EXPERIMENTAL INVESTIGATION OF THE IMPROVEMENTS OF RHEOLOGICAL AND PHYSICAL PROPERTIES IN 3D CONCRETE PRINTING MODIFIED WITH BIOCHAR AND STEEL SLAG

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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

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ABSTRACT

Three-dimensional concrete printing (3DCP) has emerged as a revolutionary construction material technology, facilitating the incremental deposition of concrete layers for the construction of three-dimensional structures. This innovative technology is gaining widespread popularity due to its distinct advantages over traditional concrete methods, offering heightened design flexibility, fully automated mechanization, and the ability to efficiently construct intricate structures within a reduced timeframe, eliminating the need for manual labor.

Contrary to the conventional concrete, assessing the flowability (the capacity of the concrete mixture to flow seamlessly and uniformly through the nozzle) and extrudability (the degree of ease with which the concrete can be pushed through or extruded from the nozzle.) of 3DCP becomes essential, as these properties are predominantly dictated by its rheological characteristics. Examining not only the compressive strength but also the buildability and open time is crucial when evaluating the mechanical characteristics of 3DCP. Compressive strength provides insight into the material's ability to withstand axial loads, while buildability and open time play essential roles in assessing construction feasibility and the temporal aspects of 3DCP

This study aims to leverage biochar as a substitute material for cementitious components and steel slag as a partial replacement material for the fine aggregate component in 3DCP in improving the rheological and mechanical properties of 3DCP, while capitalizing on the sustainable attributes and economic advantages of these substitute materials.

Key Words:

3DCP, Biochar, Steel slag, Flowability, Extrudability, Rheology, Buildability, Opentime

DEDICATION

I would like to dedicate this dissertation to my parents, my wife Narmadha Anjalee and my daughter Aarya Pradhi

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LIST OF ABBREVIATIONS

Abbreviation	Description
3DCP	Three-dimensional Concrete Printing
CECB	Central Engineering Consultancy Bureau
SLINTEC	Sri Lanka Institute of Nanotechnology Pvt. Ltd.
UOM	University of Moratuwa
UUCT	Unconfined Uniaxial Compression Test
VMA	Viscosity Modifying Agent
cP	Centipoise

LIST OF SYMBOLS

Symbol	Description	Unit
Φ	Maximum particle size diameter	[mm]
C_u	Uniformity coefficient	[-]
C_c	Coefficient of curvature	[-]
T	Maximum torque	[kgfcm]
τy	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)	