



**CIVIL ENGINEERING, SCIENCE AND  
TECHNOLOGY CHALLENGES:  
STRUCTURAL ENGINEERING AND  
CONSTRUCTION MATERIALS**

**E D I T E D B Y**

**Wan Hashim Wan Ibrahim  
Siti Noor Linda Taib  
Norsuzailina Mohamed Sutan**

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© Wan Hashim Wan Ibrahim, Siti Noor Linda Taib, Norsuzailina Mohamed Sutan

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The book is based on scientific and technological advances in various Structural Engineering and Construction Materials areas of Civil Engineering. It nurtures therefore the exchange of discoveries among research workforces worldwide including those focusing on the vast variety of facets of the fundamentals and applications within the Structural Engineering and Construction Materials arena. To offer novel and rapid developments, this book contains original contributions covering theoretical, physical experimental, and/or field works that incite and promote new understandings while elevating advancement in the Structural Engineering and Construction Materials fields. Works in closing the gap between the theories and applications, which are beneficial to both academicians and practicing engineers, are mainly of interest to this book that paves the intellectual route to navigate new areas and frontiers of scholarly studies in Structural Engineering and Construction Materials.

# **CIVIL ENGINEERING, SCIENCE AND TECHNOLOGY CHALLENGES: STRUCTURAL ENGINEERING AND CONSTRUCTION MATERIALS**

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# TABLE OF CONTENTS

CHAPTER	TITLE OF CHAPTERS	PAGE NO
1	Modified Cement System: Durability And Aesthetics	1
2	Utilization Of Recycled Aggregate As Coarse Aggregate In Concrete	6
3	Effect Of Aggregates And Curing Conditions On The Compressive Strength Of Concrete With Age	13
4	Effect Of Seawater On The Properties Of Epoxy Modified Concrete	21
5	Study The Structural Behavior Of Ferrocement Beam	29
6	Effect Of PFA On Strength And Water Absorption Of Mortar	37
7	Laboratory Study Of Water Absorption Of Modified Mortar	42
8	Performance Of Profiled Steel Sheet Dry Board System Under Flexural Bending And Vibration	48
9	The Effect Of Reinforcement, Expanded Polystyrene (EPS) And Fly Ash On The Strength Of Foam Concrete	57
10	Status Of Industrialized Building System Manufacturing Plant In Malaysia	65
11	Evaluation Of Acacia Mangium In Structural Size At Green Condition	76
12	Basic And Grade Stress For Some Timber In Sarawak	84
13	The Behavior Of Strength Properties From Three Different Tree Boles Of Aras In Sarawak	88
14	Initial Surface Absorption Of Pozzolan And Polymer Modified Mortar	93
15	The Influence Of Finely Ground Mineral Admixture (FGMA) Of Efflorescence	99
16	Characterization Of Early Pozzolanic Reaction Of Calcium Hydroxide And Calcium Silicate Hydrate For Nanosilica Modified Cement Paste	106
17	Strength Characteristics Of Mortar Containing Different Sizes Glass Powder	113
18	Influence Of Silica Based Waste Materials On The Mechanical And Physical Properties Of Mortar	120
19	Effect Of Curing And Mixing Methods On The Compressive Strength Of Mortar Containing Oil	126
20	Improving The Strength Performance Of High Volume Periwinkle Shell Ash Blended Cement Concrete With Sodium Nitrate As Accelerator	133
21	Chloride Resistance Of Blended Ash Geopolymer Concrete	138
22	Evaluation Of Water Hyacinth Stem Ash As Pozzolanic Material For Use In Blended Cement	150
23	Pozzolanic Properties Of Glass Powder In Cement Paste	158
24	Effect Of Organic Soil On Strength Properties Of Compressed Cement-Soil Block	166
25	Effect Of Base Isolator On The Structural Response Of Reinforced Concrete Multistoried Building Under Seismic Loads	174

