



Role of Treatment on Enhancing the Utilization of Agricultural Residues in Cement-Fiber Brick

by

**AMAYLIA BINTI CHE ABDULLAH
(1530511693)**

A thesis submitted in fulfillment of the requirements for the degree of
Master of Science in Manufacturing Engineering

**Faculty of Mechanical Engineering Technology
UNIVERSITI MALAYSIA PERLIS**

2021

ACKNOWLEDGMENT

Alhamdulillah, In the name of Allah S.W.T, the Most Gracious, the Ever Merciful. Praise is to Allah, Lord of the Universe and Peace and A Prayers be upon His Final Prophet and Messenger Muhammad S.A.W. Thank to Allah Almighty for give me strength to completed my Master research.

Foremost, I would like to express my sincere gratitude to my supervisor, Dr. Lee Chang Chuan for his support, patience, motivate and unlimited guidance. His kind attitude has made it possible for me to go through the research work and finally completed my Master study.

I would also like to thank to Dean of Faculty of Mechanical Engineering Technology (formerly known as School of Manufacturing Engineering), lecturers, technician lab and who are involved directly or indirectly in helping me to keep focus in order to finish my research study. Without them, my research study could not have been successfully conducted.

A very special thanks to my friends Dr. Tan Chye Lih, Dr. Irina, Dr. Nurul Husna, Aiman and Manufacturing postgraduate group for their sincerely help and knowledge. They give full support without expecting anything in return.

My deepest thanks to my husband, Fitri, my mother and family in law for providing me continuous support and encouragement throughout my years of study, through the process of researching and finally writing this thesis. Without their physically and mentally support, this accomplishment will not have been possible.

Finally, I like to express my gratitude to Ministry of Higher Education for provided Fundamental Research Grant and MyBrain15 which is have supported me in financial during my study.

TABLE OF CONTENTS

DECLARATION OF THESIS	i
TABLE OF CONTENTS	iii
LIST OF TABLES	vi
LIST OF FIGURES	vii
LIST OF ABBREVIATIONS	viii
LIST OF SYMBOLS	ix
ABSTRAK	x
ABSTRACT	xi
CHAPTER 1 : INTRODUCTION	1
1.1 Research Background	1
1.2 Problem Statements	2
1.3 Research Objectives	3
1.4 Scope of the Research Study	4
1.5 Significance of Study	5
1.6 Thesis Organization	5
CHAPTER 2 : LITERATURE REVIEW	7
2.1 Introduction	7
2.2 Agricultural Residues	7
2.2.1 Rice Husk (RH)	9
2.2.2 Corncob (CB)	14
2.2.3 Coconut Coir (CC)	18
2.3 Treatment of Natural Fiber	22
2.4 Water Retention Value (WRV) of Natural Fiber	24
2.5 Cement-Based Composite	26

2.6	Cement-fiber Brick (CFB)	32
2.7	Chapter Summary	42
CHAPTER 3 : RESEARCH METHODOLOGY		44
3.1	Introduction	44
3.2	Preparation of Raw Materials	46
3.3	Mechanical and Chemical Treatment of the Fibers	46
3.3.1	Mechanical Treatment of Fibers	47
3.3.2	Chemical Treatment of Fibers	47
3.3.2.1	Treatment with Gelatin-Hexamine Mixture (GH)	48
3.3.2.2	Treatment with Linseed Oil (LO)	48
3.3.2.3	Treatment with Sodium Metasilicate-Aluminum Sulphate Mixture (AL-SM)	48
3.4	SEM Characterization of Fibers	49
3.5	Water Retention Value (WRV) Measurement of the Fibers	49
3.6	Preparation of Mould	50
3.7	Manufacturing of Cement-Fiber Brick (CFB)	51
3.8	Physical and Mechanical Properties Characterization of CFB	52
3.8.1	Compression Test of CFB	52
3.8.2	Flexural Test of CFB	53
3.8.3	Water Absorption Test of CFB	53
3.8.4	Dimension Stability Test of CFB	54
CHAPTER 4 : RESULTS AND DISCUSSION		55
4.1	Introduction	55
4.2	Water Retention Value (WRV)	55
4.2.1	Effect of Mechanical Treatment on WRV	56
4.2.2	Effect of Chemical Treatment on WRV	57
4.3	Fibers Surface Analysis	58
4.3.1	Effect of Treatment on RH Surface	59
4.3.2	Effect of Treatment on CB Surface	60
4.3.3	Effect of Treatment on CC Surface	61

