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**CAST COMPOSITE DEVELOPMENT FOR FRACTURE
IMMOBILIZATION: AN ALTERNATIVE TO PLASTER
AND FIBREGLASS**

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(218035L)

A thesis submitted in total fulfillment of the requirements for the degree of
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Department of Civil Engineering

University of Moratuwa

Sri Lanka

January 2024

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DECLARATION OF THE CANDIDATE

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The above candidate has carried out research for this MPhil Dissertation under my supervision.

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Signature of the supervisor: Date : 04.06.2025

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Declaration

ABSTRACT

Plaster of Paris is the most commonly used orthopedic casting material, attributed to its affordability and availability compared to synthetic immobilization materials available in the market. Although widely used in orthopedic casting, plaster has many inherent drawbacks that reduce its durability and patient comfort, especially in long-term immobilization, pediatric, and elderly fracture care.

Degradation upon exposure to water, low mechanical strength, and the heavy weight of the casts have made them less popular compared to synthetic and novel materials. Although plaster casts provide slightly better thermal comfort than their synthetic counterparts, this property still requires improvement.

Through this study, an RHA-modified sustainable plaster cast was developed to fulfill the aim. Since the formula of commercially available orthopedic plaster bandages is a trade secret, this study developed a control mix (commercially available plaster) as the foremost step before selecting a suitable sustainable filler to improve the properties of traditional plaster. RHA was used as a filler material for its low weight, low density, pozzolanic activity enhancement, strength improvement, and thermal insulating properties. The study investigates the microstructure, mechanical properties, and thermal properties of 5%, 10%, and 15% RHA-modified blends made into bandages.

Syngenite formation sites and free water entrapment by RHA particles were observed during the microstructure analysis, which gives rise to variations in the mechanical and thermal characteristics of the samples developed. RHA additions reduced the weight of

the developed plaster by 12.9%–23%. However, setting times increased significantly, with 5% RHA samples increasing the setting time by 7%.

Water absorption marginally reduced in RHA-modified plaster, to approximately 24 times that of the control, but it is still significantly lower compared to waterproof fabric and fiberglass casts. The overall compressive strength increased by 49.2% at 14 days in 10% RHA-modified samples, along with a 6.2% better performance in wet crush strength compared to 5% RHA samples. Performance in tension greatly depends on the properties of the base bandage, with cotton bandages performing poorly in tension. However, 5% RHA-modified bandages showed a 5.8% improvement compared to control samples.

In terms of thermal properties, the heat of hydration reduces compared to the control, proving that RHA-modified bandages release lower heat during hydration. This pertains to the fact that CaSO_4 in the mix doesn't undergo adequate hydration in the presence of excess RHA particles. Thermal conductivity and thermal effusivity values also decrease as the RHA percentage increases. Five percent RHA-modified samples show similar thermal conductivity and thermal effusivity values of 0.35 W/mK and 695.2 W $\sqrt{\text{s}}/\text{m}^2\text{K}$, respectively, to the control. A reduction in thermal conductivity reduces the breathability of the cast, causing skin maceration and the buildup of sores. Thus, the developed bandages must possess thermal conductivity above or similar to that of orthopedic plaster.

Based on the conducted experimental analysis, the study concludes that RHA can be used as a sustainable filler to improve the mechanical characteristics of orthopedic plaster, but the thermal performance is not substantially improved. It is feasible to develop a low-cost,

low-CaSO₄-containing cast that performs marginally better or almost similar to existing plaster, with less environmental pollution and reduced CO₂ emissions.

Keywords: Rice husk ash, Fracture, Immobilization, Plaster, Sustainability

*This thesis is dedicated to;
my late grandfather, for asserting my curiosity ...*

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TABLE OF CONTENT

CHAPTER 01- INTRODUCTION	1
1.1 Background.....	1
1.2 Research Significance	4
1.3 Aim.....	4
1.4 Research Objectives	5
1.5 Flow of the Research Study	6
1.6 Thesis Outline	7
1.7 List of Publications	9
CHAPTER 02- LITERATURE REVIEW	10
2.1 Introduction	10
2.2 Material Evolution and Technique of Casting	10
2.2.1 Evolution of Casting and Splinting	10
2.2.2 Cast Application and Techniques.....	14
2.3 Methods.....	16
2.4 Findings.....	21
2.4.1 Existing orthopedic immobilization material.....	21
2.4.2 Cast padding and liners for skin shielding from direct cast contact	42
2.4.3 Complications associated with Immobilization	44
2.5 Discussion	54
2.6 Challenges and opportunities	55
2.7 Investigation of sustainable filler material for modification of plaster	56
2.7.1 Rice Husk Ash.....	57

