Lecture Notes in Mechanical Engineering

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Proceeding of 5th International Conference on Advances in Manufacturing and Materials Engineering

ICAMME 2022, 9–10 August, Kuala Lumpur, Malaysia

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Preface

The 5th International Conference on Advances in Manufacturing and Materials Engineering (ICAMME 2022) is organized as a part of KOE IIUM Congress 2022 with the aim to provide a platform for knowledge sharing and interchange among researchers, academicians, and industrial expertise in terms of current research and development especially in the advancement of knowledge in Manufacturing Engineering and Materials Engineering.

This conference provides state-of-the-art information on traditional materials and manufacturing technology that are currently placed having limited applications in the industries and/or not meeting the Industry 4.0 on digital technology. This conference, thus, gives opportunity for senior as well as young scientists and academics from different parts of the world who are actively involved with the research in advanced and sustainable material, smart manufacturing, simulation, modeling and management to come together and share their experience on the latest advancements.

We would like to take this opportunity to thank most sincerely the co-organizers, supporters, sponsors, whose support made it possible to success the event and also to award prizes. Many thanks go to the members of the Organizing Committee and the International Advisory Committee and Reviewers who reviewed the conference paper and refereed the papers for the 'Lecture Notes in Mechanical Engineering' (indexed by SCOPUS) for publication.

Finally, sincere thanks go to the authors of the papers. Without their timely submission of manuscripts of high quality, publication of these proceedings would not have been possible.

August 2022

Publication Team
ICAMME 2022

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In Situ Measurement and Remediation of Condensation Issue in Sarawak General Hospital Molecular Lab During COVID 19

Muhammad Syukri Imran Abdullah, Azhaili Baharun, Abdul Malik Zainal Abidin, Noor Muhammad Abd Rahman, and Nyuk Yen Chin

Abstract Sarawak General Hospital Molecular laboratory suffers significant condensation issues particularly above its ceiling due to combination of design and construction shortfall. Overcooling of laboratory and inappropriate selection of insulation were found to be the major contributing factor. The solution was to introduce 50 mm Expanded Polystyrene (EPS) layer as a thermal barrier within the ceiling layers. Two units of dehumidifier with a total capacity of 70L/day were installed at attic level to control humidity to 60%. The corrective measures have been able to reduce the condensation risk greatly by increasing the difference between air dew point and surface temperature of ceiling by 6.7 °C. In general, the rectification work selected was able to minimize the laboratory downtime using a sustainable, environmental and budget friendly material.

Keywords Condensation · Mold · Insulation · Thermal image · Moisture content

1 Introduction

Condensation in building is a complex issue that could contribute to sick building that requires multidisciplinary investigation and environmental monitoring. Extended dampness and periodic condensation can also corrode critical structural fasteners inside walls, floors and roofs of building leading to structural risk [1]. Building condensation issue requires correct approach to determine its root cause and finding

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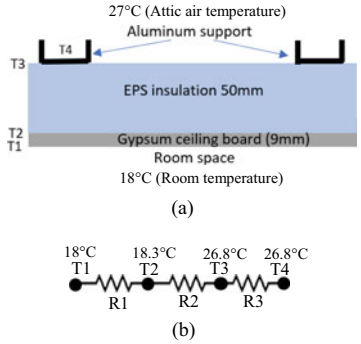
Table 1 List of relevant documented works on condensation assessment, remediation and use of expanded polystyrene

	Author	Main highlights of paper
1	Almeida and Barreira [2]	Methods of in situ measurement
2	Singh, Yu and Kim [3]	Key area and document that should be included in the building assessment
3	Lee and Yeo [4]	Adoption of IoT application such as real time sensors
4	Less et al. [5]	Important points to be considered in building with sealed and insulated attics
5	Harriman [1]	4 methods of quantitative test to identify excessive moisture accumulation
6	Galvin [6]	Removing moisture using dehumidifier in a suburban UK home
7	Cornish et al. [7]	Use of dehumidifiers as remedial measure for occupied dwelling
8	Alam et al. [8]	Performance of Expanded polystyrene (EPS) as building external wall insulation layer
9	Saadatian, Freire and Simões [9]	Life cycle assessment of EPS as building insulation material
10	Tingley et al. [10]	EPS low environmental impact
11	Li et al. [11]	Energy consumption and carbon emission in the material production phase of EPS
12	Barnaure et al. [12]	Advantages of EPS, XPS and mineral wool as building insulation
13	Caglar and Beskirli [13]	EPS inhibits heat bridge, prevents condensation and moisture build up
14	Ramli et al. [14]	How EPS satisfies building insulation requirement and fire safety

the right solution. Table 1 provides list of documented works on condensation assessment and remediation which are relevant in this paper to guide the best solution for similar problem in Sarawak General Hospital (SGH) new PCR lab building.

