Advances in Materials Used in Civil and Construction Engineering

Advances in Materials Used in Civil and Construction Engineering

Edited by

Syed Ali Rizwan, Shahid Ali,
Muzna Anam and Bilal Zahid

Cambridge
Scholars
Publishing

Advances in Materials Used in Civil and Construction Engineering

Edited by Syed Ali Rizwan, Shahid Ali, Muzna Anam and Bilal Zahid

This book first published 2025

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-0364-4963-6
ISBN (Ebook): 1-0364-4963-7

TABLE OF CONTENT

LIST OF ILLUSTRATIONS

LIST OF TABLES

FOREWORD

It gives me great pleasure to introduce the proceedings of the conference organized by the National University of Computer and Emerging Sciences (FAST) titled "Advances in Civil and Construction Engineering" held in December 2022. These proceedings present a remarkable collection of research papers presented and discussions held during the conference.

In these proceedings, readers will find a wealth of knowledge and innovation in the form of cutting-edge research papers, enlightening case studies, and thought-provoking discussions. The diverse range of topics covered in the conference represents the dynamic nature of civil and construction engineering, including but not limited to structural analysis and design, sustainable infrastructure development, construction materials and techniques, project management, and emerging technologies. The technical contributions from esteemed professionals, researchers, and participants from academia from around the globe, highlight the ongoing efforts to address the challenges in our ever-evolving built environment.

It is my sincere hope that these proceedings will serve as a valuable information source for the international community of civil and construction engineers, consultants, policymakers, and other stakeholders. I believe that the collective wisdom contained within this compilation will inspire further innovation and foster collaboration for advancement in civil engineering.

I extend my heartiest gratitude and appreciation to all the authors, reviewers, organizers, and conference participants who made this publication possible.

Dr. Tahir Masood
Managing Director and President
National Engineering Services Pakistan Pvt. Ltd.

Lahore Pakistan
December 2022

PREFACE

This book is a collection of the proceedings of an international conference called the International Conference on **"Advances in Civil and Construction Engineering ACCE 2022"**, held from December 1st-3rd, 2022, at the University of Management and Technology and the National University of Computer and Emerging Sciences in Lahore. The papers were invited on almost all aspects of these two engineering specialties and were subjected to a two-stage peer review. The percentage of selected papers was around 25%. The book contains several chapters, such as civil engineering materials, structural engineering, water resources and environmental engineering, construction management, and transportation engineering. The presented papers have been grouped under the aforementioned areas. It is worth noting that approximately 90 percent of the speakers were world-class researchers and academicians, while the remaining 10 percent represented top-tier universities from Pakistan. The book presents the latest and state-of-the-art papers that are essential for leading consultants, academicians, and contractors. It is hoped that the readers will find this book as a valuable collection of their liabilities. In case of further information, the undermentioned may kindly be contacted.

Prof. Dr Syed Ali Rizwan
Civil Engineering Department, Fast
Lahore, Pakistan

ACKNOWLEDGMENTS

On behalf of **Rector NUCES-FAST Dr. Aftab Maroof** and **Air Marshal Asif Raza**, Rector University of Management and Technology, the undermentioned is deeply indebted to them for their wholehearted support, encouragement,, and patronage.

I am also grateful to the technical committees, review experts, organizing committees, and management committees for their untiring support. Thanks, are also due to representors who came from around the globe to present their work and interact with their Pakistani counterparts. I would also like to extend my vote of thanks to **Muhammad Bilal Zahid (UMT)**, **Engr. Waqas Ajmal, Engr. Muzna Anam, Engr. Abdul Moeiz Khan, Engr. Muhammad Tayyab** and **Engr. Abdul Rafey Asad (NUCES-FAST)** for their help. Without their help, it would have been an impossible task.

A special thanks goes out to the book editors, **Engr. Abdur Rehman Zahid (NUCES-FAST)** and **Engr. Noor Fatima (NUCES-FAST),** for their invaluable work and the indelible mark they leave on every page.