4.4	Physical Properties of CFB	63
4.4.1	Effect of Fibers Type on Physical Properties of CFB	63
4.4.2	Effect of Fibers Composition and Treatment on Physical Properties of CFB	64
4.5	Mechanical Properties of CFB	68
4.5.1	Effect of Fibers Type on Mechanical Properties of CFB	68
4.5.2	Effect of Fibers Treatment on Mechanical Properties of CFB	68
4.5.3	Effect of Fibers Composition on Mechanical Properties of CFB	69
4.6	Conclusion	72
CHAPTER 5 : CONCLUSIONS AND RECOMMENDATIONS		73
5.1	Introduction	73
5.2	Conclusion	73
5.3	Recommendation	74
REFERENCES		76
APPENDIX A		82
APPENDIX B		83
APPENDIX C		84

LIST OF TABLES

	PAGE
Table 2.1: Basic properties of some natural fibers	8
Table 2.2: Chemical composition of some natural fibers	9
Table 2.3: The main composition of RH	9
Table 2.4: Researches on cement-based composites utilized RH fiber	13
Table 2.5: Researches on cement-based composites utilized CB fiber	17
Table 2.6: Researches on cement-based composites utilized CC fiber	21
Table 2.7: The chemical treatment on the natural fibers and their purpose / advantages on composites properties	23
Table 2.8: The advantages and disadvantages of using lignocellulosic waste	27
Table 2.9: Design and development of cement-fiber brick (CFB)	33
Table 3.1: Size categories of Natural fiber for mechanical & chemical treatment	47
Table 3.2: Material composition for CFB	51
Table 4.1: Water Retention Value (WRV) for mechanical treatment at different mesh size of fiber	56
Table 4.2: Water Retention Value (WRV) for chemical treatment at different mesh size of fiber	57
Table 4.3: Physical properties of cement-fiber brick (CFB)	63

LIST OF FIGURES

	PAGE
Figure 3.1: Flow of process methodologies	45
Figure 3.2: Mould of brick made from plywood	50
Figure 3.3: General brick specification (Malaysia Standard)	51
Figure 4.1: Comparison between the WRV % of untreated and treated fibers	58
Figure 4.2: SEM micrographs of fibers – RH	60
Figure 4.3: SEM micrographs of fibers – CB	61
Figure 4.4: SEM micrographs of fibers – CC	62
Figure 4.5: Water absorption of CFB	65
Figure 4.6: Dimensional change of CFB	67
Figure 4.7: Compressive strength	70
Figure 4.8: Flexural strength	71

LIST OF ABBREVIATIONS

CFB	Cement Fiber-Brick
RH	Rice Husk
CB	Corncob
CC	Coconut Coir
WRV	Water Retention Value
GH	Gelatin-Hexamine
LO	Linseed Oil
AL-SM	Sodium Metasilicate-Aluminium Sulphate
NaOH	Sodium Hydroxide
LPW	Limestone Powder Waste
RS	Rice Straw
SD	Saw Dust
OPC	Ordinary Portland Cement
CFRCC	Coir Fiber Reinforce Cementitious Composite
PC	Plain Concrete
WSD	Wood Saw Dust
WRHA	White Rice Husk Ash
VKP	Virgin Kraft Pulp
OCC	Old Corrugated Container
PWT	Processed Waste Tea
KFQR	Kaolin Fine Quarry Residue
GBFR	Granite Basalt Fine Quarry Residue
GBFS	Granulated Blast Furnace Slag
WGP	Waste Glass Powder
SEM	Scanning Electron Microscope