## **TABLE OF CONTENTS cont.**

<b>CHAPTER</b>	<b>TITLE OF CHAPTERS</b>	<b>PAGE NO</b>
26	Toner Used In The Development Of Foamed Concrete For Structural Use	184
27	Finite Element Simulation Of Damage In RC Beams	192
28	Seismic Performance Of Damper Installed In High-Rise Steel Building In Bangladesh	200
29	Characteristics Of Steel Fiber Reinforced Concrete With Recycled Coarse Aggregate	213
30	Finite Element Analysis Of A Strengthened Beam Deliberating Elastically Isotropic And Orthotropic CFRP Material	218
31	Compressive Strength Of Foamed Concrete In Relation To Porosity Using SEM Images	229
32	Predicting The Structural Performance Of Sandwich Concrete Panels Subjected To Blast Load Considering Dynamic Increase Factor	241
33	Partial Replacement Of Cement By Coffee Husk Ash For C-25 Concrete Production	258
34	Porosity, Permeability And Microstructure Of Foamed Concrete Through SEM Images	267
35	Some Mechanical Characteristics Of Concrete Reinforced With Dried Water Hyacinth And Quarry Dust As Fine Aggregates	282
36	Potential Use Of Cinder Gravel As An Alternative Base Course Material Through Blending With Crushed Stone Aggregate And Cement Treatment	290
37	Water Permeability And Chloride And Sulphate Resistance Of Rubberised Fibre Mortar	302
38	Case Study Of Structural Health Monitoring In India And Its Benefits	315
39	Comparing Compressive Strengths Of Layered And Random Placement Of Expanded Polystyrene Wastes In Quarry Dust Blocks	324
40	Experimental Study On Application Of Marble Waste As Conventional Aggregate For Base Course Materials	331
41	Evaluation Of The Performance Of Waste Marble Dust As A Mineral Filler In Hot-Mix Asphalt Concrete	349
42	Linear And Nonlinear Free Vibration Analysis Of Rectangular Plate Compressive Strength Of Mortar Containing Oil	367
43	Influence Of Oil Palm Spikelets Fibre On Mechanical Properties Of Lightweight Foamed Concrete	379
44	Experimental Study On Behavior Of Unprotected Foamed Concrete Filled Steel Hollow Column Under Fire	388

# CHAPTER 6

## EFFECT OF PFA ON STRENGTH AND WATER ABSORPTION OF MORTAR

Gingos, G.S. and Mohamed Sutan, N.\*

### ABSTRACT

Partial replacement of cement by mineral admixtures or pozzolans can possibly improve the durability of mortar which directly related to its water absorption. Pulverized Fuel Ash (PFA) is one of the pozzolans that is locally available. Laboratory studies have been conducted on mortar mixes of 0.3w/c, 0.4w/c and 0.5w/c ratios with 10%, 20% and 30% PFA replacements. Mortar cubes were tested to determine their water absorption rates and compressive strengths as they mature. Amount of PFA replacements in the mortar has significant effects on the strength development and water absorption rate of the mortar. Results shows that 20% PFA mortars of 0.5w/c ratio is the best mix to reduced rate of water absorption and achieved higher compressive strength.

