Investigation of the properties of self-healing basalt concrete based on Bacillus subtilis suitable for construction use in Nigeria

Исследование свойств самовосстанавливающегося базальтового бетона на основе Bacillus subtilis, пригодного для использования в строительстве в Нигерии

by

CHIADIGHIKAOBI Paschal Chimeremeze, PhD

ЧИАДИГХИКАОБИ Паскал Чимеремезе, к.т.н

Department of Civil Engineering

Afe Babalola University, Ado-Ekiti, Ekiti State, Nigeria

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INTRODUCTION

Backgrounds

Concrete is one of the building blocks of modern architecture because of its ubiquity, adaptability, and capacity to withstand high static loads. The application spreads from residential structures to industrial infrastructure and all in between. Nevertheless, due to the benefits of concrete, it is fundamentally brittle and thus vulnerable to fracture from environmental loads, mechanical stimuli, and thermal cycling.

INTRODUCTION CONT'D

Backgrounds cont'd

These cracks, while often appearing superficial, can significantly impact the structural integrity and durability of concrete, allowing the ingress of water, chemicals, and other deleterious agents (Jonkers & Schlangen, 2007). This results in accelerated decline, especially in tropical areas such as Nigeria, where temperature and humidity volatility exacerbate these weaknesses.

INTRODUCTION CONT'D

Problem Statement

In Nigeria, the construction industry is especially challenged by a shortage of high-grade materials, poor infrastructure maintenance, and economic downturns, which lead to high repair and rehabilitation costs. These problems highlight the urgent need for new and improved countermeasures to extend the durability and service life of concrete elements.

INTRODUCTION CONT'D

Problem Statement cont'd

Self-healing concrete represents a significant breakthrough in the field of construction technologies and structural materials, which provides the capability for autonomous crack repair by means of microbial healing, encapsulated healing agents, and autogenous phenomena. These characteristics not only extend the lifespan of stands but also lessen the costs of maintenance, thereby promoting sustainable construction.

INTRODUCTION CONT’D

Problem Statement cont’d

The use of self-healing concrete has a major role to play in the industry of Nigerian construction, as it offers a way to solve these problems. However, its adoption requires an understanding of its physico-mechanical properties, especially under the environmental and operational conditions specific to Nigeria (De Belie et al., 2018).

INTRODUCTION CONT'D

Aim of Research

This study aims to offer a holistic perspective on the appropriateness of self-healing concrete for construction in Nigeria by investigating the physico-mechanical properties of the self-healing concrete.

INTRODUCTION CONT'D

Objectives of the Research

The objectives of this research are as follows:

i. To investigate the physicochemical properties of self-healing concrete, including compressive strength, permeability, crack healing effectiveness, and durability.

ii. To identify suitable self-healing mechanisms applicable to Nigerian construction practices.

iii. To monitor the self-healing process using non-destructive methods like Ultrasonic Pulse Velocity test (UPV)

LITERATURE REVIEW

Table 1: Summary of previous studies

Author	Title	Key Contributions
Joseph & Gardener, 2014	The emergence of self-healing materials	Early research in the late 20th century laid the foundation for the development of self healing materials, focusing on polymers and coatings that mimic natural healing mechanisms
Siddique et al	Innovative approaches to concrete repair	The integration of healing agents into microcapsules or hollow fibers within concrete mixes represents one of the earliest innovations in self healing.
Hamidi & Rouhi, 2021	Understanding Autogenous Healing in Concrete	Autogenous healing occurs mainly due to the further hydration of unreacted cement particles leading to the formation of calcium carbonate which helps repair cracks.

