MODELLING THE INFLUENCE OF SPENT BLEACHING EARTH ASH ADDITION ON THE MORTAR PROPERTY

LEE JUN HONG

FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
2022

MODELLING THE INFLUENCE OF SPENT BLEACHING EARTH ASH ADDITION ON THE MORTAR PROPERTY

LEE JUN HONG

THESIS SUBMITTED IN FULFILLMENT FOR THE BACHELOR'S DEGREE OF ENGINEERING WITH HONOURS (CIVIL ENGINEERING)

FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
2022

UMS
UNIVERSITI MALAYSIA SABAH

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL : **MODELLING THE INFLUENCE OF SPENT BLEACHING EARTH ASH ADDITION ON THE MORTAR PROPERTY**

IJAZAH : **SARJANA MUDA KEJURUTERAAN DENGAN KEPUJIAN (KEJURUTERAAN AWAM)**

SAYA : **LEE JUN HONG** SESI PENGAJIAN : **2018-2022**

(HURUF BESAR)

Mengaku membenarkan tesis *(LPSM/~~Sarjana~~/~~Doktor Falsafah~~) ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/)

[ ]	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di AKTA RAHSIA RASMI 1972)
[ ]	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
[/]	TIDAK TERHAD	

Disahkan oleh:

ANITA BINTI ARSAD
PUSTAKAWAN KANAN
UNIVERSITI MALAYSIA SABAH

(TANDATANGAN PENULIS)

(TANDATANGAN PUSTAKAWAN)

Alamat Tetap: **NO. 25, JALAN RASA SAYANG, TAMAN RASA SAYANG 72100 BAHAU, N.S.**

·(DR. HIDAYATI)

(NAMA PENYELIA)

TARIKH: **5 OGOS 2022**

TARIKH: 1/8/2022

Catatan:
*Potong yang tidak berkenaan.
*Jika tesis ini SULIT dan TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.
*Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana Secara Penyelidikan atau disertai bagi pengajian secara kerja kursus dan Laporan Projek Sarjana Muda (LPSM).

DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equations, summaries and references, which have been duly acknowledged.

19th July 2022

Lee Jun Hong
BK18110041

CERTIFICATION

NAME	:	**LEE JUN HONG**
MATRIC NO.	:	**BK18110041**
TITLE	:	**MODELLING THE INFLUENCE OF SPENT BLEACHING EARTH ASH ADDITION ON THE MORTAR PROPERTY**
DEGREE	:	**BACHELOR OF ENGINEERING WITH HONOURS**
FIELD	:	**CIVIL ENGINEERING**
VIVA DATE	:	**19th JULY 2022**

CERTIFIED BY;

SINGLE SUPERVISION Signature

SUPERVISOR

Dr. Hidayati Asrah

ACKNOWLEDGEMENT

First of all, I am grateful to get my thesis writing done under the supervision and guidance of Dr. Hidayati. I appreciate her belief in me by giving me a valuable topic to work on. I appreciate more her patience in answering my any doubt and her comments to make the possible best for my thesis writing. Next, I thank my family members (my mummy, brother, sister, grandma, uncle and aunts) for always checking on me, trying to fulfill my every need and supporting my life decisions. To the one(s) I love and those who love me, I wish to share the glory with you all. To my coursemates, I feel honored that we could work hard together in the struggle to accomplish what we were supposed to accomplish. Wish we all have the best career kickstart. Then, special mention is given to anyone who ever showed my mercy or lent me a helping hand during my degree study until I came to this far and submitted my thesis. Lastly, I thank myself for keep making things workable and still staying mentally positive at the ultimate whenever I am at a low. Highs and lows, I'll celebrate. To end here, I quote a line from a song titled 'Smile' by Katy Perry:

"Long hard road to get that redemption,
but no shortcuts to a blessing."

