

**Development of a Portable Non-Destructive Measurement System for Moisture
Content in the Construction Industry**

By
JUAN RODERICK
12101017

BACHELOR'S DEGREE
in

MECHANICAL ENGINEERING - MECHATRONIC CONCENTRATION
FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY



SWISS GERMAN UNIVERSITY
The Prominence Tower
Jalan Jalur Sutera Barat No 15, Alam Sutera
Tangerang, Banten 15143 – Indonesia

Revision after the Thesis Defense on 09 July 2025

STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.



Juan Roderick

Student

Date

Approved by:



Dr. Rusman Rusyadi

Thesis Advisor

Date

Dr. Yunita Umniyanti, S.Si, M.Sc.

Thesis Co-Advisor

Date 15/7/2025

Dr. Maulahikmah Galinium, S.Kom, M.Sc

Dean

Date

ABSTRACT

By

Juan Roderick

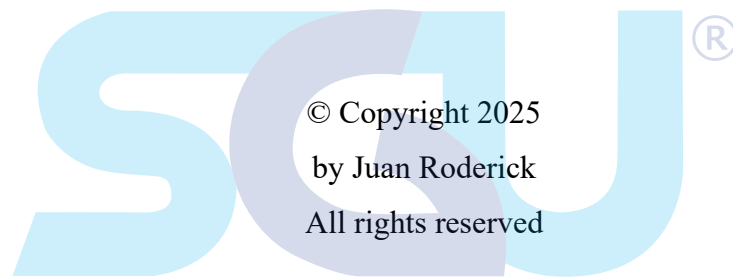
Rusman Rusyadi, Advisor

Yunita Umniyanti, Co-Advisor

SWISS GERMAN UNIVERSITY

Moisture in construction materials causes significant structural and health problems. This thesis addresses the need for an affordable and non-destructive measurement solution by developing a portable capacitive moisture sensor. The methodology involved designing a handheld device with a custom spiral capacitive sensor controlled by an ESP32 microcontroller. The system measures capacitance via a DC charge-discharge cycle. It incorporates a temperature sensor for enhanced accuracy. The components are housed in a portable, 3D-printed chassis with an OLED display for real-time feedback. Findings show the successful creation of a functional prototype weighing 298g with a 37.5-hour calculated battery life. A logarithmic relationship between capacitance and moisture content in plaster was established, and the system integrates a temperature compensation algorithm and a moving average filter to ensure stable readings. The research concludes with a successful proof-of-concept for a low-cost, non-destructive moisture meter that meets the project's primary objectives, offering a viable alternative to destructive methods.

Keywords: Capacitive Sensing, Non-Destructive Testing, Dielectric Constant, Moisture Content, Gravimetric Method



DEDICATION

I dedicate my work in this thesis paper for my parents as their support throughout my academic journey. I also dedicate this paper for the improvement of quality control in Indonesian building industry.



ACKNOWLEDGEMENTS

First of all, I would like to acknowledge my advisor and co-advisor, Dr. Rusman Rusyadi and Dr. Yunita Umniyanti for their helps and assistance throughout the thesis paper. Even though it is filled with ups and downs they show their support and helping me to figure out the best course of action and lead me to the best possible outcome.

I am also grateful for the help that I received from the teaching assistant Thomas Martines. He helped me through hard time and helping me to set up and use testing equipment such as LCR meter and Oscilloscope which is crucial to the sensor validation. In addition, thank you for letting us stay late in the lab to finished the thesis work.

I also want to thank PT. CKS for allowing me to come to the construction site and letting me to go around and take data from different places. Going to a construction site has opened my mind about how the construction industry is especially in water proofing. It is a once in a life time opportunity that I was able to experienced.

I want to express my deepest thanks to all my friends; Nathanael, Nicholas, Richky, Vasettha, Davin, Edgard, Staney, Andrew, Ryan, Justin and many more that I could not mentioned one by one. Who have helped me through my journey from the start of this paper until the end of the paper.

