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بسم الله الرحمن الرحيم

عناوين الأبحـــاث

- Unlocking the Cholesterol Content: A Comprehensive Analysis of Cholesterol Levels in Dairy Products, Fats, and Oils Through High-Performance Liquid Chromatography
  Mokhtar S. S. Al - Salimi-Fares S. S. Al-Saidi - Adel A. M. Saeed
- Bilateral Generating Functions for the Two-Parameter, Three-variable Srivastava polynomials
  Dr. Salem Saleh Barahmah
- A new extended beta function involving generalized mittag-leffler function and it's Applications
  Dr. Salem Saleh Barahmah
- تربية و زراعة بعض أنواع النحل البري الملقح لطيف واسع من النباتات
  أ.د عبدالسلام محمد - Prof:Abdoalsalam mohamed gaool Al-Hjry
- مقال بحثي في كيمياء تحليل البيئة
  دراسة بعض الصفات الفيزيوكيميائية والملوّثات غير العضوية للمياه العادمة النّاتجة من مدبغة لودر للبيئة المجاورة
  جمال أحمد عبدالله الدهبلي - علي ناصر أحمد الكوم - عادل أحمد محمّد سعيد
- Flora Abyan governorate
  Abdul-Nasser Al-Gefr1i
- Investigation of the Absorbing the Crash Impact of Car Accedient Due Tube Inversion
  Eng. Abdulhakim Hamood Ahmed Abdulwahid-Dr. Fawaz Ahmed Ghaleb Noman-Eng. Nezar Nasser Ali Haithm
- Investigation of the inside temperature to arrive comfortable condition1: case study Mechanical workshop building
  Dr. Fawaz Ahmed Ghaleb Noman
- FIELD BALANCING FOR SINGLE BLADE FAN
  Eng. Saleel Saeed Abdo - Prof. Dr. Ahmed Saleh Alhunaishi

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INVESTIGATION OF THE INSIDE TEMPERATURE TO ARRIVE COMFORTABLE CONDITION: CASE STUDY MECHANICAL WORKSHOP BUILDING

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Abstract

Mechanical workshops are considered as important buildings in faculty of engineering. It is a place for the students and teachers to get practical experiences and activities. Thermal comfort is an essential requirement in most occupied spaces because it affects the productivity, health and thermal satisfaction of the occupants. Natural ventilation, which may provide occupants with good indoor thermal comfort, and reduce energy costs, has become an important sustainable strategy in building designs. Most of the mechanical workshop buildings in countries with a hot and humid climate use a combination of natural ventilation and electrical fans are commonly used as a space cooling method to provide thermal comfort to the occupants. This article presents the results of a field measurement study that was conducted on the mechanical workshop building which is locat-ed in Faculty of Engineering, University of Aden, Yemen. The purpose of study is to investigate of the inside temperature to arrive comfortable condition of the Mechanical Workshop Building un-der the present ventilation system. The measurements were recorded within duration of one year, starting from October 2021 to September 2022 on the middle of months. The measured values were then compared to the corresponding limit as specified in the ASHRAE Standard-55. It was found that the inside temperature at the selected locations of the mechanical workshop building exceed the respective upper limits as recommended in the ASHRAE Standard-55. This shows that the existing air ventilation method via the use of natural ventilation and electrical fans in the me-chanical workshop building are not able to provide an adequate level of thermal comfort to the occupants for all the stipulated months. Therefore, an alternative ventilation method is needed to improve the thermal comfort inside the Mechanical Workshop building.

Keywords: Mechanical Workshop Building, Natural Ventilation, Electrical Fan, Inside Temperature, Thermal Comfort, Hot and Humid Climate.