Lee Jun Hong
19th July 2022

ABSTRACT

There is a need to use reliable and faster methods for quantifying the characteristics of construction materials when the physical tests become not practical. Modelling method was attempted to see if it could predict the compressive strength of modified mortar subjected to few factors. It was done through a design model of response surface methodology (RSM) built in Design-Expert 13 software. As spent bleaching earth ash (SBEA) is the least commonly used among the other known supplementary cementitious materials, it was used to modify the mortar in this study to popularize its usage. To initiate the predictive simulation, the laboratory result of tested mortar modified with SBEA of different sizes at different cement replacement content and testing ages was obtained. The SBEA sizes were categorized original (unground) size and ground size. The SBEA content used to replace the cement in mortar was ranged between 10% and 50%. The testing ages of produced mortar were 7 days, 28 days and 90 days. The prediction values given by the model simulation were displayed in different graphical plots and then compared to the actual values through statistical measures. The simulation prediction accuracy was supported by analysis of variance (ANOVA). After applying the practical constraints, the optimization result proposed the suitable SBEA content in the range of 10–50% to give the optimal ultimate compressive strength to the modified mortar. From the result, it shows that 27.56% unground SBEA and 50% ground SBEA gave the best 90-day compressive strength to the modified mortar. In the simple words, this study predicted the compressive strength of mortar modified with SBEA of different sizes at different ages to determine the optimal usage content of SBEA.

ABSTRAK

PEMODELAN PENGARUH SIFAT MORTAR DARIPADA PENAMBAHAN ABU TANAH LUNTUR TERPAKAI

Terdapat keperluan untuk menggunakan cara yang boleh diharap dan cepat untuk mengkuantitikan ciri-ciri bahan pembinaan apabila ujian fizikal menjadi tidak praktikal. Pembentukan model dilakukan untuk mengkaji keupayaannya dalam menjangkakan nilai kekuatan mampatan mortar yang diubah suai atas beberapa faktor. Model tersebut dihasilkan melalui reka bentuk daripada kaedah permukaan tindak balas yang didapati dalam perisian Design-Expert 13. Memandangkan "abu tanah luntur terpakai" (SBEA) jarang digunakan sekali dalam kalangan bahan tambahan bersimen lain yang sudah diketahui, SBEA digunakan untuk mengubah suai mortar dalam kajian ini untuk mempopularkan penggunaannya. Untuk memulakan simulasi jangkaan, keputusan uji kaji makmal yang dijalankan atas mortar yang diubah suai dengan SBEA yang berlainan saiz pada kandungan penggantian simen dan tempoh ujian yang berlainan telah diperolehi. Saiz SBEA dikategorikan kepada saiz tidak terkisar (asal) dan saiz terkisar. Kandungan yang digunakan untuk menggantikan simen dalam mortar adalah antara 10% dan 50%. Tempoh ujian pada mortar hasilan adalah 7 hari, 28 hari dan 90 hari. Nilai-nilai jangkaan yang dihasilkan dari simulasi model ditunjukkan dalam beberapa bentuk plot grafik dan dibandingkan dengan nilai-nilai sebenar melalui cara statistik. Ketepatan jangkaan simulasi disokong dengan analisis varians (ANOVA). Selepas mempertimbangkan kekangan praktikal, keputusan pengoptimuman mencadangkan kandungan SBEA yang sesuai dalam julat 10–50% untuk memberi nilai optima kekuatan mampatan terakhir kepada mortar yang diubah suai. Keputusan tersebut menunjukkan 27.56% SBEA tidak terkisar dan 50% SBEA terkisar telah memberi kekuatan mampatan optima hari ke-90 kepada mortar yang diubah suai. Secara ringkasnya, kajian ini menjangkakan nilai kekuatan mampatan mortar yang diubah suai dengan SBEA dan menentukan kandungan optima penggunaan SBEA.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

2D	-	Two-Dimensional
3D	-	Three-Dimensional
AC	-	Acrylate Polymer
ANFIS	-	Adaptive Neuro-Fuzzy Interface System
ANN	-	Artificial Neural Network
ANOVA	-	Analysis of Variance
BBD	-	Box-Behnken Design
CCD	-	Central Composite Design
DOE	-	Design of Experiment
EPP	-	Eco-Processed Pozzolan
EVA	-	Ethylene Vinyl Acetate
FA	-	Fly Ash
FFD	-	Full Factorial Design
GHG	-	Greenhouse Gas
MAE	-	Mean Absolute Error
OPC	-	Ordinary Portland Cement
PVA	-	Polyvinyl Alcohol
RMSE	-	Root-Mean-Square Error
RRMSE	-	Relative-Root-Mean-Square Error
RSE	-	Root-Square Error
RSM	-	Response Surface Methodology
SBEA	-	Spent Bleaching Earth Ash
SBR	-	Styrene-Butadiene Rubber
SCMs	-	Supplementary Cementitious Materials
VA	-	Volcanic Ash
VA/VeoVa	-	Polyvinyl Acetate-Vinyl Carboxylate
XRD	-	X-Ray Diffraction

