

THESIS

**POTENTIAL OF A CHICKEN EGGSHELL-RESIN
COMPOSITE AS A HUMERUS BONE PHANTOM MODEL:
A MATERIAL CHARACTERIZATION STUDY**



By:

LADYA CHERYL AZ ZAHRA
NPM: 22037010018

**PHYSICS STUDY PROGRAM
FACULTY OF ENGINEERING AND SCIENCE
UNIVERSITAS PEMBANGUNAN NASIONAL "VETERAN"
JAWA TIMUR
SURABAYA
2026**

**POTENTIAL OF A CHICKEN EGG-SHELL-RESIN COMPOSITE AS A
HUMERUS BONE PHANTOM MODEL: A MATERIAL CHARACTERIZATION
STUDY**

THESIS

Submitted to Partially-Fulfill the Requirements In
Obtaining a Bachelor of Science (S.Si) Degree
Physics Study Program

By

LADYA CHERYL AZ ZAHRA
NPM: 22037010018

**BACHELOR OF PHYSICS STUDY PROGRAM
FACULTY OF ENGINEERING AND SCIENCE**

UNIVERSITAS PEMBANGUNAN NASIONAL "VETERAN"

JAWA TIMUR

2026

APPROVAL PAGE
POTENTIAL OF A CHICKEN EGGSHELL-RESIN COMPOSITE AS A
HUMERUS BONE PHANTOM MODEL: A MATERIAL
CHARACTERIZATION STUDY

By:

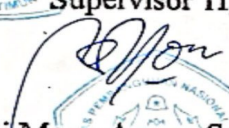
LADYA CHERYL AZ ZAHRA
NPM: 22037010018

Has been defended before and accepted by examination Team
Physics Study Program
Universitas Pembangunan Nasional "Veteran" Jawa Timur
Date: 2 July 2026

Approved
Supervisor 1


Primiasari Cahya Wardhani, S.Si., M.Sc.
NIP. 21219921128310

Supervisor II,


Nenni Mona Aruan, S.Pd., M.Si.
NIP. 199102202024061001

Examiner I


Akbar Sujiwa, S.Si., M.Si.
NIP. 199102202024061001

Examiner II


Fajar Timur, S.Si., M.Si.
NIP. 199312042024061006

Acknowledged,
Coordinator of The Physics Study Program


Dr. Dira Ernawati, S.T., M.T.
NIP. 197806022021212003

Acknowledged by,
DEAN OF THE FACULTY OF ENGINEERING AND SCIENCE
UNIVERSITAS PEMBANGUNAN NASIONAL "VETERAN"
JAWA TIMUR


Prof. Dr. Dr. Jariyah, M.P.
NIP. 196504031991032001

STATEMENT OF PLAGIARISME-FREE

I, the undersigned:

Name : Ladya Cheryl Az Zahra
NPM : 22037010018
Program : Bachelor's degree (S1)
Study Program : Physics
Faculty : Engineering and Science

Hereby declare that in this scientific document of this Thesis, there are no parts of other scientific works that have been submitted to obtain an academic degree at any Higher Education institution, and there are also no works or opinions that have been written or published by other individuals/institutions, except those that are cited in writing in this document and published in full in the bibliography

And I declare that this scientific document is free from elements of plagiarism. If any indications of plagiarism are found in this thesis in the future, I am willing to accept sanctions in accordance with the applicable laws and regulations

Thus, this statement is made sincerely without any coercion from anyone and is intended to be used as appropriate

