

**DEVELOPMENT OF A SUSTAINABLE CONCRETE MIX
USING RICE HUSK ASH AND STEEL SLAG FOR 3D
PRINTING**

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The Research Thesis was submitted in partial fulfilment of the requirements for the
Degree of Bachelor of Science of Engineering

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DECLARATION

I declare that this is my 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 our 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.

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Date: June 14, 2024

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ABSTRACT

Three-dimensional printing has emerged as a transformative technology in the construction industry, offering efficiency and reduced reliance on labour. The automated process of 3D concrete construction, particularly through contour crafting, has minimized labour requirements, eliminated the need for formwork, and garnered acclaim for its sustainability. However, challenges persist, with the choice of proper mix design and materials standing out as a critical factor. This research addresses a significant challenge in 3D concrete technology the excessive use of cement and chemical admixtures. While previous studies have explored partial cement substitution, little attention has been given to replacing fine aggregate. This research focuses on substituting rice husk ash for cement, emphasizing the contribution to bio-concrete by offsetting carbon dioxide emissions. The use of rice husk ash, a well-studied material, aims to enhance workability and flowability.

Furthermore, the study introduces the novel concept of substituting fine aggregate with steel slag, a construction waste material. This collaboration between rice husk ash and steel slag presents a unique challenge due to the irregularities in shape, water absorption properties, and porosity of steel slag. The research aims to analyse the behaviour of 3D concrete in both fresh and hardened states when these two components are combined as partial replacements. The research aims to identify the optimum replacement percentage of steel slag as fine aggregate in 3D concrete, supplemented by a partial substitution of a bio-based cementitious compound. The study explores the rheological behaviour of the fresh concrete, laying the groundwork for future modifications. Objectives include introducing 3D concrete to the Sri Lankan construction industry, replacing fine aggregate with steel slag, employing cost-effective testing methods for rheological properties, and incorporating rice husk ash as a partial replacement for cement.

This research contributes to the sustainable development of 3D concrete technology, offering insights into material substitutions that enhance environmental and economic aspects, making it a valuable endeavour for the construction industry.

Key Words:

3D printable concrete, Rice husk ash, Steel slag, Rheology, Sustainable 3DCP

DEDICATION

I would like to dedicate this dissertation to my parents, my husband and my daughter
Aarya Pradhi Gamalath

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LIST OF ABBREVIATIONS

Abbreviation	Description
3DCP	3D Concrete Printing
CECB	Central Engineering Consultancy Bureau
RPM	Rotation Per Minute
SLINTEC	Sri Lanka Institute of Nanotechnology Pvt. Ltd.
SSA	Steek Slag Aggregate
UUCT	Unconfined Uniaxial Compression Test
UOM	University of Moratuwa
VMA	Viscosity Modifying Agent
CS	Control Sample

LIST OF SYMBOLS

Symbol	Description	
Φ	Maximum particle size diameter	[mm]
C_u	Uniformity coefficient	[-]
C_c	Coefficient of curvature	[-]
T	Maximum torque	[kgfcm]
τ_y	Yield stress	[kgf/cm ²]
H	Diameter of the vane	[cm]
D	Height of the vane	[cm]
Θ	Angle of rotation in vane	[degrees]
k	Spring constant of the vane apparatus	[cm/kgf]
A_{thix}	Structuration rate	[kPa/min]
H'	Rising speed of the object	[m/min]
ρ	Bulk density of the mixture	[kN/m ³]
$\tau_{0,0}$	Initial static stress at t=0 time	[kPa]
H	Height of the object	[m]
V	Printing velocity	[m/min]
h_0	Layer height	[m]
L	Contour length	[m]
cP	Centipoise (unit of dynamic viscosity in centimeter-gram-second/CGS)	