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Many negative environmental impacts have been raised due to human activities in different industries. Construction industry is one of the main contributors to the climate change due to waste disposal and greenhouse gas (GHG) emissions through different stages, from resource consumption, energy-intensive operations to demolition. The waste management in the manufacture industry is also one of the challenges as it is usually handled improperly, eventually causing the disposal of wastes into the landfills which further increase the land demand as time passes. It is necessary to adapt the wastes to compensate the high demand of natural resources which are usually costly and obtain alternative ways to conserve the environment. Hence, the wastes shall be recycled as much as possible, and perhaps reused in the construction industry to the greatest extent in order to reduce the resultant environmental impacts due to construction. One of the ways to reuse the recycled wastes is by introducing them as a composition in the material preparation for the construction industry. The possibility of replacing the construction materials with industrial wastes offers the technical and environmental benefits which are important in the need of sustainable development.

As a matter of fact, there are concrete and mortars incorporated with partial replacement of conventional cement by supplementary cementitious materials (SCMs). When there is less demand of conventional cement, the carbon footprint due to its production can be lessen, thus reducing the climate change impacts. To optimize or support the use of recycled wastes in the material preparation, there is a need to evaluate the characteristic properties of the final products to check whether they can be approved based on the standards. To achieve this, laboratory tests are usually done on the modified materials. The laboratory tests, however, are mostly complex and time-consuming due to long procedure. Hence, there is also a need to develop an alternate to determine the influence of the wastes added into the product materials.

Due to these two needs mentioned above, many researches in the construction industry have been developed in using locally available wastes for construction material production due to these needs. This study is proposed on the basis of these two needs, by using spent bleaching earth ash (SBEA) in producing the mortar. The motivations to promote the use of SBEA in modifying the mortar is to reduce its negative impact on the nature upon its disposal into the landfills and increase its popularity as a SCM. Mortar, instead of concrete, is used as the testing subject in this study as the SBEA modification had been mostly done on the concrete before (Elffie Yunus *et al.*, 2019; Rokiah *et al.*, 2019a; Kho, 2021).

1.2 Problem Statement

Spent bleaching earth ash (SBEA), as an extraction waste from the palm oil refining process, is the least common and used among the other known SCMs (e.g., fly ash, slag, silica fume, etc.) in the construction industry. Our country, Malaysia, is known to greatly produce palm oil fruits, resulting in much SBEA which is usually ended up in the landfills without proper pre-treatment. SBEA facilitates the greenhouse gas (GHS) emissions due to the natural anaerobic degradation and possesses fire hazard due to its pyrogenic nature. Its disposal into the landfills may be limited by stricter environment regulations in the near future (Azri Sukiran *et al.*, 2009). This urges the need of often adapting SBEA for a practical utilization, especially in the cement production for the construction. Furthermore, there is an indispensable requirement to develop accurate and faster methods for predicting the quantitative characteristics of construction materials. The scope of study of many previous researches on the construction material characteristics were limited to the laboratory tests. Among them, most are about the modified concrete and rarely modified mortars. It is also found that only few individual studies studied the use of modelling in evaluating the characteristic properties, which is usually the compressive strength, of the mortars modified with the common SCMs such as volcanic ash and silica fume (Annisa *et al.*, 2019; Nasir Amin *et al.*, 2021) .

Despite the potential of SBEA as a material substitute in the mortar production and the capability of modelling to give characteristic evaluation, there is no individual research has been devoted to both of these together. In other words, the experimental design modelling on mortar modified with SBEA addition for partial cement replacement has never been done before. Hence, this study aims to further support the use of SBEA in modifying the mortar by confirming its influence on the compressive strength. This will be done by the method of modelling. Through this method, the need of seeking another alternative to quantify the engineering properties of a material can be fulfilled when the laboratory tests are not favourable or practical physically. This study will further determine the optimal replacement percentage of SBEA as the cement substitute in mortar production based on the modelling optimization.

