A Study on Utilization Potential of Microbial Biopolymer treated Wastes in Civil Engineering

Thesis submitted in partial fulfilment for the Award of

Doctor of Philosophy

Submitted by

NITEESH SINGH BONAL

DEPARTMENT OF CIVIL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY (BANARAS HINDU UNIVERSITY)

VARANASI – 221005

Roll No. 16061012

2022

भारतीय प्रौद्योगिकी संस्थान
काशी हिन्दू विश्वविद्यालय

IIT INDIAN INSTITUTE OF TECHNOLOGY
BANARAS HINDU UNIVERSITY

DECLARATION BY THE CANDIDATE

I, **Niteesh Singh Bonal** certify that the work embodied in this thesis entitled -"**A Study on utilization potential of microbial biopolymer treated wastes in civil engineering** " is my own bonafide work carried out under the supervision of **Prof. Arun Prasad** at Indian Institute of Technology (BHU), Varanasi. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma.

I declare that I have faithfully acknowledged, given credit to, and referred to the research workers wherever their works have been cited in the text and the body of the thesis. I further certify that I have not wilfully lifted up some other's work, paragraph, text, data, results, etc. reported in the journals, books, magazines, reports, dissertations, thesis, etc., or available at web-sites and included them in this thesis and cited as my own work.

Date:

Place: Varanasi

Niteesh Singh Bonal

Certificate from Head of the Department/ Supervisor

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

22/06/2022

Prof. Arun Prasad
(Supervisor)
Department of Civil Engineering
Indian Institute of Technology (BHU)
Varanasi, India (221005)

24.06.2022

Signature of the Head of Department

विभागाध्यक्ष / HEAD
जानपद अभियांत्रिकी विभाग
Department of Civil Engineering
भारतीय प्रौद्योगिकी संस्थान (बी.एच.यू.)
Indian Institute of Technology (B.H.U.)
वाराणसी-221005/Varanasi-221005

भारतीय प्रौद्योगिकी संस्थान
काशी हिन्दू विश्वविद्यालय

IIT INDIAN INSTITUTE OF TECHNOLOGY
BANARAS HINDU UNIVERSITY

CERTIFICATE

It is certified that the work contained in the thesis titled "**A Study on utilization potential of microbial biopolymer treated wastes in civil engineering**" by Niteesh Singh Bonal has been carried out under my supervision and this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all the requirements of Comprehensive Examination, Candidacy and SOTA for the award of Ph.D. Degree.

22/06/2022

(Prof. Arun Prasad)
(Supervisor)
Department of Civil Engineering
Indian Institute of Technology (BHU)
Varanasi-221005

भारतीय
प्रौद्योगिकी
संस्थान
काशी हिन्दू विश्वविद्यालय

IIT INDIAN INSTITUTE OF TECHNOLOGY
BANARAS HINDU UNIVERSITY

COPYRIGHT TRANSFER CERTIFICATE

Title of the Thesis: "A Study on utilization potential of microbial biopolymer treated wastes in civil engineering"

Name of the Student : Niteesh Singh Bonal

Copyright Transfer

The undersigned hereby assigns to the Indian Institute of Technology (Banaras Hindu University) Varanasi all rights under copyright that may exist in and for the above thesis submitted for the award of the degree **"Doctor of Philosophy"**.

Date:

Place: Varanasi

(Niteesh Singh Bonal)

Note: However, the author may reproduce or authorize others to reproduce material extracted verbatim from the thesis or derivative of the thesis for author's personal use provided that the source and the Institute's copyright notice are indicated.

ACKNOWLEDGEMENTS

The satisfaction and euphoria that accompanies the successful completion of any task would be incomplete without the mention of the people who made it possible, whose constant guidance, encouragement and support fructified my effort with success.

I consider it my privilege to express my gratitude and respect to all those who guided me in the completion of my Ph.D. Thesis report.

First, I would like to thank my supervisor and mentor Dr. Arun Prasad, Professor, Civil Engineering Department, Indian Institute of Technology (Banaras Hindu University) for providing me this valuable opportunity for presenting this thesis which has not only enhanced my knowledge about the subject but also increased my confidence level. I take this opportunity to thank him for his constant guidance and invaluable advice which has made this work much easier.