التحقق من درجة الحرارة الداخلية للوصول إلى حاله مريحة: دراسة حالة مبنى الورشة الميكانيكية

الملخص:

تُعَد الورش الميكانيكية من المباني المهمة في كليات الهندسة. كونها مكان للطلاب والأساتذة لإجراء أنشطة أبحاثهم وتجاربهم العلمية. تُعَد الراحة الحرارية مطلبًا أساسيًا في الورش الميكانيكية، لتاثيرها على الإنتاجية والصحة والرضا الحراري للأفراد. وكذالك التهوية الطبيعية استراتيجية مهمة ومستدامة في تصميمات المباني، فهي توفر للأفراد راحة حرارية داخلية جيدة، وتقلل من تكاليف الطاقة. تستخدم معظم مباني الورش الميكانيكية في البلدان ذات المناخ الحار والرطب مزيجًا من التهوية الطبيعية والمراوح ألكهربائية التي تستخدم بشكل شائع كوسيلة لتبريد المباني لتوفير الراحة الحرارية للأفراد. يعرض هذا المقال نتائج دراسة قياس ميدانية أجريت على مبنى الورشة الميكانيكية الواقع في كلية الهندسة، جامعة عدن، اليمن. الغرض من هذه الدراسة تقييم مستوى الراحة الحرارية داخل مبنى الورشة الميكانيكية عن طريق قياس درجة حرارة الهواء في نظام التهوية الحالي. وقد تم تسجيل القياسات خلال عام كامل ابتداء من شهر أكتوبر 2021م إلى شهر سبتمبر عام 2022م. ثم تمت مقارنة القيم المقيسة بالحد المقابل كما هو محدد في معيار **ASHRAE Standard -55.** ووجد أن درجة حرارة الهواء في المواقع المختارة داخل مبنى الورشة الميكانيكية تتجاوز الحدود العليا الخاصة بها على النحو الموصى به في **ASHRAE Standard-55.** هذا يدل على أن طريقة التهوية الحالية من خلال استخدام التهوية الطبيعية والمراوح ألكهربائية في مبنى الورشة الميكانيكية غير قادرة على توفير مستوى مناسب من الراحة الحرارية للأفراد خلال الأشهر المحددة لذلك، وهناك حاجة إلى طريقة تهوية بديلة لتحسين الراحة الحرارية داخل مبنى الورشة الميكانيكية.

الكلمات المفتاحية: مبنى الورشة الميكانيكية، التهوية الطبيعية، المروحة ألكهربائية، درجة الحرارة الداخلية، الراحة الحرارية، المناخ الحار والرطب

الكلمات المفتاحية: مبنى الورشة الميكانيكية، التهوية الطبيعية، المروحة ألكهربائية، درجة الحرارة الداخلية، الراحة الحرارية، المناخ الحار والرطب

1.0 INTRODUCTION

There is a close relation between the thermal comfort and the energy consumption in buildings. Occupants' demand for higher thermal comfort has increased the number of heating and air-conditioning systems installed in buildings. Buildings account for about 40% of the global energy consumption and contribute over 30% of the CO2 emissions [1, 2]. A considerable amount of this energy is consumed in buildings via heating, cooling and dehumidifying to provide thermal comfort. This increasing in energy consumption is worsening in regions with harsh climatic conditions and poses a major challenge in countries having a shortage of electricity such as Yemen. Natural ventilation, which may provide occupants with good indoor thermal comfort, and reduce energy consumption, has become an important sustainable strategy in building designs [3].

The large space halls also known as high span spaces have been constructed in many places worldwide, including Yemen. They are also known as enclosed ventilated air spaces which contain various contaminant and heat sources [4]. Large space constructions such as workshop building, industrial buildings, aircraft hangars, sports halls, mosques, and stadiums are distinguished from other space constructions in terms of their energy consumption [5]. These spaces advance issues that are related to indoor air quality and thermal comfort [6],[7],[8],[9]. A mechanical workshop building is considered as one type of a large space building in faculty of engineering. It is a place of great importance for the students and teachers to perform their practical activities such as welding, product the metal from furnaces test and heat treatment of material…etc. Thermal comfort inside the

Mechanical Workshops building is therefore an important requirement because it affects the productivity, health and thermal satisfaction of the occupants [10]. The thermal comfort and indoor air quality in mechanical workshops building have not been widely studied [11],[12],[13]. There is a lack of in-depth study and analysis of thermal comfort and indoor air quality inside Mechanical Workshops building. Hence, there is a need to conduct such studies for the benefit of the occupants.

Thermal comfort is an essential requirement in most occupied spaces. According to ASHRAE Standard thermal comfort can be defined as “that condition of mind which expresses satisfaction with the thermal environment”. Thermal comfort is determined by evaluating six parameters [14]. Four of the parameters are related to the environment while the other two are related to the human. The environmental parameters are relative humidity (RH), air temperature, (T_a), air velocity (V_a) and mean radiant temperature (T_{mrt}). while the human parameters are clothing and activity levels. According to Markus [15], air temperature is the most important parameter that affects the indoor thermal environment. In this study the evaluation of the thermal comfort inside the mechanical workshop building was performed by measuring the air temperature.