1.3 Research Questions

The objectives of this study are made based on few research questions:

i. How does the addition of spent bleaching earth ash influence the compressive strength of the modified mortar?
ii. Can modelling method quantify the compressive strength of the modified mortar, like how the laboratory tests did?
iii. What is the optimal replacement percentage of spent bleaching earth ash as cement substitute in the production of mortar?

1.4 Research Objectives

The below shows the main objectives of this study based on the developed research questions:

i. To determine the compressive strengths of mortar modified with spent bleaching earth ash at different sizes, amounts and testing ages by modelling.
ii. To determine the optimal replacement percentage of spent bleaching earth ash as cement substitute in the mortar.

1.5 Research Scope

The characteristic evaluation will be done through software modelling, instead of physical laboratory tests. The software used will be Design-Expert 13. There will be laboratory database given based on different parameters of mortar modified with SBEA as the basis to do modelling. The testing subject of this study is the cement mortar, in which the cement is partially replaced while the cement substitute used is the SBEA. The study property is limited to compressive strength only, subjected to different sizes of SBEA (18.6 μm – ground; 29.3 μm – unground), cement replacement percentages (minimum at 10%; maximum at 50%) and testing ages of the modified mortar (7 days; 28 days; 90 days).

1.6 Research Significance

This study shows the ability of a design model in helping to predict the properties of mortar containing various amount of SBEA. By confirming the positive influence of SBEA on the modified mortar compressive strength based on the data from software modelling in this study and the laboratory data given, it will be more convincing to support the usefulness of SBEA as a cement substitute, thus popularizing its usage in the construction industry. Such usefulness can give commercial value to SBEA. This study also determines the optimal amount to substitute the cement with SBEA in the mortar for the best resultant compressive strength at the ultimate age.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature obtained from the researchers in the past, whose writing content could be related to the topic of this study. There was literature reviewed on mortar modification using different materials, general knowledge on spent bleaching earth ash (SBEA), SBEA contribution in engineering properties, modelling or optimization of properties, response surface methodology (RSM) and its design models, as well as the model performance evaluation.

2.2 Modification of Mortars

The production of conventional mortar depends heavily on conventional materials such as cement, sand and stones. Their ever-increasing costs has led to the introduction of an alternate construction materials which are available locally, especially the wastes from different industries. Modified mortars are introduced to replace the conventional mortar (Jonathan & Charles, 2017). Modified mortars are those with partial replacement of cement and/or aggregates. In this study, the modified mortar is referred to the mortar with cement partially replaced with SBEA. There were previous studies focused on the engineering properties of mortars modified with fly ash (Warzer *et al.*, 2019), polymers (Tsai, 2017; Kim, 2020), latex with bamboo fibers (Banjo & Temidayo, 2018), natural pozzolan (Şükrü & Ahmet, 2006) and seaweeds (Retno *et al.*, 2014). The reviews from the studies show that the fly ash as cement replacement up to 75% increased the mortar compressive strength up to 88 MPa at the 90th day, the ethylene vinyl acetate (EVA) polymer as cement replacement gave the mortar compressive strength up to 50.27 MPa at the 28th day while the natural pozzolan as cement replacement at optimum 10% gave a mortar compressive strength of 55.2 MPa at the 28th day.

2.2.1 Influence of Fly Ash Addition in Mortar

There was a previous study evaluated the compressive, tensile and flexural strengths of mortar modified with fly ash (FA) based on different water-cement ratios and curing times (Warzer *et al.*, 2019). Fly ash was chosen to evaluate its influence on the mortar as it has benefits of lower cost for mortar production, less harmful emission to the environment, lower hydration heat at the early stage and better workability (Siddique, 2003; Vipulanandan & Mohammed, 2015). In the study, data were collected from the existing literature to perform statistical analysis and modelling. There were studies agreed that FA incorporation can significantly improve the compressive and split tensile strengths of mortar (Reddy & Gupta, 2008; Çakır & Sofyanl, 2015), also improve the flexural shear and bond strengths with the steel reinforcement in parallel (Ravichandran & Balasubramanian, 2014; Kondraivendhan & Bhattacharjee, 2015; Senin *et al.*, 2016; Erdem *et al.*, 2016: 313). From the data collection, the water-cement ratio of modified mortar with FA ranged from 0.20% to 0.80%, while the corresponding compressive, tensile and flexural strengths up to 90 days ranged from 15 MPa to 88 MPa, 0.4 MPa to 5 MPa and 1 MPa to 10MPa, respectively. Over 1000 data collected from the related researches in 10 countries had advanced some points. Firstly, the compressive strength of mortar modified with FA was not directly correlated with the water-cement ratio up to 90 days of curing. The compressive strength increased with curing age for all FA replacements, as agreed by Amarnath *et al.* (2012). Secondly, the acceptable percentage of FA replacing the cement in the mortar could range between 5% and 75% by the dry weight of the cement, as indicated in the existing literature. Thirdly, the FA content effected the tensile strength better and had the lowest influence on the compressive and flexural strengths of the modified mortar. This shows that the resultant tensile strength did not correlate to the resultant compressive strength very well, as modelled by Vipulanandan (2015) which was compared to the model by Eberhardt