I express my sincere gratitude to the Head of the Department of Civil Engineering, IIT (BHU)**,** for providing me all requisite facilities and encouragement during the course of this work.

I would also like to express my sincere thanks to RPEC members Assoc. Prof. Bala Ramudu Paramkusam, Civil Engineering Department, Indian Institute of Technology (Banaras Hindu University) and Assoc. Prof. Rajesh Rai, Mining Engineering Department, Indian Institute of Technology (Banaras Hindu University) for giving valuable inputs and suggestions to widen my research from various perspectives.

I also want to acknowledge the support of the entire family, colleagues of Civil Engineering Department and the staff member of the Geotechnical Engineering laboratory Mr. Basanta Prasad, Mr. Netra Pal and Mr. Nand Lal Ram for helping me throughout this work which enabled me to complete my dissertation work successfully.

At last but not the least I want to thanks the omnipresent almighty god for support and for answering my prayer in every moment.

Date:

Place: IIT (BHU), Varanasi (**Niteesh Singh Bonal)**

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

w	Water content
m_b	Mass of biopolymer
m_b / m_w	Biopolymer-to-water ratio
m_b / m_{br}	Biopolymer-to-bauxite residue in mass
q_u	Unconfined compressive strength (kPa)
CMO	Coal mine overburden waste
XG	Xanthan gum
GG	Guar gum
XG+GG	Composite gum
OMC	Optimum moisture content
MDD	Maximum dry density
P	Biopolymer content (%)
c	Cohesion
$\phi°$	Peak Friction angle
TT	Thermal treatment
WTT	Without thermal treatment
GG(WTT)	Guar gum without thermal treatment
GG(TT)	Guar gum with thermal treatment
XG(WTT)	Xanthan gum without thermal treatment
XG(TT)	Guar gum with thermal treatment
F-T	Freezing and thawing cycles
XRD	X-ray diffraction
SEM	Scanning Electron Microscopy

PREFACE

Rapid global population growth and development in the civil infrastructure have arisen the need of developing knowledge to enhance the strength properties of the existing soils or waste for civil and geotechnical engineering purposes. Since the beginning of human civilization, several different techniques and materials have been employed to stabilize the soil/waste. The use of a conventional method such as cement binders are associated with many environmental problems, so materials described as environmentally friendly called microbial biopolymers have been developed for application in engineering purposes.

Over the years, environmental issues have forced engineers and researchers to focus on new methods that use biological processes in soil/waste stabilization techniques. This research focuses on the application of biopolymer, xanthan, and guar gum, to bauxite residue and coal mine overburden waste to enhance mechanical and hydraulic properties. The primary potential application of waste stabilization with biopolymer is the construction of various engineered structures such as roads, embankments, impervious barriers, etc., to control erosion, permeability and enhance biodegradation of contaminants as they seep through the structure.

The thesis entitled" **A Study on utilization potential of microbial biopolymer treated wastes in civil engineering"** comprises five chapters. The research begins with an introduction, which briefly describes biopolymer, industrial waste (bauxite residue), and coal mine overburden waste in **Chapter 1**. The literature review on the potential application of biopolymer in stabilizing soil/waste is advocated by numerous researchers for various engineering purposes. This chapter also covers the scope and objective of this study.

In **Chapter 2**, description of the materials used in this research and their physical and chemical properties. This chapter also explains the preparation of samples and its methodology for the various test performed in this study.

The results and discussions of all the laboratory tests performed on bauxite residue and coal mine overburden waste treated with xanthan and guar gum is presented in **Chapter 3**. The experiments include the Compaction test, Tri-axial compression test, Unconfined compressive, Durability test (Freezing and thawing), Permeability test, Colorimeter analysis, Mineralogical and morphological test have been performed at different biopolymer concentrations and curing time.

Chapter 4 describes the potential application of biopolymer treated waste in civil and geotechnical engineering. A case study on the biopolymer application for slope and surface stabilization is reviewed. This chapter also explains the environmental, economic, social benefits, and future challenges of biopolymer application.

Finally, **Chapter 5** includes a conclusion based on all the experiments and discussion.