2.7.2 Graphene Oxide	61
2.8 Chapter Summary.....	63
CHAPTER 3- MIX DESIGN OPTIMIZATION	67
3.1 Introduction	67
3.2 Phase I- Control sample development.....	67
3.2.1 Material selection and sample preparation.....	67
3.2.2 Method of preparation.....	70
3.2.3 Problems encountered in Phase I	72
3.3 Altering the pathway -Phase II.....	73
3.3.1 Replacement of PVA crystals with PVA glue	73
3.3.2 Replacement of DCM with water and an inhibitor	73
3.3.3 Precautions to follow when using NH ₃	77
3.3.4 Issues encountered	77
3.4.1 RHA for thermal comfort.....	78
3.4.2 GO for strength gain.....	79
3.4.3 Problems encountered in Phase III.....	80
3.5 Initial study- Compression testing	81
3.6 Altering the pathway – Phase IV	83
3.6.1 Superplasticizer for workability and strength gain	83
3.7 Comparison of results obtained in Phase III and Phase IV	87
3.8 Chapter Summary.....	88
CHAPTER 4- DEVELOPMENT OF RHA MODIFIED PLASTER BLENDS.....	89
4.1 Introduction	89
4.2 Selecting the RHA replacement percentage.....	89

4.3 Compression testing to select the optimum RHA replacement percentages.....	91
4.4 Chapter summary	95
CHAPTER 05- PERFORMANCE EVALUATION OF RHA BASED ORTHOPEDIC PLASTER	96
5.1 Introduction	96
5.2 Final mix design and specimen development	97
5.3 Preparation of samples for testing	99
5.4 Microstructure Analysis	99
5.4.1. Investigation of microscopic characteristics of the material -SEM	99
5.6.2. Investigation of material porosity and breathability	117
5.5. Mechanical Performance Analysis.....	121
5.5.1 Investigation on material weight and density.....	121
5.5.2 Investigation of setting time - Vicat test	125
5.5.3 Investigation of water absorption- Bead test.....	130
5.5.4 Investigation of compressive strength.....	135
5.5.5 Investigation of wet crush strength	147
5.5.6 Investigation of the tensile strength of samples	152
5.6 Thermal Performance Analysis.....	157
5.6.1 Investigation on heat of reaction	157
5.6.2 Investigation of heat conductivity and thermal effusivity.....	162
5.7 Theoretical verification of heat of reaction	170
5.8 Chapter Summary.....	172
CHAPTER 6- CONCLUSION AND FUTURE WORK	176
6.1 Introduction	176

6.2	Conclusions from Chapter 2.....	176
6.3	Conclusions from Chapter 3	180
6.4	Conclusions from Chapter 4.....	181
6.5	Conclusions from Chapter 5	182
6.6	Recommendations for future research.....	192

LIST OF FIGURES

Figure 1: Main stages of the fracture healing process 1) Hematoma formation 2) Fibrocartilaginous callus formation 3) Bony callus formation 4) Bone remodeling	1
Figure 2: Steps followed in the research study	6
Figure 3: Timeline of evolution of orthopedic immobilization material developed by the author.....	13
Figure 4: Steps followed for the systematic literature survey.....	16
Figure 5: PRISMA Flowchart.....	20
Figure 6: a) Open burnt RHA b) RHA microstructure under SEM	57
Figure 7: Pozzolanic activity in the presence of RHA particles in concrete.....	59
Figure 8: Conversion of graphite to graphene oxide and to reduced graphene oxide and into graphene [117]	62
Figure 9: Mechanical mixing of the control mix using a hand-held mechanical stirrer.	70
Figure 10: Ammonium Borate retarder mixed with a portion of batch water.	76
Figure 11: 4g/L GO solution obtained from CGT, the pH of GO lies between 2-3	80
Figure 12: Visual observation of agglomerated GO in CaSO ₄	80
Figure 13: Developed samples for compression testing	81
Figure 14: The variation of color with increasing additions of RHA a) 5% RHA b)10% RHA c)15% RHA d)20% RHA	91
Figure 15: Variation of compressive strength with different RHA percentages.....	93
Figure 16: Variation of weight with different RHA percentages.....	94
Figure 17: Variation of density with different RHA percentages.....	94
Figure 18: Prepared bandage samples of the control	98
Figure 19: a) Hitachi FlexSEM 1000 SEM used for imaging and sample positioning b) Sample positioning of observation tray.....	100
Figure 20: SEM image of the control sample at x 1000, showing syngenite formation sites	101
Figure 21: HPMC binder particle agglomerates at x 500	102