LIST OF SYMBOLS

C	Compressive strength
W	Maximum load indicated by machine
A	Average of gross areas of the upper and lower bearing specimen surface
σ	Flexural stress
F	Load at a given point on the load deflection curve, (N)
L	Support span (mm)
b	Width of test beam (mm)
d	Depth or thickness of tested beam (mm)
m_1	Dry weight of specimen
m_2	Apparent mass of the saturated specimen weight in liquid
m_3	Mass of the saturated specimen weighed in air
W_{sat}	Weight of specimen at saturated condition
W_{dry}	Weight of specimen at dry condition
$V_{saturated}$	Volume of specimen at saturated condition
V_{dry}	Volume of specimen at dry condition

Peranan Rawatan untuk Meningkatkan Penggunaan Sisa-Sisa Pertanian dalam Bata-Gentian Simen

ABSTRAK

Baru-baru ini, masalah sisa global yang semakin meningkat telah menyedarkan seluruh dunia untuk lebih prihatin tentang kelestarian alam sekitar dengan menggalakkan penggunaan bahan yang berkekalan seperti sumber alam semulajadi. Untuk mengurangkan kesan sampingan bahan sintetik ke atas alam sekitar, ini termasuk penggunaan produk sampingan dan bahan buangan dalam pembinaan bangunan. Penggunaan bahan buangan di dalam pembinaan akan memberi banyak manfaat. Dalam kajian ini, bata gentian simen (CFB) dihasilkan dari sekam padi (RH), tongkol jagung (CB) dan sabut kelapa (CC) dengan kandungan 10%, 20% and 30% gentian. Gentian ini dirawat secara mekanikal dan kimia untuk mengkaji kesan rawatan pada permukaan dan Nilai Pengekalan Air (WRV) gentian semulajadi. Rawatan kimia seperti *Gelatin-hexamine* (GH), minyak bijan (LO) dan *natrium metasilicate-aluminium sulfat* (AL-SM) telah digunakan dalam kajian ini. Rawatan ini digunakan untuk mengubahsuai gentian sebelum proses batu bata demi meningkatkan sifat penyahairan (sifat fizikal) dan meningkatkan ikatan antara gentian dan simen (sifat mekanik). Nisbah gentian/simen 1:9, 2:8 dan 3:7 telah digunakan dalam kajian ini. Hasil menunjukkan bahawa sifat-sifat CFB dipengaruhi oleh jenis gentian, rawatan dan komposisi gentian. Tanpa mengira jenis rawatan dan komposisi gentian, CCB menunjukkan nilai penyerapan air (WA) yang paling tinggi iaitu sebanyak 5.49% diikuti dengan RHB sebanyak 10.72% dan CBB sebanyak 12.34%. CCB juga menunjukkan kekuatan mampatan dan lentur lebih besar daripada yang diperolehi oleh gentian lain. Gentian yang dirawat dengan minyak bijan (LO) menghasilkan bata dengan sifat fizikal yang baik berbanding dengan yang lain. Diperhatikan bahawa kandungan gentian juga memainkan peranan penting dalam mempengaruhi sifat mekanikal CFB. CFB dengan 20% wt gentian menunjukkan kekuatan yg lebih baik tanpa megira jenis rawatan yang digunakan. CFB dengan rawatan minyak bijan (LO) menunjukkan kekuatan bata yang tertinggi iaitu 4.7-8.8 MPa untuk kekuatan mampatan dan 1.7-3.1 MPa untuk kekuatan lenturan. Dari hasil yang diperolehi, didapati bahawa CC adalah gentian yang paling berpotensi dan LO sebagai rawatan terbaik yang dapat meningkatkan sifat bata simen yang dihasilkan. Maka, ia membuktikan bahawa jenis gentian, rawatan dan komposisi gentian memainkan peranan penting dalam penghasilan bata yang berkekuatan tinggi dan memenuhi kriteria untuk pembinaan. Walaupun masih banyak kajian perlu dilakukan pada masa hadapan, hasil ini menunjukkan bahawa konsep bata komposit hijau untuk infrastruktur lestari boleh dilaksanakan.