**Keywords:** Mortar, Pulverized Fuel Ash (PFA), Water Absorption Test, Compressive Strength

### INTRODUCTION

Mortar basically consists of cement, sand and water. Ordinary Portland Cement (OPC) plays a very important role in mortar as binder. Due to its increasing energy consumption and high Carbon Dioxide (CO<sub>2</sub>) emission from its production, alternative binding materials are needed to partially replace OPC. Mortar with cement replacement of mineral admixtures or pozzolan is called modified mortar. The use of partial cement replacement such as pozzolanic materials can improve the durability of the mortar produced. Pulverized Fuel Ash (PFA) is one of the pozzolanic materials widely used as cement replacement to produce high durability mortar [1][ 2]. Durability of mortar is directly related to its water absorption. The higher water absorbed by mortar the less durable it becomes. Water absorption of a mortar specimen is measured by drying the specimen to a constant mass, immersing it in water, and measuring the increase in mass as a percentage of dry mass. It is one of the important properties that determine the durability of mortars. Good mortar mix has water absorption well below 10 % by mass. Factors such as type of materials used, additives, temperature and length of exposure can affect the amount of water absorbed. Water absorption can also influence the strength of mortar. Previous studies indicated that low-calcium fly ash (ASTM Class F) improved the interfacial zone microstructure [3]. Computer simulation studies predicted that replacing 20% of cement with fly ash with smaller particles size resulted in higher interfacial strength than that of control Portland cement paste [4]. Previous studies also showed that PFA reduced the porosity of concrete hence contributed to the higher concrete strength [5]. In order to contribute further to the current knowledge in PFA cement replacement in mortar, a laboratory study was carried out to investigate on any possibility of waterproof effects of PFA in mortar and its contribution to mortar strength.

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## EXPERIMENTAL PROGRAM

### MATERIALS AND SPECIMENS PREPARATION

Materials used in this study are commercially available Ordinary Portland Cement (OPC) equivalent to ASTM Type 1 cement, a commercially available fly ash equivalent to ASTM Type F fly ash and normal grade river sand [6]. Mortar mixes of water-to-cement ratio (W/C) of 0.3, 0.4 and 0.5 were prepared. PFA replaced cement at levels of 10%, 20% and 30% by mass. The dimension of mortar cubes was 100 x 100 x 100mm. All mortars were removed from the moulds after 24 hours casting and then dry cured. Compressive strength and absorption rate of mortars were determined at age of 1, 7, 14, 21 and 28 days.

### WATER ABSORPTION TEST

Water absorption test is a measure of the capillary forces exerted by the pore structure causing fluid to be drawn into the body of the material [4]. The amount of water absorbed by mortar mixes depends on the water tightness or waterproofness of the mixes. All mixes were subjected to water absorption test at the end of curing period of 1, 7, 14, 21 and 28 days after demoulding. They were taken from the curing tank 2 days before the test and later oven dried at  $100 \pm 5^\circ\text{C}$  for 7 days until a constant mass was achieved. Each mix was then weighed. The samples were covered with wax, except the bottom area before they were immersed in trays containing water. The reason of covering the cube with wax is to prevent air from entering the void during immersing process, since the cube is not fully soak in water, but only about 30-35mm of water level. The start time was immediately recorded. After 7 days, the mixes were removed from the tank, shook to remove bulk of the water, and dried with a cloth as fast as possible to remove all free water on the surface. They were then weighed again. The measured water absorption by each mix was expressed as the increase in the mass as a percentage of the oven dry mass.

### COMPRESSIVE STRENGTH TEST

All mixes were subjected to compressive strength test at the end of curing period of 1, 7, 14, 21 and 28 days after demoulding. This test was carried out to determine the maximum compressive load it can carry per unit area. Since strength of mortar was directly related to the structure of hydrated cement paste, this test was important not only to determine the strength development of the mortar specimen, but also the quality of the mortar specimen. A good mortar specimen should achieve the targeted mean strength at the end of 28 days [2].

The experimental program can be summarized in the flow chart as shown in Figure 1.

