DEVELOPMENT OF COIR FIBER BASED INSULATIVE COMPOSITE MATERIAL TO REDUCE THERMAL HEAT IN BUILDINGS

Lanka Geeganage Chamath

(208020D)

Thesis submitted in partial fulfilment of the requirements for the degree

Master of Philosophy

Department of Materials Science and Engineering

University of Moratuwa

Sri Lanka

November 2022

DECLARATION

I declare that this is my own work, and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

I hereby grant to The University of Moratuwa the irrevocable, non-exclusive, and royalty free license to archive and make accessible my work in whole or in part in all forms of media, now or hereafter known. I agree that the document mentioned above may be made available immediately for worldwide access unless an embargo applies.

I retain all other ownership rights to the copyright of my work. I also retain the right to use in future works (such as articles or books) all or part of my work. I understand that I am free to register the copyright to my work.

Signature: UOM Verified Signature Date: 24/11/2022

L.G. Chamath

The above candidate has carried out research for the MPhil thesis under my supervision.

Signature of the supervisor: UOM Verified Signature Date: 24/11/2022

Name of the Supervisor: Dr. (Mrs) G.A. Sewvandi

Signature of the supervisor: UOM Verified Signature Date: 2022/11/24

Name of the Supervisor: Dr. L.K.T. Srimal

DEDICATION

This dissertation is dedicated to my loving parents who always encouraged and motivated me during my ups and downs.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to my research supervisor, Dr.(Mrs) A.S. Galhenage, not only for her guidance throughout my research but also for the knowledge and experience that she has shared with me. Her guidance and advice carried me through all the stages of this research she played a major role in my career development also. Next, I would also like to thank my other supervisor, Dr. L.K.T Srimal, Senior Lecturer, Department of Mechanical and Manufacturing Engineering, University of Ruhuna, for closely guiding me in this work and having fruitful discussions throughout the period.

I also thank Mrs. M.M.P.D Samarasekara, former director of the Institute of Technology, University of Moratuwa (ITUM), Major General (Rted.) S.K. Thirunavukarasu, Director/ITUM, and Eng J.M.P. Gunasekara, Head of the Division of Mechanical Engineering Technology, for allowing me to join the staff of the ITUM, and giving invaluable support in administrative issues. Many thanks are due to the academic staff members for reducing my academic workload and permitting me to focus on my research work. I would like to take this opportunity to acknowledge the support given by Mr. K.L.D.J Liyanage of Production Laboratory, and all the academic and non-academic members in Division of Mechanical Engineering Technology, ITUM and Division of Chemical Engineering Technology ITUM.

Special thanks are due to the academic and non-academic staff in the Department of Materials Science and Engineering for their continuous support during my research works. Further, I am thankful to Mrs. T.L.K. Kumari, and Department of Mechanical Engineering, University of Moratuwa. Special thank goes to Department of Physics, The Open University of Sri Lanka, for providing lab facilities for this study.

Finally, my heartfelt appreciation to my family members for taking many hardships to warrant me a disturbance-free environment for successful completion of this study.

L.G. Chamath

ABSTRACT

Energy consumption is a critical factor in building design. Maintaining a comfortable indoor temperature consumes high energy than other necessities such as lighting and cooking. The building envelope is the main component of the building that transfers heat between indoor and outdoor environments. During the daytime, a proper ventilation system or an air conditioning system can control the heat in a building. Insulation layers are also used under the roofing sheets to control the heat transfer through the roof because a building's roof contributes to a significant heat gain in tropical countries.

Sustainable insulation materials have been more attractive in the last two decades due to biodegradability, low embodied energy, availability, and non-toxicity. Sustainable insulation materials are primarily fabricated using lignocellulose fiber (natural plant fibers). Then it is mandatory to add binder material to adhere to fibers and the material formulated as a composite material, and an air void should be introduced to the combination of fiber and binder to increase insulation properties. Now the whole material can be identified as a three-phase composite material. Thus, the volume fraction of each phase (fiber, binder, and air void) is the most critical factor which controls these composites' insulation properties.

The insulation properties of the material can be analysed using experimental, analytical, and numerical methods. Analytical and numerical methods are more attractive than experimental methods. However, there are limited number of studies on the effect of volume fraction with insulation properties in a three-phase composite. In this study, the effective thermal conductivity (K_{eff}) of the composite was analysed through the analytical and numerical models and validated through the experimental results. The results concluded that the experimental results agreed with the numerical and analytical results. Furthermore, a novel mathematical model has been proposed to find the K_{eff} of the three-phase composite using the analytical and numerical methods. The proposed model shows better agreement with the experimental result. Therefore, it can be used to develop this research area further.

Keywords: Building insulation, Composites, Coir fibers, Thermal conductivity

TABLES OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

GHG	Global Greenhouse Gas
IEA	International Energy Agency
AC	Air Condition
MFA	Microfibril Angle
TGA	Thermal Gravimetric Analysis
DTGA	Derivative Thermal Gravimetric Analysis
FWO	Flynn Wall Ozawa
FEM	Finite Element Method
EMA	Effective Medium Approximation
EMT	Effective Medium Theories
FTIR	Fourier Transform Infra-Red Spectroscopy
SEM	Scanning Electron Microscope
NR	Natural Rubber
GHP	Guarded Hot Plate
DSC	Differential Scanning Calorimetry
KAS	Kissinger Akahira Sunose