LITERATURE REVIEW CONT'D

Table 1: Summary of previous studies cont'd

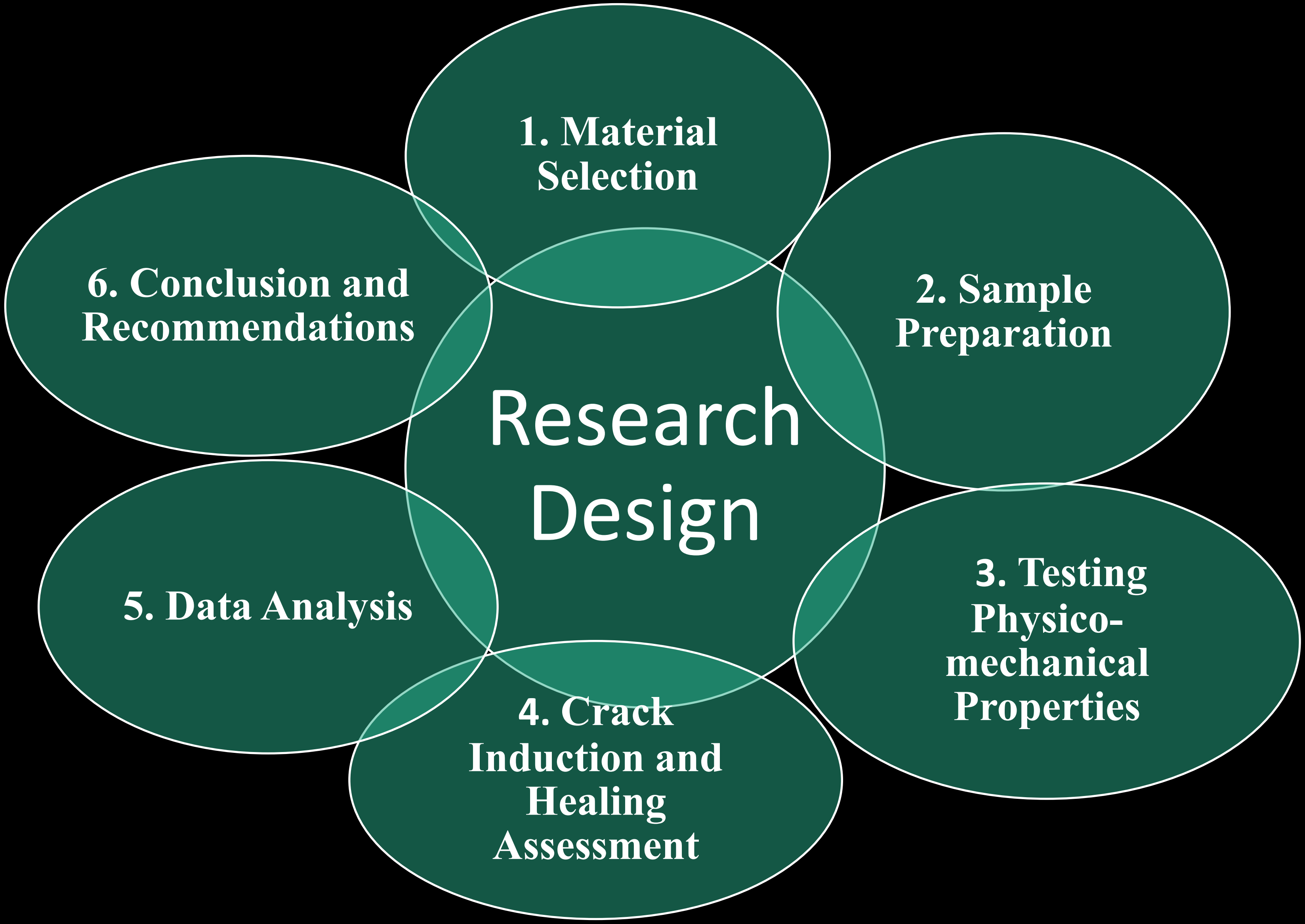
Author	Title	Key Contributions
Li & Herbert, 2014	Mechanism of Capsule-Based Self-healing	The release of encapsulated healing agent occurs when a fissure breaches the capsules, allowing the healing agent to flow into the crack and facilitate the repair process.
Owolabi & Faleye, 2019	**Challenges of Sustainable Construction in Nigeria**	**Comprehensive review of the various challenges hindering the widespread adoption and implementation of sustainable construction practices within Nigerian context**

LITERATURE REVIEW CONT'D

Table 1: Summary of previous studies cont'd

Smoky Hill Engineering, 2023	**Understanding Self-Healing Concrete: Impacts on Construction Industry**	**Industry-oriented analysis of self-healing concrete, focusing on its potential impacts on the construction sector.**
Babalola & Harinarain, 2024	Sustainable Building Codes and Regulations in Nigeria	In-depth examination of the existing sustainable building codes and regulations within Nigeria
Rahat & Navneet, 2011	Microbial concrete: A review on the recent trends in self-healing concrete technology.	The emerging trends in self-healing concrete technology that leverage microbial processes.

RESEARCH METHODOLOGY
Research Design



RESEARCH METHODOLOGY CONT'D
Materials and Methods

Crushed stones of 12mm size

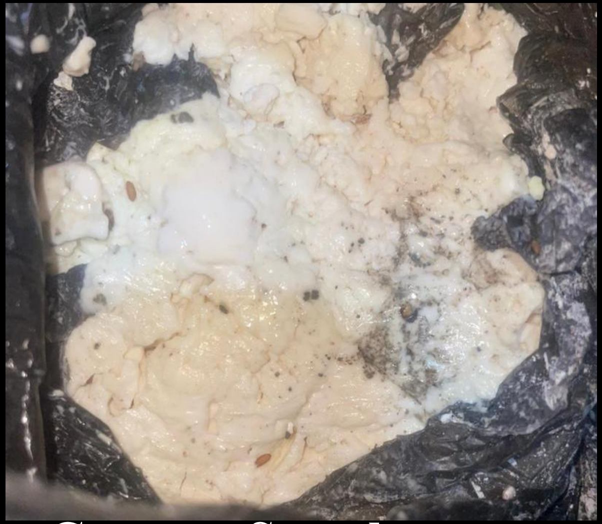
Bacillus subtilis sample

Fine aggregate

Potable water

Binder

Basalt fibre



Cassava Starch

Figure 1: Experimental materials

RESEARCH METHODOLOGY CONT'D
Experimental Procedures and Tests

1. Preparation of Self-Healing Concrete Specimens

Experimental Procedures and Tests

2. Testing of Mechanical Properties

3. Evaluation of Self-Healing Efficiency

4. Durability Tests

RESULTS

Water Absorption Test

Table 2: Water absorption test after 7days curing

Bacteria percentage	Dry weight (kg)	Weight-after immersion (kg)	% water absorption
0%	2.00	2.05	2.5
1%	2.35	2.40	2.13
3%	2.30	2.35	2.17
6%	2.30	2.35	2.17