2 Problem Statement

The new SGH molecular lab ceiling structure had collapsed due to ceiling condensation, improper thermal insulation system and very low indoor room temperature. This paper describes the remediation work taken to ensure safety and minimum downtime.



$$Q = -kA\frac{T_o - T_i}{L} = \frac{T_o - T_i}{R_{th}} \quad (1)$$

Q= heat flux through plane (W)
Ti = Inside layer temperature
To = Outside layer temperature
k = materials conductivity ($W.m^{-1}.k^{-1}$)
L= Plane thickness (m)
A= Plane area (m^2)
R_{th}= material thermal resistance

Fig. 1 Cross section of new ceiling assembly and corresponding thermal circuit

3 Methodology

A site investigation was carried out to identify the cause which have led to the development of condensation and eventually the collapse of ceiling structure. For this purpose, several tools and monitoring instrument were used such as pocket thermal imager, material moisture meter, surface, and air temperature datalogger as well as relative humidity dataloggers. The choice of remedial work is governed by time and budget constraint and the need to reduce laboratory downtime as it is critically required to operate during COVID 19 pandemic surge. 50 mm Expanded Polystyrene (EPS) was proposed as insulation layer in the new gypsum ceiling assembly as it is readily available in the market at low cost. Portable dehumidifiers were also used to control the attic air relative humidity (RH) to 55%. A condensation risk assessment was carried out on the new ceiling assembly as shown in Fig. 1a. Point T1 to T4 represents the change of temperature across the ceiling material layers. The conduction heat transfer formula were used to calculate the temperature gradient between layers of material [15].

Temperature gradient across ceiling material layers for a range of room temperature and attic air temperature combination were calculated. Analysis indicates that surface temperature at T3 and T4 are less sensitive to the cold indoor temperature with the use of EPS insulation over the gypsum ceiling board.

4 Results and Discussion

4.1 Site Assessment Result

Background check of the new lab building reveals that there have been complaints about water dripping off the ceiling from the laboratory staff a few months after it was built. Observation also revealed that water has been accumulating on the U-shaped

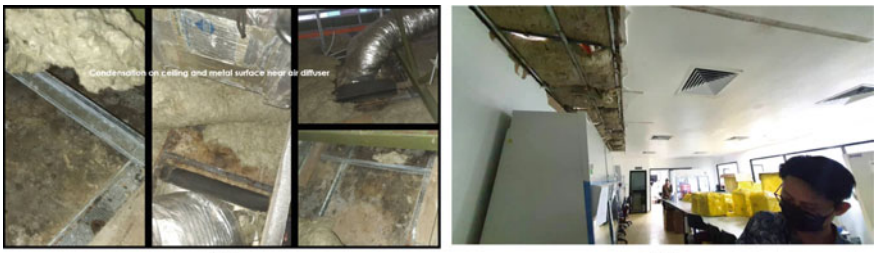


Fig. 2 Incident of ceiling cave in due to heavy condensation build up above ceiling

metal support of the ceiling due to condensation of humid air in the attic as shown in Fig. 2a. The lab indoor air temperature was found to be at 16 °C have led to the over cooling of ceiling board and its metal support. The topside surface temperature of ceiling and metal support was lower than the dew point temperature of the attic air at time of measurement. The attic area RH was nearly 100% particularly at night-time since the attic was leaky and not sealed entirely. The ceiling finally collapsed as shown in Fig. 2b.

Thermal camera scanning also confirms the cold surface condition of the ceiling topside ranging between 16 °C and 21 °C. The original rockwool insulation layer which was placed loosely above the ceiling have failed to prevent the condensation. Furthermore, rockwool is a breathable material which allow air vapor to pass through it [16]. Material moisture check also revealed high level of water content up to 48% that exceeded the recommended limit of 15%.