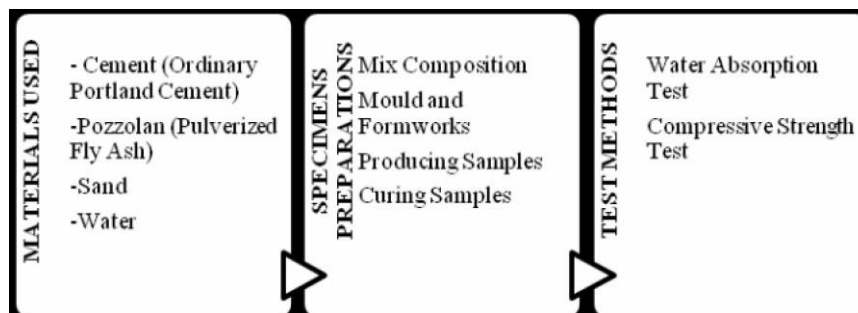


Figure 1: Flow Chart of the Experimental Program



## RESULTS AND ANALYSIS

### WATER ABSORPTION TEST

Figure 2 and 3 show the same trend of water absorption rate for all 4 mixes. It shows that 10% PFA mix had the highest absorption rate compares to other mortar mixes. The other mixes had almost equal water absorption rate. 20% PFA mix had almost constant water absorption rate for the whole 28 day test. 20% PFA mix and 30% PFA mix shows almost the same trend which is relatively small changes in water absorption rate. Figure 4 shows that 0.5 w/c has the lowest absorption rate in all mixes comparing to 0.3w/c and 0.4w/c ratios. Overall results show that control mixes had highest water absorption percentile compare to the other mixes particularly at day 14. At day 28, for 0.5w/c ratio the more cement replaced with PFA the less the rate of water absorption.

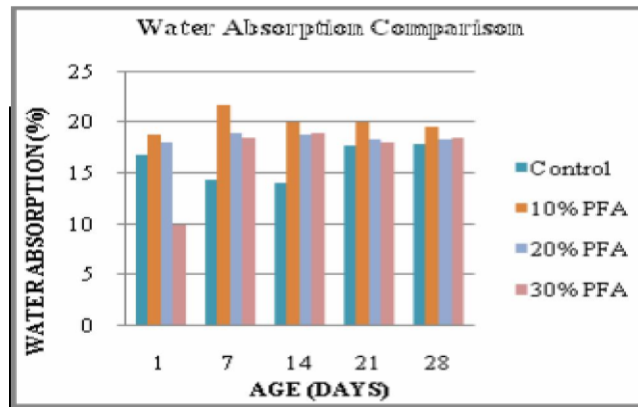


Figure 2: Water absorption for 0.3 w/c ratio

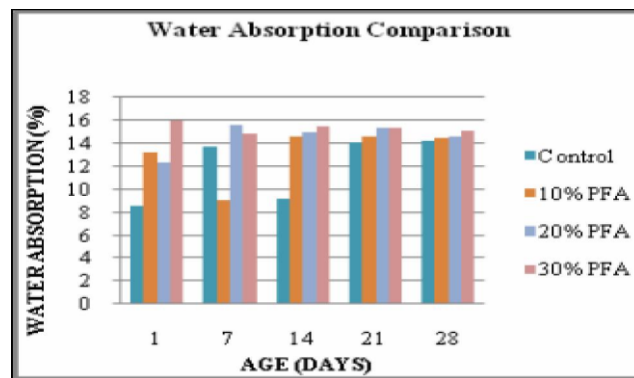


Figure 3: Water absorption for 0.4 w/c ratio

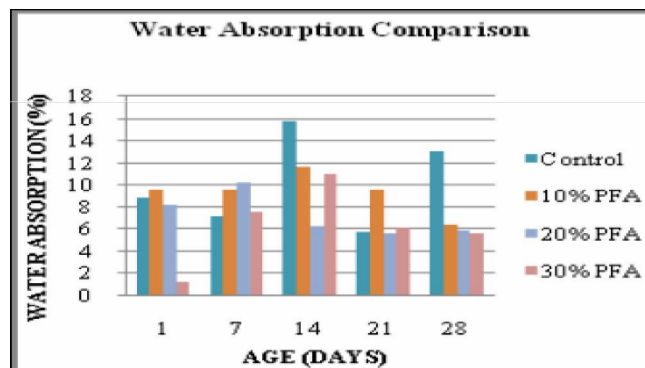


Figure 4: Water absorption for 0.5 w/c ratio

## COMPRESSIVE STRENGTH TEST

Figure 5 shows almost the same compressive strength at day 1 for all mixes relatively. Control mix shows constant increase whereas sample 20% PFA and 30% PFA show uneven development in strength. 10% PFA mix increased sharply in strength for the first 14 days.