(2012). However, such correlation shown was not in good agreement with the existing empirical equation suggested by Raphael (1984) and FIP (1991). Additional FA content could improve the tensile strength of modified mortar at 50% the most. Amarnath *et al.* (2012) added that the mortar modified with FA has a higher tensile strength than the concrete of same compressive strength.

2.2.2 Influence of Polymer Addition in Mortar

Polymers were proven to be a good cement substitute in mortar production. There was a study focused on the mortar modified with polymers replacing the Type I Portland cement, which are ethylene vinyl acetate (EVA) and polyvinyl acetate-vinyl carboxylate (VA/VeoVa) at 3%, 5% and 8% by the weight of cement (Tsai-Lung Weng, 2017). The study found that the VA/VeoVa gave greater effects to the modified mortar than the EVA. The VA/VeoVa specimens performed better compressive and bonding strengths, as well as presented thermal expansion and drying shrinkage characteristics similar to the control specimens. However, the polymers gave the lowest effectiveness in water permeability and adhesion, as tested by Waclaw *et al.* (2021). The early compressive strength presented by the EVA specimens was lower as compared to the control specimens, but became higher at the 28th day. However, this finding is different to that of Kim M.O. (2020) as the EVA specimens were shown to have higher compressive strength than the control specimens at both early age (7th day) and 28th day. It was further concluded that the VA/VeoVa gave a greater bonding strength than the EVA specimens, corroborating the findings of Zhao *et al.* (2011). The addition of polymers was found to delay the setting times, except the VA/VeoVa with 0.5 water-cement ratio which shortened slightly the setting times.

The EVA-modified cement mortar was focused in another study by Kim M.O. (2020), with additional polymers which are acrylate polymer (AC), polyvinyl alcohol (PVA) and styrene-butadiene rubber (SBR). He concluded that the cement mortar modified with polymers had improvement in compressive, flexural and pull-off bond strengths, as shown in the Table 2.1, Table 2.2 and Table 2.3. This agrees that the use of polymers in modifying the mortar or concrete is effective for the longer service life of a structure by reducing the cracks, as stated by Chen and Won (2015). Kim *et al.* (2016) also supported that these high strengths can contribute to better cracking resistance due to the ability to sustain a greater maximum load. Another conclusion is that the polymers showed stronger influence on the flexural strength rather than the compressive strength. Among the four polymers tested, the EVA specimens generally gave the best performance to the modified mortar, improving the compressive strength up to 50.27 MPa and flexural strength up to 11.09 MPa at the 28th day. The tested compressive strength of the PVA specimens was 48.9 MPa, which is quite close to the value (48.7 MPa) reported by Kim *et al.* (2016). The tested compressive strength of SBR specimens was also 36% higher than that of AC specimens, showing a good agreement with previous study done by Li *et al.* (2018) and Medeiros *et al.* (2009). Meanwhile, the AC specimens showed a 14% lower compressive strength as compared to the control specimens.