LIST OF ABBREVIATIONS

a, b = empirical constants in IDF relationships

C = empirical constant in IDF relationship

d = rainfall duration (T)

e = empirical constant in IDF relationship

i = rainfall intensity (L/T)

K = empirical function in IDF relationship

K_T = Frequency factor

m = empirical constant in IDF relationship

P = Precipitation (rainfall) (L)

T_r = Return period (years)

S = Standard deviation

x = Observed value

$\bar{X}$ = Mean of observed values

CIVIL ENGINEERING MATERIALS

CHAPTER ONE

DEVELOPMENT OF GEOPOLYMER MORTAR AT AMBIENT CONDITION BY USING LIMESTONE POWDER

KHURAM RASHID AND KHADIJA MAWRA

Biographies

Khuram RASHID is an Associate Professor at the University of Engineering and Technology, Lahore, Pakistan. He received his Bachelor's and Master's from the same university and PhD from Japan. He is a member of the Pakistan Engineering Council, and Pakistan Engineering Congress, and was a member of the Asian Concrete Federation, and Japan Concrete Institute. His research interests include the development and performance of sustainable construction materials and strengthening of reinforced concrete structures.

Khadija MAWRA is a lecturer at the University of Engineering and Technology, Lahore, Pakistan. She completed her Master's degree in Construction Engineering and Management from NUST, Pakistan. Her research interests are Sustainability, Modular Construction, and Building Information Modelling.

Abstract

Geopolymer is an emerging material in the construction industry, but hot curing is required for the strength evolution of low calcium fly ash (FA) based geopolymer, which makes it energy intensive and is not suitable for real application. Although slag was added to attain strength at ambient conditions, but it increases the cost, and its availability is also an issue. Therefore, this work was designed, to get the strength at ambient conditions

by activating widely available uncalcined lime powder and FA in the alkaline environment (a combination of NaOH and Na_2SiO_3). River sand was also incorporated to develop geopolymer mortar. Specimens were exposed to three curing regimes; ambient curing, sun-dried, and hot curing and finally compressive strength was evaluated after 7 days. It was observed that due to the addition of limestone powder(LSP), the strength at ambient conditions was 26 MPa, and it further increased (39 MPa) under hot curing conditions. Furthermore, to reduce the cost, the alkaline to precursor ratio was reduced from 0.18 to 0.12, and mixture was pressed at 20 MPa molding pressure and more than 16 MPa strength was attained at ambient condition. It can be easily concluded that the observed compressive strength can be widely used in residential and commercial projects to fulfill the demand for construction materials and to reduce cement consumption.

Keywords: ambient cure; compressive strength; curing regimes; geopolymer mortar; hot curing; lime; molding pressure.

Introduction

Ordinary Portland Cement (OPC) is well renowned binding material but is considered an environmental burden due to a lot of CO_2 emissions. Several trials have been made by reducing the amount of cement in concrete by adding supplementary cementitious materials [1]. However, geopolymer materials are considered as the alternative material to cement paste, mortar, and concrete. Therefore, needs to be explored in more detail to replace conventional mortar or fired clay brick.

Geopolymers, which are considered part of alkali-activated materials, are one of the most promising materials in this respect. The process of geopolymerization involves the activation of rich silica and alumina materials in an alkaline environment [2]. The aluminosilicates are known as precursors such as clays (illite, halloysite, kaolinite, etc.) [3], and ashes (FA, bagasse ash, and rice husk ash, etc.) [4]. FA is a silica and alumina-rich precursor that is widely available in many countries. It has been used in cementitious products widely, many standards have also been developed for its efficient utilization [5]. The utilization of FA is only possible when it gets activated in an alkaline environment. In terms of the selection of a precursor, the basic philosophy to be kept in mind for obtaining a superior product is the degree of reaction based on the availability of amorphous

silica and alumina in the source material. Similarly, other parameters that influence the compressive strength during geopolymerization include alkaline to precursor and sodium silicate (Na_2SiO_3) to sodium hydroxide (NaOH) ratios, the molarity of NaOH and curing temperature, etc [6-8]. The mixture of NaOH and Na_2SiO_3 results in better strength development as compared to using them individually as an alkaline activator. Reducing the alkaline/precursor (A/P) ratio for FA-based geopolymer mortar decreases its cost. Another significant factor to consider, especially for geopolymerization, is the molding pressure [9-12], which might have a favorable impact on compressive strength. Pressure increases the rate of geopolymerization, but it also decreases porosity while increasing the bulk density. Moreover, there is a big variation in the temperature or curing condition of cement mortar as it requires very high temperature. Slag has been used along with the FA to cure the resultant geopolymer product at ambient conditions. Slag is rich in Calcium, and activated at the ambient condition to form the calcium-alumino-silicate-hydrate (C-A-S-H) gel and thus gets the strength [7]

With this background, a new couple has been proposed in this work, where FA was coupled with the LSP. Three curing regimes have been adopted to cure the specimen at ambient conditions and compare it concerning the hot curing condition. Hence, a systematic approach has been proposed in this work to synthesize geopolymer which fulfilled the mechanical strength criterion of ASTM standards for brick masonry.