Table 3: Water absorption test after 14days curing

Bacteria percentage	Dry weight (kg)	Weight-after immersion (kg)	% water absorption
0%	2.05	2.10	2.44
1%	2.20	2.25	2.27
3%	2.15	2.20	2.33
6%	2.15	2.20	2.33

Table 4: Water absorption test after 28days curing

Bacteria percentage	Dry weight (kg)	Weight-after immersion (kg)	% water absorption
0%	2.20	2.25	2.27
1%	2.30	2.35	2.17
3%	2.20	2.25	2.27
6%	2.25	2.30	2.2

Table 5: Compressive strength of samples with varying percentages of bacillus subtilis

Percentage of bacteria	Curing period		
	7 days	14 days	28 days
	Compressive strength (MPa)		
0%	10.84	14.21	17.52
1%	10.93	14.72	17.94
3%	12.71	15.35	20.32
6%	11.35	14.92	19.53

Ultrasonic Pulse Velocity Test

This test is done to assess the effectiveness of the self-healing on the concrete. Tests were carried out before the controlled load was applied, immediately after the load was applied and after respective days (3, 7 & 14days) of self-healing to monitor the self-healing process. Results from these tests is used to get the modulus of elasticity.

Table 6: Transit time of basalt fibre reinforced concrete embedded with bacillus subtilis before loading

Percentage of bacteria	Curing period		
	7 days	14 days	28 days
	Transit time (in microseconds)		
	Before loading		
1%	27.9	27.1	27.4
3%	28.2	27.7	26.9
6%	26.8	25.1	26

Table 7: Transit time for basalt fibre reinforced concrete embedded with varying percentages of bacillus subtilis (immediately after loading)

Percentage of bacteria	Curing period		
	7 days	14 days	28 days
	Transit time (in microseconds)		
	Immediately after loading		
1%	28.4	27.9	28.2
3%	28.9	28.5	27.6
6%	27.5	25.9	26.8

Table 8: Velocity for basalt fibre reinforced concrete emebedded with varying percentages of bacillus subtilis (before loading)

Percentage of bacteria	Before loading		
	Curing period		
	7 days	14 days	28 days
	Velocity(m/s)		
1%	3584.22	3690.0	3649.64
3%	3546.10	3610.11	3717.47
6%	3731.34	3984.06	3846.15

Table 9: Velocity of basalt fibre reinforced concrete embedded with bacillus subtilis(Immediately after loading
)

Percentage of bacteria	Immediately after loading		
	Curing period		
	7 days	14 days	28 days
	Velocity(m/s)		
1%	3521.13	3584.23	3546.10
3%	3460.21	3508.77	3623.19
6%	3636.36	3861.00	3731.34

Table 10: Modulus of elasticity of basalt fibre reinforced concrete embedded with bacillus subtilis

Percentage of bacteria	Before loading		
	Curing period		
	7 days	14 days	28 days
	Modulus of elasticity(MPa)		
1%	30186	29955	30622
3%	28923	28019	30404
6%	32717	34123	33272

Table 11: Modulus of elasticity of basalt fibre reinforced concrete embedded with bacillus subtilis

Percentage of bacteria	Immediately after loading		
	Curing period		
	7 days	14 days	28 days
	Modulus of elasticity(MPa)		
1%	29,370	28,260	29,556
3%	27,531	26,470	28,880
6%	30,420	32,045	31,325

Figure 2: Visual inspection (initial crack stage)

Figure 3: After days of self-healing

Case Studies of Self-Healing Concrete Applications

Case Studies of Self-Healing Concrete Applications

1. Application in Highways

2. Application in Residential Buildings

3. Application in Industrial Structures

CONCLUSIONS

The research into self healing concrete's physical and mechanical aspects proves it can greatly improve how long buildings last and how green construction is in Nigeria. The study found that compared to regular concrete, self healing concrete is stronger, better at sealing cracks and more waterproof. These qualities are especially helpful in Nigeria's climate where buildings face tough conditions, crack often and do not always get the maintenance that they need.

By using healing agents like Bacillus Subtilis, self healing concrete slows down damage and cuts down on the need for outside fixes. This makes it a good option for solving infrastructure problems in cities in Nigeria.

RECOMMENDATIONS

i. Further research and development: continued research should be done to focus on optimizing the composition of self healing concrete using locally available materials and healing agents.

ii. Pilot projects and field trials: government groups and businesses should team up to try out self healing concrete in real projects all over Nigeria. This would show how well it works over time and if it is affordable.

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Thank You