Table 2.1: Averaged Compressive Strengths Measured

Compressive Strength	Control	AC	PVA	SBR	EVA
(days)	(MPa)				
7	35.15	27.32	41.61	34.86	44.03
28	37.72	32.34	49.91	44.14	50.27

Source: Kim M.O. (2020)

Table 2.2: Averaged Flexural Strengths Measured

Flexural Strength	Control	AC	PVA	SBR	EVA
(days)	(MPa)				
7	6.23	6.31	7.45	6.79	7.91
28	6.81	7.92	9.91	9.62	11.09

Source: Kim M.O. (2020)

Table 2.3: Averaged Pull-Off Bond Strengths Measured

Pull-Off Bond Strength	Control	AC	PVA	SBR	EVA
(days)	(MPa)				
7	2.53	2.47	3.23	3.23	3.40
28	2.88	3.41	3.68	3.71	3.42

Source: Kim M.O. (2020)

2.2.3 Influence of Latex Addition with Bamboo Fibers in Mortar

Another study supported the possibility of cement mortar modified with acrylic latex paint and reinforced with bamboo fibers (Banjo & Temidayo, 2018). The study was established in the need of overcoming some potential deficiencies of cement mortar, including the poor tensile strength, high porosity, crack formation, poor impact strength, high water permeability and low chemical resistance. The tests in the study were conducted at 0.5 cement-fine sand ratio and 0.56 water-binder ratio. A total of 135 samples were tested after 28, 45 and 60 days of curing. The study concluded that the 1.5% bamboo reinforcement and 10% latex paint as cement gave the excellent compressive, splitting tensile and flexural strengths to the modified mortar during the adopted curing period. This verifies the finding of another previous study that the optimum latex paint constituent for the composite is 10% of cement content used (Akinyemi & Omoniyi, 2017). The improved mortar strengths was believed to be a result from the improved interfacial bond and pressure in the natural fiber matrix contributing to a better crack reduction, as reported by Savastano *et al.* (2009).

2.2.4 Influence of Natural Pozzolan Addition in Mortar

The properties of modified mortar due to the influence of natural pozzolan replacing the cement was also studied (Şükrü & Ahmet, 2006). The effects of the natural pozzolan content (10%, 20%, 25%, 30% and 35%) upon the compressive strength, workability, setting time and soundness of the modified mortar at 0.50 water-cement ratio were examined. The study showed that the natural pozzolan partially replacing the cement gave less early compressive strength to the modified mortar, as shown in Table 2.4. However, such strength difference between the modified mortar and conventional mortar decreased gradually in the following days. In fact, Erdoğdu *et al.* (2001) ever stated that the natural pozzolan blended cement is expected to give the strength reaching and even exceeding the strength given by Portland cement only at the ultimate age. By adding a relatively much natural pozzolan as a cement substitute in the mortar, the durability properties could be provided without reducing the standard minimum strength which is 32.5 MPa. Other than that, the study found that the increasing natural pozzolan addition improved the workability, while the water demand to obtain the same consistency increased only relatively. This was suggested earlier by Pan *et al.* (2003) that the natural pozzolan as cement substitute has lubricant effects which can improve the consistency and thus the workability of the mortar. The increasing natural pozzolan addition could also cause a delay of about 20 minutes in the setting times and a decrease of 2/3 in the volume expansion rate of cement matrix. However, Çolak (2002) related the delay in setting times to the increase in the water-cement ratio.

Table 2.4: Compressive Strengths Based on Natural Pozzolan Content

Sample	1st Day	2nd Day	7th Day	28th Day
NP00	12.0	21.3	40.1	60.8
NP10	9.9	18.1	36.1	55.2
NP20	7.4	13.2	30.5	49.6
NP25	6.5	11.9	27.2	45.6
NP30	5.9	11.3	23.4	41.7
NP35	5.3	10.8	22.0	37.8

Source: Şükrü & Ahmet (2006)

2.2.5 Influence of Seaweed Addition in Mortar

The advantages of mortar modified with natural polymer was studied to investigate the compressive and splitting tensile strengths influenced (Retno *et al.*, 2014). The study showed that both Eucheuma Cottonii in gel form and Gracilaria Sp. in powder form replacing the cement are effective in increasing the bonding mechanism and density of the modified mortar by gelling and thickening. This supports the statement of Barros *et al.* (2013) which tells that both Eucheuma Cottonii (gel) and Gracilaria Sp. (powder) can perform as epoxy resin in the mortar due to their rheological properties. The specimen containing Gracilaria Sp. powder performed greater values of compressive and splitting tensile strengths as compared to the control specimens. This can be supported by Arham *et al.* (2013) who claimed that the Gracilaria Sp. performs lower shrinkage and better ductility as compared to Eucheuma Cottonii. It was found out that the optimum mortar mix composition involving the seaweeds was 0.5% by the cement weight. This optimum replacement content shall be confirmed in the future further study.