This article presents findings from a field measurement conducted on mechanical workshop building located in Faculty of engineering, university of Aden, Yemen. The study goal is to evaluate the thermal comfort inside the mechanical workshop by measuring the inside temperature. The measurements were recorded within duration of one year, starting from October 2021 to September 2022 on the middle of months. The measured values were then compared to the corresponding limit as specified in the ASHRAE Standard-55.

2.0 FIELD MEASUREMENTS

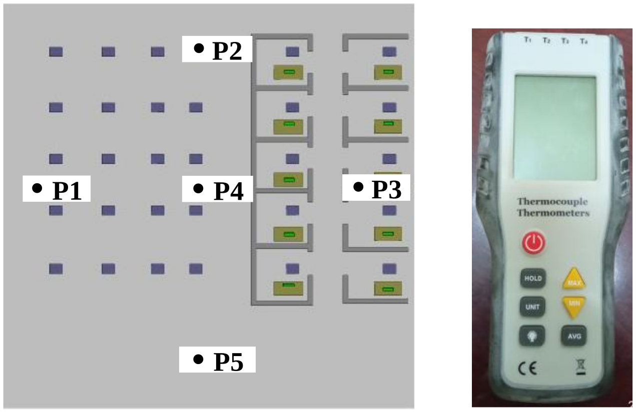
The mechanical workshop building was selected as a case of study for this research. The photo of the mechanical workshop building is shown in **Figure (1a).** It is one of the largest typical mechanical workshops building in faculty of engineering, university of Aden. It was built in the year 2007 and constructed based on rectangular shape with length, L = 13 m, width, W = 10 m and height, H = 6 m. The total built-up area of the hall building is 130 m^2. The hall building of mechanical workshop can be occupied by about 35 people. The walls of mechanical workshop building are built with three doors and eight windows. The mechanical workshop does not use air conditioning system. It rather uses natural ventilation for cooling purposes. The natural ventilation in the mechanical workshop is supported by 9 units of ceiling electrical fans as can be seen in **Figure (1b).**

The purpose of the field measurement is to obtain the values of parameters which influence the level of thermal comfort inside the workshop building. In this study the evaluation of the thermal comfort inside the workshop building was performed by measuring the inside temperature ,which is the most important factor that affects the indoor thermal environment [15].

Figure 1: (a) A photo of the mechanical workshop building; (b) Internal view of the mechanical workshop building.

The inside temperature was acquired at five chosen locations inside the building. These locations were indicated by points P1 to P5 as shown in **Figure (2a)**. The inside temperature at these points was measured at the (1.1 m) height from the ground level. It is decided to be 1.1m because of consideration of human activities like sitting and standing [16, 17]. The measurements were recorded within duration of one year, starting from October 2021 to September 2022 on the middle of months. The data were conducted from 08:00 AM to 16:00 PM with a 30- minutes interval.

Thermocouple Thermometers instruments is used for the measuring inside temperature with accuracy ± (0.4% + 0.5ºC) are shown in **Figure (2b).**



(a) **(b)**

Figure 2: (a) Locations of measuring inside temperature points (P1 to P5) of the Mechanical Workshop, and (b) Thermocouple Thermometers Instruments used for the field measurement.

3.0 RESULTS AND DISCUSSION

Figure (3) shows the inside temperature distribution varies for all month throughout the year from October 2021 to September 2022. It is observed that, higher inside temperature was recorded in the months of May, June and July ranging from 32.4°C to 36.3°C. The inside temperature in the months of October, November, March, April, August and September was moderate and was ranging from 30.0°C to 33.5°C. The lower inside temperature was recorded in December, January and February ranging from 28.3°C to 31.3°C. It can also be observed that the higher inside temperature occurs for all month in the south part of the mechanical workshop (location P3). The inside temperature at the east, middle and west part (locations P2, P4 and P5) was moderate, while the temperature in the north part of the mechanical workshop hall (location P1) is the lowest. It can also be observed that the patterns of inside temperature distribution for all months are the same. June month was chosen to be discussed in details because it has the highest inside temperature ranging from 32.6°C to 36.3°C.

