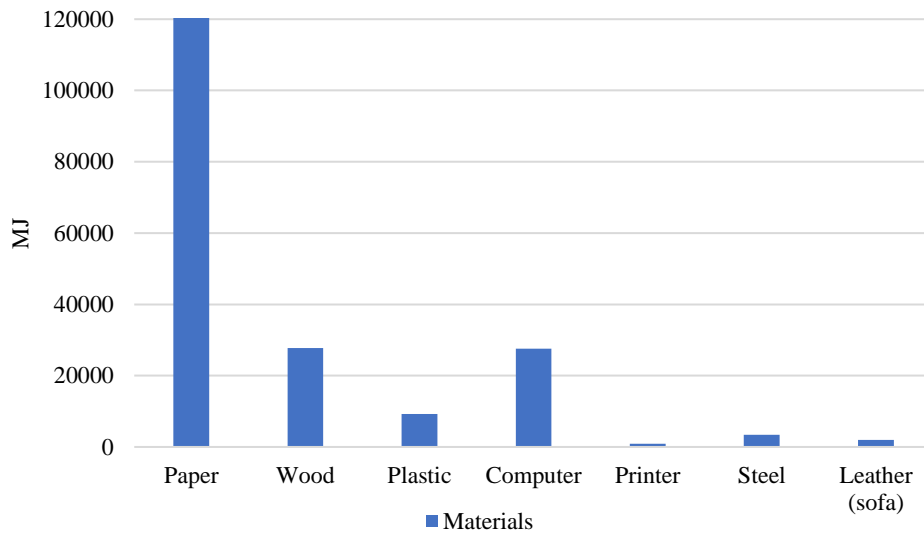


Figure 1. Fire load of combustible materials

### 3.2 Amount of Fire Load and Fire Load Density

More information that characterizes the buildings surveyed should be collected, in order to get a more rational design fire [5]. The fire loads materials such as wood, steel, paper, plastic, computer, printer and leather are 27705.6 MJ, 3428.18 MJ, 163460.7 MJ, 9246 MJ, 27533.52 MJ, 875.4 MJ and 1962.5 MJ, respectively. From Figure 1, the paper is higher than other combustible material. Fire load density ( $\text{MJ/m}^2$ ) is an important parameter in determining the design fire which indicates the total heat energy per area that will be released through complete combustion of all combustible within a compartment. It represents the severity of fire in terms of its tendency of area or building fire reach fully developed fire in specific duration.

The bigger number of the fire load inside the building or close space and the rate at which it burns are the two key factors that affect how long a fully established fire last [6]. Greater burning times due to higher fire load values increased the risk of property damage [7] and structural liability [8]. Therefore, it is essential to calculate the fire load density of combustible materials into buildings. In this study, the total of fire load density of the library is  $234211.9 \text{ MJ/m}^2$  that is falls under high class of fire. Previous researchers had concluded Fire Load Density (FLD) less than  $11513.7 (\text{MJ/m}^2)$  fall under low class of fire based on Table 3.

Table 3. Classes of fire based on fire load density

Class of Fire	Fire load density ( $\text{MJ/m}^2$ )
Low	$< 11513.7 \text{ MJ/m}^2$
Medium	$11513.7 \text{ MJ/m}^2 - 23027.4 \text{ MJ/m}^2$
High	$> 23027.4 \text{ MJ/m}^2$

The duration of a fully developed fire mainly depends on the amount of fire load in the enclosure and the fire burning rate [9]. Office building with FLD  $520 \text{ MJ/m}^2$  literally could reach fully developed fire with 90 minutes of burning duration after ignition [10] while compartment with  $680 \text{ MJ/m}^2$  of FLD (wood) burned for almost 110 minutes [11]. Higher value of fire load caused longer burning duration, thus resulted in higher potential of property's damage [12] and structure liability [11]. Hence it is crucial to estimate and control the loading of combustible materials as a fire load in building. Previous researchers had concluded average FLD for residential is  $500 \text{ MJ/m}^2$  [13], high rise residential  $1400 \text{ MJ/m}^2$  due to small average living area[14], [12], hotel  $560 \text{ MJ/m}^2$  [15]office range from  $348 \text{ MJ/m}^2$  to  $1321 \text{ MJ/m}^2$  [16] and shop  $600 \text{ MJ/m}^2$ .

## 4. CONCLUSION

This paper reports the fire load is calculated by using a combination method. The combination method is defined as the combination of both inventory and direct methods. As for non-movable materials such as a reading table, counter table and steel rack, the weight of the materials is calculated by inventory method. For movable materials like books and journals, the weight of the materials is calculated by the direct weighing method. The total fire load density is  $234211.9 \text{ MJ/m}^2$ . In order to reduce the amount of fire load, regular inspection and fire protection systems such as sprinkler systems, smoke detection, and so on are needed in reducing the fire risk. The result from this study which is the result of calculating of fire load will help to provide an adequate and suitable fire protection system based on the fire load. With this calculation of fire load, firefighters and other safety experts will use this fire load calculation to evaluate the potential severity of a fire in a particular area. This fire load can also be used to design a fire emergency structure that is adequate for any

building or area. It can also be used to determine the risks. According to fire load in terms of fire hazard it presents, various elements should be considered like the quantity of combustible materials, the distribution the premises, how flammable the materials are, the potential smoke production and potential spread rate of surfaces flames. From the survey at the school library, movable material like books and paper is high in the library. The only suitable way is to introduce proper safety management such as fire action plan and fire protection plan. The provision and use of fire suppression systems such as sprinkler systems drastically can reduce the impact of fire load on design.

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## CONFLICT OF INTEREST

The authors declare no conflicts of interest.

## AUTHORS CONTRIBUTION

N. I. Ab Razak (Methodology, Formal Analysis, Data curation, Writing- original draft

N. S. Suhaimi (Conceptualization; Supervision, Writing- review& editing)

W. Z. Wan Sulaiman (Supervision; Writing – reviewing & editing)

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