4.2 Remediation Work and Monitoring

Remediation work took about 7 working days to complete. Primary solution includes the installation of EPS on top of ceiling and deploying two units of portable compact dehumidifier with combine moisture removal capacity of 72L/day. Both the dehumidifiers are located above the ceiling to control the attic RH to 60% which led to a significantly lower air dewpoint of about 18.9 °C. Apart from that some minor modifications were made to the ceiling air conditioning air diffuser to divert cold air away from the adjacent ceiling surface. Figure 3 shows post treatment attic area air humidity of about 60%.

The measured surface temperature on top of the new ceiling was 23.5 °C or 4.6 °C higher than the attic air dew point. This differential value increased up to 6.7 °C with the installation of dehumidifier inside the attic area. It was also observed that the room temperature drops by 1.5 °C from 24.1 °C to 22.6 °C with the presence of dehumidifier. This is most probably due to the drying effect of the dehumidifier in the attic which partly absorbed latent load from the room. Figure 4a and b shows the ceiling surface temperature before and after the modification of air diffuser. Figure 4c

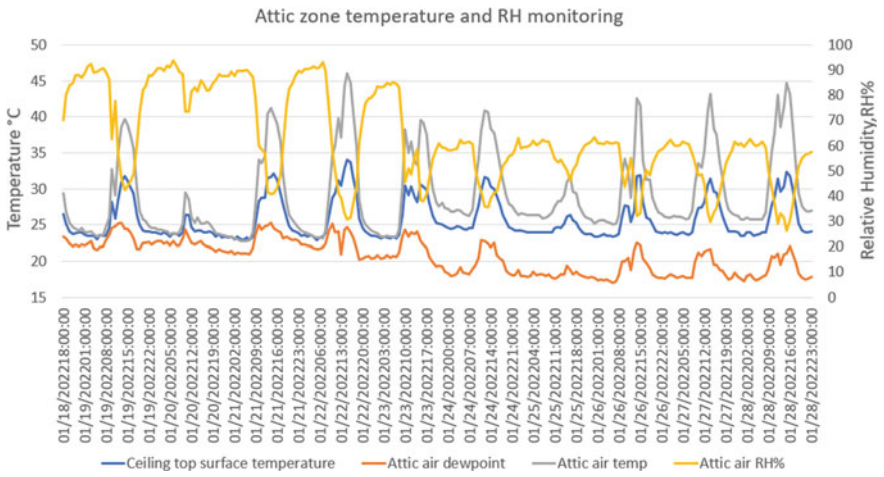
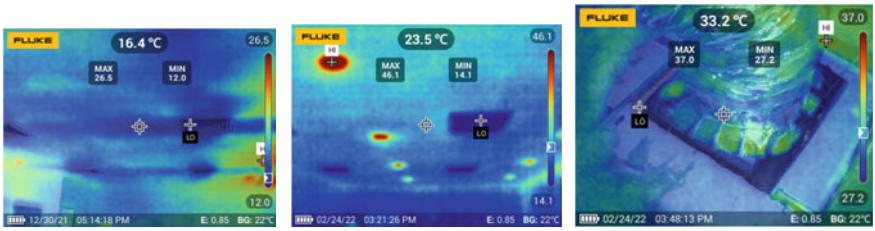


Fig. 3 Attic zone temperature and RH condition



(a) Before remediation (b) After remediation (c) Top part of ceiling after remediation

Fig. 4 Ceiling surface temperature before and after modification of AC air diffuser

shows thermal image on top of the ceiling assembly reveals that the were no cold spot present anymore that would cause condensation risk.

5 Conclusion

In general, the risk of condensation on top of the ceiling surfaces is very low because there were no cool surfaces for attic air moisture to form dew or water droplets. Application of EPS insulation and compact portable dehumidifier provided quick corrective option to eliminate the risk of condensation. The remediation work was carried out using most sustainable and fastest possible method to minimize laboratory downtime, hospital service interruption and reduced future risk. The method also considered time, budget and resources constraint faced by the building owner and the project team.

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