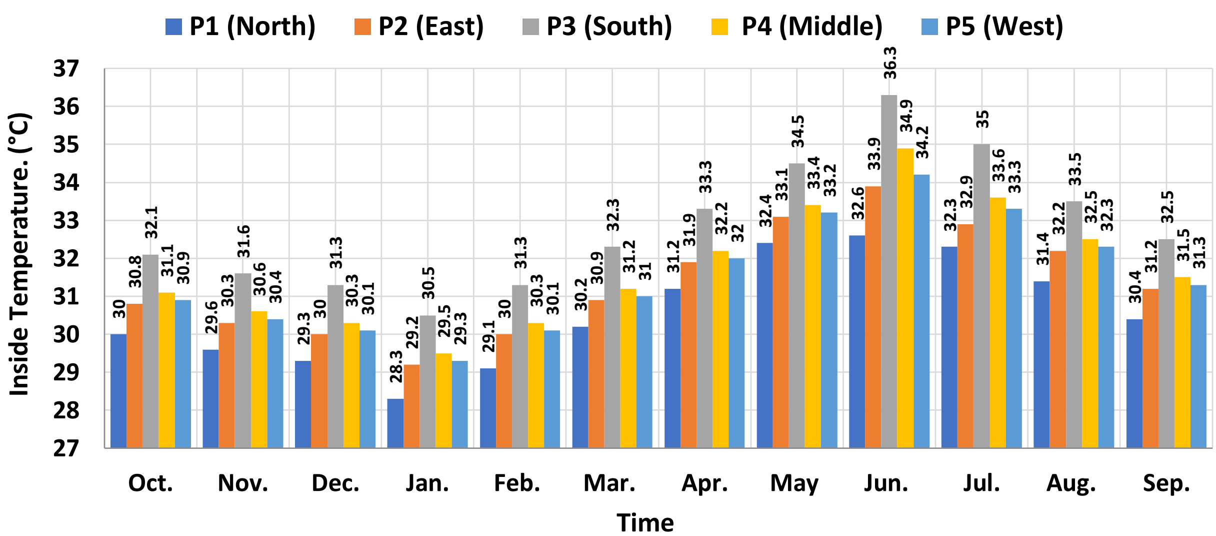


Figure 3: Inside temperature at various locations in the Mechanical Workshop Building from October 2021 to September 2022.

Figure (4) shows the variation of the inside temperature at five selected locations of the mechanical workshop hall from 8:00 a.m. to 6:00 pm in the June month. It can be seen that the inside temperature for at all locations has similar trends, in which increasing and experienced decreasing in the similar period. The temperature follows an ascending order steadily from 8.00 am to 1.00 pm. This is because the inside temperature inside the workshop hall rose gradually due to the solar radiation that is transmitted into the mechanical workshop hall through the roof and vertical wall. However, the inside temperature follows the descending trend after 1.00 pm. This is because of less heat was being transferred to the air inside the mechanical workshop hall due to the reduction in solar radiation intensity as the time elapses. At any given time, the inside temperature in the south region of the mechanical workshop hall (location P3) is the highest while the inside temperature in the other areas (locations P1, P2, P4 and P5) is the lowest. This is because the peoples and welding operations that occupy the mechanical workshop hall release heat from their body to the surrounding air. The highest inside temperature at 1.40 p.m. was about 36.3°C, at location P3, while the lowest inside temperature at this time was 32.6°C, at location P1. This indicates that the inside temperature value in all points inside the mechanical workshop building varies means that the thermal comfort level is not equally distributed. An addition the condition inside the mechanical workshop hall is not quite thermally comfortable to the occupants.