Figure 22: Presence of voids and sites of cracking in plaster bandage specimens at x100	103
Figure 23: HPMC agglomeration and void presence of plaster bandage samples at x500	104
Figure 24: Large RHA particle detected in 5% RHA modified blends, showing CaSO_4 crystallization on top of the particle at x100	105
Figure 25: Closer observation on the crystallization on top of RHA particles	106
Figure 26: Short sturdy flake like crystal formation in RHA blends, these engulf the RHA particles as RHA entraps water the crystals require for formation	107
Figure 27: Unhydrated CaSO_4 sites, flake like crystal formation, Syngenite formation sites and cracks on 5% RHA modified bandages samples observed at x 65	108
Figure 28: RHA particle detection sites, larger crack widths and partially hydrated zones of plaster in 5% RHA modified blends x 500	109
Figure 29: Microstructure of the 10% RHA modified paste including unhydrated zones and RHA distribution at x70	110
Figure 30: RHA particles and the crystal formation due to partial hydration and presence of PVA at x1000.....	111
Figure 31: Crystal formation in 10% RHA modified bandages at x500.....	112
Figure 32: Microstructure of 15% RHA modified paste of the blend, showing unhydrated CaSO_4 zones x70	113
Figure 33: Crystal formation in 15% RHA modified samples x1000.....	114
Figure 34: Crystal formation due to availability of RHA particles and presence of pores in the microstructure at x100.....	114
Figure 35: Microstructure of 15% RHA modified bandage samples with unhydrated zones and longer cracks, cracking increases with higher RHA percentages at x100.....	115
Figure 36: As RHA percentage rises microcracks have reduced but crystals are unmethodical and irregular at x1000.....	116
Figure 37: Dimensions of cylindrical.....	121

Figure 38: Cylindrical samples made of developed bandage samples for compression testing	122
Figure 39: Weight distribution of cylindrical samples.....	123
Figure 40: Density variation of tested samples -control and RHA modified samples..	124
Figure 41: Vicat apparatus set up for initial and final setting time measurement of the tested samples.....	127
Figure 42: Setting time comparison of tested samples.....	128
Figure 43: Bead time alteration of different samples per test cycle.....	134
Figure 44: Sample loaded to the Instron 5569A for compression testing.....	137
Figure 45: Variation of compression loading for tested samples at 24 hours.....	140
Figure 46: Variation of compression loading for tested samples at 7 days	141
Figure 47: Variation of compression loading for tested samples at 14 days	142
Figure 48: Comparison of the variation of compression loading for tested samples....	143
Figure 49: Wet crush comparison of tested samples.....	150
Figure 50: a) How the test samples are fitted to the Dynacell b) The sample test specimens	154
Figure 51: Comparison of tensile loading of samples.....	156
Figure 52: Heat of hydration of tested samples.....	159
Figure 53: Comparison of heat flow of tested samples.....	160
Figure 54: Heat flow vs time of the control	161
Figure 55: a) the sensor of the C-Therm TCi b) sample placement for thermal conductivity studies.....	164
Figure 56: Thermal conductivity variation with variation in RHA %	166
Figure 57: Thermal effusivity variation with variation in RHA %.....	167
Figure 58: Thermal effusivity vs thermal conductivity of tested samples	168
Figure 59: Steady state heat transfer through multiple cylindrical layers.....	170

LIST OF TABLES

Table 1: The most common immobilization periods and the average period for fracture union for commonly fractured bones for cases with no complications [7]	2
Table 2: Properties of RHA.....	58
Table 3: Composition of RHA	58
Table 4: Original mix design developed by Lewry [100]	67
Table 5: Mix design for control blend.....	71
Table 6: Preparation of the control blend with Ammonium Borate.....	74
Table 7: Mix design with NH ₃ Borate retarder	74
Table 8: Mix design with retarder and Graphene Oxide.....	78
Table 9: Compressive strength of tested cubes	82
Table 10: Altered mix design incorporating PCE and excluding Ammonium Borate....	84
Table 11: Compression test results of the samples developed under phase IV.....	86
Table 12: Comparison between phase III and phase IV results for modified blends.....	87
Table 13: Mix design for different RHA modified plaster samples.....	90
Table 14: Compression test results and weight of different RHA replacement percentages	92
Table 15: Finalized mix design for samples, including RHA modified blends	97
Table 16: BET surface and pore radius of tested blends	119
Table 17: Average bead time calculation for each tested sample	133
Table 18: Average load to failure in 24 hours, 7-day and 14-day compression testing of samples	139
Table 19: Weight alteration before and after water immersion	148
Table 20: Wet crush strength results of tested samples	148
Table 21: Ultimate tensile strength and load at failure of tested samples.....	156
Table 22: Thermal conductivity and effusivity of tested samples	165
Table 23: Heat flow values of heat of hydration, theoretically calculated	172
Table 24: Base material availability, cost and environmental impact of popularly used immobilization material.	190
Table 25: Manufacturing cost and energy analysis for immobilization material popularly used in clinical settings.	190
Table 26: Performance-cost benefit summary of popularly used immobilization material.	191

LIST OF ABBREVIATIONS

RHA- Rice Husk Ash

GO- Graphene Oxide

ASTM- American Society for Testing and Materials

MSD- Material Safety Data

PRISMA- Preferred reporting Items for Systematic Reviews and Meta- Analyses

IEEE- Institute of Electrical and Electronics Engineers

CO- Carbon Monoxide

HCN- Hydrogen Cyanide

RTV- Room Temperature Vulcanized

PLA- Poly Lactic Acid

rGO- Reduced Graphene Oxide

DCM- Dichloro Methane

PVA- Poly Vinyl Alcohol

HPMC- Hydroxy Methyl propyl Cellulose

POP- Plaster of Paris

SEM- Scanning Electron Microscopy

BET- Brunauer-Emmett-Teller