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 Masters in Philosophy

Department of Civil Engineering

University of Moratuwa

Sri Lanka

January 2024

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Name of the supervisor:. Dr. Rasindu Weerasinghe .....

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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 $W\sqrt{s}/m^2K$, 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-$CaSO_4$-containing cast that performs marginally better or almost similar to existing plaster, with less environmental pollution and reduced CO_2 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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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