Surabaya, 20 July 2026

Who made the statement,



Ladya Cheryl Az Zahra
NPM. 22037010018

ABSTRACT

A phantom is a simulation medium widely used in radiology and medical physics to replicate the characteristics of biological tissues. This study aimed to validate the material characteristics of a modified bone phantom based on chicken eggshell and calcium carbonate (CaCO_3) composites as a model of the human arm bone. The phantom material consisted of an epoxy resin matrix (30 wt%) with two filler compositions: 35 wt% chicken eggshell–35 wt% CaCO_3 (Sample A) and 50 wt% chicken eggshell–20 wt% CaCO_3 (Sample B). The eggshell powder was sieved to 200 mesh (74 μm), mixed using the hand lay-up method, molded in a silicone mold, and cured at room temperature for 24–48 hours. Material characterization included density and porosity measurements using the Archimedes method, followed by elemental composition analysis using X-ray Fluorescence (XRF). The results indicated that variations in filler composition influenced the physical properties of the phantom material. The sample containing a higher proportion of chicken eggshell exhibited a higher calcium content and physical characteristics that were closer to those of cortical bone. These findings demonstrate that the combination of chicken eggshell, calcium carbonate, and epoxy resin has the potential to serve as an alternative material for bone phantom fabrication with physical properties comparable to human cortical bone.

Keywords: bone phantom, chicken eggshell, calcium carbonate, density, porosity, X-ray fluorescence (XRF).

PREFACE

Alhamdulillah, the author expresses praise and gratitude to Allah SWT for His grace and blessings, allowing the thesis titled “Potential of A Chicken Eggshell- Resin Composite As A Humerus Bone Phantom Model: A Material Characterization Study” to be completed. This thesis is prepared as one of the requirements to obtain a Bachelor of Science degree in the S-1 Physics Study Program at the Universitas Pembangunan Nasional “Veteran” Jawa Timur. The author realizes that the preparation of this thesis is inseparable from the assistance, guidance, and support of various parties. Therefore, on this occasion, the author would like to express the deepest gratitude to honorable:

1. Prof. Dr. Ir. Akhmad Fauzi, M.MT., IPU., Rector of Universitas Pembangunan Nasional “Veteran” Jawa Timur.
2. Prof. Dr. Dra. Jariyah. M.P., the Dean of the Faculty of Engineering and Science, Sains Universitas Pembangunan Nasional “Veteran” Jawa Timur.
3. Dr. Dira Ernawati, ST. MT., Coordinator of the Physics Study Program, Faculty of Engineering and Science, Universitas Pembangunan Nasional “Veteran” Jawa Timur.
4. Primasari Cahya Wardhani, S.Si., M.Sc., dan Nenni Mona Aruan, S.Pd., M.Si., as the Thesis Supervisors, for their guidance during the preparation of this report.
5. The author's parents and family who always provide love, advice, and support both morally and materially, whose endless love and prayers give encouragement to pursue education.
6. Ahmad Aufinal Muna who provided unexpected support to the author in the completion of this thesis..
7. Thank you to myself for persevering until now, may this achievement open new doors of opportunity.

The author has strived to provide the best in writing this thesis, but the author realizes that this thesis is still far from perfect. Therefore, the author hopes for constructive suggestions and criticisms so that this research can be beneficial to readers and serve as input for the world of education in the future.

Surabaya, 10 October 2025

Ladya Cheryl Az Zahra

TABLE OF CONTENTS

STATEMENT OF PLAGIARISME-FREE	iii
ABSTRACT	iv
PREFACE.....	v
TABLE OF CONTENTS	vi
LIST OF TABLES.....	ix
LIST OF FIGURES	x
CHAPTER I.....	1
INTRODUCTION	1
1.1 Background.....	1
1.2 Problem Formulation.....	3
1.3 Research Objectives	4
1.4 Research Benefits	4
1.5 Research limitations	5
CHAPTER II	6
LITERATURE REVIEW	6
2.1 Radiology.....	6
2.2 Radiology Phantom	6
2.2.2 Types of Radiology Phantoms.....	7
2.3 Arm Phantom.....	9
2.3.1 Size of the Arm Phantom.....	9
2.3.2 Phantom Properties for Radiation.....	10
2.3.3 Human Arm Bone Anatomy.....	13
2.3 Composition of the Arm Bone Phantom	20