Figure 6 shows that 20% PFA mix and 30% PFA mix have a similar linear increment trend in strength development. Meanwhile control mix has slow development in strength in the beginning and achieved high strength at the end of 28 days. 10% PFA mix has sharp increases in strength development in the first 7 days

Figure 7 shows a different trend in the strength development as compared to the previous mixes with 0.3w/c and 0.4w/c ratios. Control mix achieved the highest final strength at 28 days, showing sharp increase in strength for the first 14 days and the last 21 to 28 days. 10% PFA mix and 20% PFA mix behave almost similarly which is sharp increase in the first 7 days and a slow strength development afterwards. Whereas for 30% PFA mix, a linear trend can be seen as constant strength development is achieve.

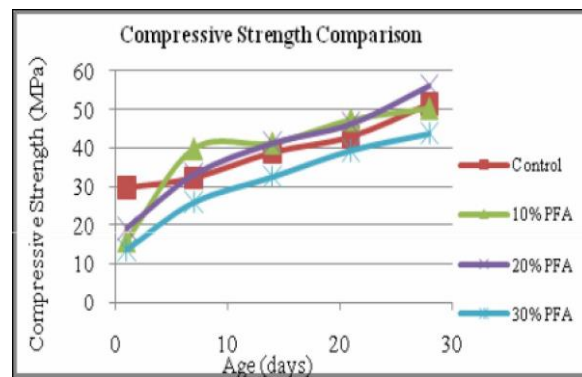


Figure 5: Compressive strength for 0.3 w/c ratio

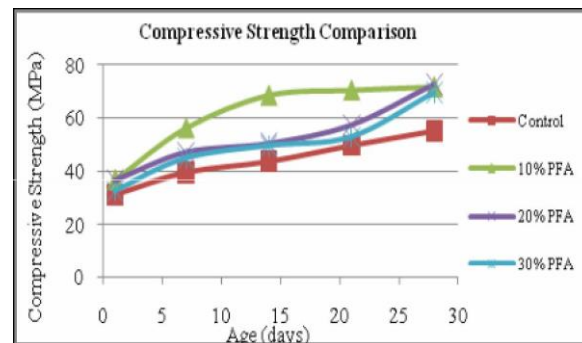


Figure 6: Compressive strength for 0.4 w/c ratio

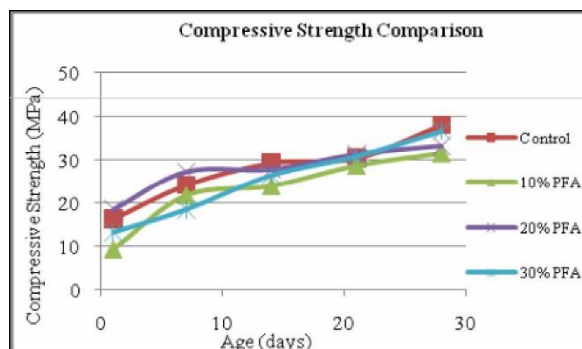


Figure 7: Compressive strength for 0.5 w/c ratio

## CONCLUSIONS

The effects of replacing cement with PFA to the compressive strength and absorption rate of mortar were investigated. The compressive strength and absorption rate of mortar with 10%, 20% and 30% PFA cement replacements and of 0.3w/c, 0.4w/c and 0.5w/c ratios were compared to control mortar. The following conclusions that can be drawn based from the results are:

1. 0.4w/c ratio shows significant effects on the compressive strength of mortar at the age of 28 days.
2. 20% PFA replacement mortar of 0.5w/c ratio shows higher compressive strength than the control mortar.
3. Water absorptions of PFA mortars of 0.5w/c ratio at 28 days were much lower as compared to control mortar.
4. 20% PFA mortars of 0.5w/c ratio is the best mix to reduced rate of water absorption.

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