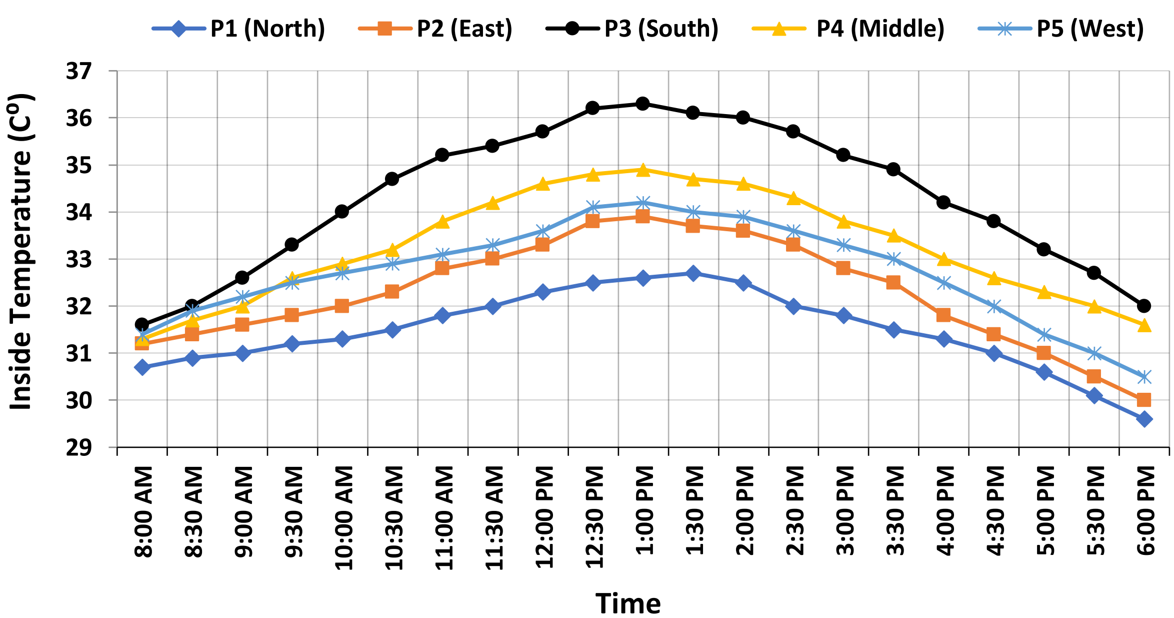


Figure 4: Hourly variation of inside temperature at all data collection locations for June, 2022.

The method executed to assess the level of thermal comfort inside the mechanical workshop building was by comparing the measured inside temperature with the corresponding ranges stipulated in the ASHRAE Standard-55 those in the literatures. **Table 1** shows a comparison between the measured values of inside temperature of the workshop building for all the months, under the present ventilation condition, with the corresponding ranges and stipulated in the ASHRAE Standard-55 [18] and those in the literatures. It can be observed that for all the months, the measured inside temperature of the workshop building is higher and ranging from 28.3°C to 36.3°C which exceeded the acceptable thermal comfort range that is listed in Table 2. This is, on average, about 35% higher than the range of inside temperature recommended in the ASHRAE Standard-55 [18]. This indicates that the condition inside the mechanical workshop building is not quite thermally comfortable to the occupants. This also suggests that the existing air ventilation system is not capable of providing the adequate thermal comfort inside the mechanical workshop building. Statistical Year-Book (2003) suggest that, to achieve the thermal comfort range in a hot humid climate, the inside temperature should be between 25°C and 28°C [19]

Table 1: The comparison of the thermal comfort parameter by various standards with the previous studies

Parameter	Measured inside temperature (°C) in the Mechanical Workshop Building from October 2021 to September 2022												Acceptable range	
													Standards	Literature Review
Inside Temperature (°C)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	ASHRAE Standard [18]	Yemen [19]
	30.0 - 32.1	29.6 - 31.6	29.3 - 31.5	28.3 - 30.5	29.1 - 31.3	30.2 - 32.3	31.2 - 33.3	32.4 - 34.5	32.6 - 36.3	32.3 - 35.0	31.4 - 33.5	30.4 - 32.5	23 - 26	25 - 28

4.0 CONCLUSION

This study presents the results of a field measurement aimed to investigate of the inside temperature to arrive comfortable condition of the Mechanical Workshop Building located in Faculty of engineering, university of Aden, Yemen. The results show that, the measured inside temperature of the workshop building is well outside the recommended limits specified by ASHRAE standard. This shows that the existing methods via the use of natural ventilation and electrical fans in the mechanical workshop building are not able to provide an adequate level of thermal comfort to the occupants for all the stipulated months. Therefore, an alternative method is needed to improve the thermal comfort inside the Mechanical Workshop building.

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