2.3.1	Chicken Eggshell	20
2.3.2	Epoxy Resins	23
2.3.3	Calcium Carbonate (CaCO_3)	24
2.5	Phantom Standardization Based on ISO 4037-3:2019 and ASTM S-792.....	25
2. 6	Research Hipotesis	26
2. 7	Previous Study	28
CHAPTER III		30
RESEARCH METHOD		30
3.1	Research Design	30
3.2	Place and time Research	32
3.3	Research Tools and Materials.....	32
3.3.1	Tools	32
3.3.2	Materials	34
3.4	Research Variables	34
3.4.1	Independent Variables	34
3.4.2	Variabel Terikat	34
3.4.3	Variabel Kontrol	34
3.5	Research Procedure	35
3.5.1	Data Analysis Stage and Discussion	40
CHAPTER IV		43
RESULTS AND DISCUSSION.....		43
4.1	Physical Test Results of the Arm Phantom	43
4.2	Density Test Results	44
4.3	Porosity Test Results	45
4.4	Comparison Density and Porosity	47
4.5	XRF Test Results.....	49

4.4.1 XRF Spectrum Analysis of A-Series Samples	51
4.4.3 Comparison between Sample A and Sample B XRF Spectra	61
4.4.4 Relationship between XRF Elements and Human Bone Elements	63
CHAPTER V	65
CONCLUSION AND SUGGESTION.....	65
5.1 Conclusion	65
5.2 Suggestion	66
REFERENCES	67
APPENDIX	71

LIST OF TABLES

Table 2. 1 XRF Analysis Result of CaCO ₃ Epoxy Resin Composite Sample	20
Table 2. 2 Eggshell Comparison	22
Table 2. 3 Phantom Standardization Based on ISO 4037-3:2019 and ASTM D-792	26
Table 2. 4 Previous Study	28
Table 3. 1 Independent Variables of Chicken Eggshell and dan CaCO ₃	34
Table 3. 2 Material Composition of Bone Model Using Chicken Eggshell	39
Table 4. 1 Physical Test Data of Arm Phantom.....	43
Table 4. 2 Material Test Data – Density	45
Table 4. 3 Material Test Data – Porosity	46
Table 4. 4 Comparison of Phantom, Human Cortical Bone and Previous Studies.....	48
Table 4. 5 Characteristic Energy and Elemental Concentration of A- Series XRF Samples	54
Table 4. 6 Atomic Number and Relative Atomic Mass of XRF Elements.....	54
Table 4. 7 Estimated Zeff of A-Series Samples.....	55
Table 4. 8 Characteristic Energy and Elemental Concentration of B- Series XRF Samples	59
Table 4. 9 Estimated Zeff of B-Series Samples	61
Table 4. 10 Average Zeff of Group A and Group B	62

LIST OF FIGURES

Figure 2. 1 Arm Phantom (True Phantoms Solution, 2021).....	9
Figure 2. 2 Arm Anatomy (Pearson Education, 2009)	13
Figure 3. 1 Silicone mold.....	32
Figure 3. 2 Mortar.....	32
Figure 3. 3 Mesh (HardwareMISE Sdn. Bhd., 2019)	32
Figure 3. 4 Beaker glass (Dankoff, 2026).....	33
Figure 3. 5 Spatula (Eisco labs, 2022).....	33
Figure 3. 6 Digital Scale (Michaels, 2025).....	33
Figure 3. 7 Vernier Caliper (Redfluid, 2024)	33
Figure 3. 8 XRF (Malvern Panalytical, 2018)	33
Figure 3. 9 Flowchart of Arm Phantom Fabrication.....	35
Figure 3. 10 Dimension of the Arm Bone Phantom.	36
Figure 3. 11 a) Top view, b) bottom view, c) front view, and d) side view of the phantom with the arm bone.	36
Figure 3. 12 Top View of the Phantom Cover.....	37
Figure 4. 1 a) Diameter of Samples A, b) Length of Sample A (right) and Sample B (Left), c) with top of Phantom	43
Figure 4. 2 a) Sample A b) Sample B.....	50
Figure 4. 3 Spectrum Chicken Eggshell Phantom A-Series Samples	51
Figure 4. 4 Spectrum Chicken Eggshell Phantom B-Series Samples.....	57