TABLE OF CONTENTS

	Page
STATEMENT BY THE AUTHOR.....	2
ABSTRACT.....	3
DEDICATION.....	5
ACKNOWLEDGEMENTS.....	6
TABLE OF CONTENTS.....	7
LIST OF FIGURES	9
LIST OF TABLES.....	10
CHAPTER 1 - INTRODUCTION.....	11
1.1 BACKGROUND	11
1.2 PROBLEM STATEMENT.....	12
1.3 THESIS OBJECTIVES	12
1.4 SIGNIFICANCE OF STUDY	13
1.5 SCOPE AND LIMITATIONS.....	13
1.6 THESIS STRUCTURES	14
CHAPTER 2 - LITERATURE REVIEW.....	15
2.1 Building Method	15
2.2 Moisture Sensing Methods	16
2.2.1 Pin Moisture Meter	17
2.2.2 X-Ray	18
2.2.3 Capacitance	19
2.2.4 Microwave and Radar	22
2.2.5 Infrared.....	23
2.2.6 Gravimetric	24
2.3 Data Taking.....	25
CHAPTER 3 – METHODOLOGY	28
3.1 System Overview	28

3.2 Mechanical Design and Selection	29
3.3 Electrical Design and Selection	32
3.4 Program and Control Design	40
3.5 Testing and Validation	41
3.5.1 Microcontroller Testing	41
3.5.2 Capacitance Testing	42
CHAPTER 4 – RESULTS AND DISCUSSION	43
4.1 Result Introduction.....	43
4.2 Components Level Result and Discussion.....	43
4.2.1 Esp32 capacitance reading vs LCR meter capacitance reading.....	43
4.2.2 Portability Factor	46
4.3 System Level Result and Discussion	48
4.3.1 Timing Delay of esp32.....	48
4.3.2 Capacitance vs Moisture calibration.....	48
4.3.3 Filtering Method	56
4.3.4 Final Capacitance to Moisture content	58
CHAPTER 5 – CONCLUSION AND RECCOMENDATIONS	60
5.1 Conclusion	60
5.2 Recommendation for Future Work	61
GLOSSARY	62
REFERENCES	63
CURRICULUM VITAE	68
APPENDICES	70
A. MECHANICAL DESIGN	70
B. ELECTRICAL DESIGN.....	72
C. DATASHEETS.....	73
D. SOURCE CODES.....	75

LIST OF FIGURES

Figures	Page
2.2.1.1 Usage of pin moisture meter	17
2.2.2.1 X-ray Visualization	18
2.2.3.1 Electric field lines of various capacitor configurations	20
2.2.3.2 Temperature against dielectric constant of water	21
2.2.4.1 Microwave Moisture Measurement meter	22
2.2.5.1 Absorption graph of Infrared	23
3.1.1 System Overview	28
3.1.2 Overall System Diagram	29
3.2.1 Sensor Chassis	30
3.2.2 Sensor chassis enclosure	30
3.2.3 Handle	31
3.2.4 Final Assembly Visualization	31
3.3.1 Spiral capacitive sensor	32
3.3.2 Capacitive sensor inscribes in an air block	33
3.3.3 Ground (left), Positive Terminal (right)	34
3.3.4 Output of the Simulation	35
3.3.5 Wiring Diagram	37
3.4.1 Flow chart of program	40
4.2.1.1 Data points of LCR meter against ESP32 reading	46
4.2.2.1 Total Weight of the whole item	47
4.3.1.1 Timing of ESP32	48
4.3.2.1 Sample conditioning	49
4.3.2.2 Moisture level against capacitance	52
4.3.2.3 Plotted data of ESP32 and moisture level with logarithmic regression	54
4.3.2.4 Residual Plot	55
4.3.3.1 Capacitance vs Time Step	56
4.3.3.2 Comparison of two types of filters	57

LIST OF TABLES

Tables	Page
2.2.3.1 Table of dielectric constant of common building material	19
3.3.1 Current Consumption table	39
4.2.1.1 Mean of ESP32 capacitance reading vs LCR meter reading 100 kHz	43
4.2.1.2 Summary of the ESP32 mean data	45
4.2.2.1 Current reading based on Fluke 87V	46
4.3.2.1 Compiled data from 0% to 9% moisture	50
4.3.2.2 Linear Regression Model of the Mean reading of Esp32	53
4.3.2.3 Logarithmic Regression Model of the Mean reading of Esp32	53