Research Significance

OPC is used globally every year, and it contributes greatly to the world's CO_2 emissions. However, its use in concrete and mortar is environmentally unsustainable. This work was designed to develop FA-based geopolymer coupled with lime, a widely available material. The LSP was used without calcination to produce a cleaner environment. Moreover, the curing condition may also be the ambient or sun-dried condition to make it more sustainable. Hence, a systematic approach has been proposed in this work to synthesize geopolymer and to replace conventional concrete blocks or fired clay bricks. The authors believe that this study will have a positive effect on the construction industry.

Experimental Investigation

Materials

For the production of geopolymer mortar, FA, sand (river, dune), alkaline activators (NaOH, and Na_2SiO_3), LSP (calcium carbonate), and distilled water were used. The FA was classified as class F and having low calcium content (4.81%), because the total amount of SiO_2 (54.14%), Al_2O_3 (28.19), and Fe_2O_3 (4.93%) is higher than 70%, and the CaO content less than 10%, according to ASTM C 618 [13]. The color of FA was light grey having a density of 1058.6kg/m^3. Types of sand used are River Sand (RS) and Dune Sand (DS). The sodium hydroxide (NaOH) was taken in pallet form having a white color. Sodium hydroxide was used to activate the FA so that FA exhibits good cementitious properties. Sodium Silicate was colorless and clear in physical properties. It was taken in gel form and also used to activate the FA. LSP was taken in powdered form and white color.

Specimens

Dry mixing of precursors i.e. FA and lime and filler material i.e. sand (river or dune) was carried out for 30 seconds with high speed mixer. By the addition of an alkaline activator, sodium silicate (Na_2SiO_3), and sodium hydroxide solution (NaOH), wet mixing was carried out for a further two min 30s, and a paste was formed. The work was divided into three series. In Series I, the paste was formed with 0.18 Alkaline/Precursor ratio (A/P) and 1.5 NaOH/Na_2SiO_3 with the river sand and was filled in three layers in cube molds which were tested after placing under three curing regimes i.e. Oven-dry, Sun-dry, ambient dry. Then, the mix proportion was changed in Series II by reducing A/P to 0.12 and NaOH/Na_2SiO_3 to 1.0, and cylinders (diameter of 71 mm) were filled with this paste in three layers with 12 times tamping at each layer. Then these were placed in the Universal Testing Machine (UTM) and a load was applied to obtain 20 MPa molding pressure. The specimen was taken out carefully from the cylindrical mold and was kept under ambient temperature. The same mix proportion was used in Series III with dune sand but it formed a slurry because of the change in porosity and surface roughness of particles so cubes of 2.75 mm in size were cast. A schematic diagram for preparation of geopolymer mortar specimens is shown in Fig. 1-1 and mix proportions for different series can be found in Table 1-1.

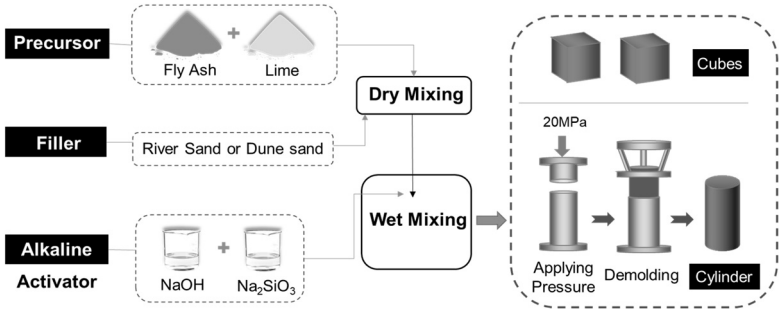

Fig. 1-1: Schematic Diagram of Specimen Preparation

Table 1-1: Summary of mix proportion and the specimens prepared in all series

Series	FA	Lime	Sand	Na_2SiO_3/ NaOH	A/P	Pressure MPa	Curing
Series-I	40	10	50	1.50	0.18	N.A	Oven-Dry Sun-Dry Ambient
Series-II	40	10	50	1.0	0.18	20	Ambient
Series-III	40	10	50	1.0	0.18	N.A	Ambient