Role of Treatment on Enhancing the Utilization of Agricultural Residues in Cement-Fiber Brick

ABSTRACT

Recently, increasing global waste problem has awaken worldwide to more concern about environmental sustainability by encouraging of utilizing sustainable materials such as those from natural resources. In order to reduce the detrimental effect of synthetic materials on the environment, it has challenged engineer to investigate how it can be achieved by benefiting the agricultural residues into useful products. These included the use of by-products and waste materials in building construction. The use of these waste materials in construction will realize much benefit. In this research study, cement-fiber brick (CFB) are prepared from 10, 20 and 30% wt of rice husk (RH), corncob (CB) and coconut coir (CC) fiber. These fiber are mechanically and chemically treated in order to study effect of treatment on surface morphologies and Water Retention Value (WRV) of the natural fibers. Chemical treatment such as gelatin-hexamine (GH), linseed oil (LO) and sodium metasilicate-aluminium sulphate (AL-SM) was applied in this study. These treatments are used to modify the fibers prior to bricks fabrication in order to improve their dewatering behaviour (physical properties) and enhance the cement-fiber bonding (mechanical properties). Fiber/cement ratio of 1:9, 2:8 and 3:7 was used for CFB fabrication. Results showed that the properties of CFB were affected by type of fibers, treatments and fiber composition. Regardless of kind of treatments and fiber compositions, coconut coir brick (CCB) showed the greater water absorption (WA) which is 5.49% follow by rice husk brick (RHB) and corncob brick (CBB) which is 10.72% and 12.34% respectively. CCB also showed compression and flexural strength values greater than those obtained for other fibers. In case of type of treatments applied, fiber treated with LO produced bricks with better physical properties compared to others treatment. It was observed that fiber content also played an important role on influencing the mechanical properties of CFB. CFB with 20% wt fiber shows better compression and flexural strength regardless of treatment applied. CFB of LO treated fibers possess the higher properties, 4.7-8.8 MPa and 1.7-3.1 MPa for compression and flexural strength respectively. From the result obtained, it was found that CC has shown the most potential fiber and LO shows the best treatment that enhance the properties of the fabricated cement-brick. Thus, it proved that type of fibers, treatments and fiber composition has significant role in producing the high strength of bricks and meet the building criteria for construction. It is demonstrated that the concept of green composite bricks for sustainable infrastructure is feasible, although an extensive amount of research remains ahead.

CHAPTER 1 : INTRODUCTION

1.1 Research Background

Agricultural waste is an unavoidable by-product of most human activity. Economic development and rising living standards have led to increases in the quantity and complexity of generated waste such as rubber, oil palm, cocoa, rice and coconut. In Malaysia, out of total quantities of residues generated, only 27% is used, the rest is disposed of by burning (Zafar, 2011). The generation of these residues poses a major disposal problem now that burning is being actively discouraged by the Department of Environmental of Malaysia (Zafar, 2011). Recycling the wastes as building and construction materials will realize much benefit not only to pollution's solution but also to the solution of economical design of buildings.

The development of fiber reinforcement for the building industries has begun since 1969. Some researcher has developed reinforced concrete using glass fiber. They found that there is decreasing in strength of concrete after five to thirty days due to the chemical attacked (Grimer & Ali, 1969). The development continues grow by using carbon fiber in cement. At that time, building construction industries are not able to afford carbon fiber because it is quite expensive and the cost for manufacturing increase (Ali, 1972). Hence, the researcher tried another alternative to overcome the problem. They used natural fiber such as coconut coir, bamboo and jute which is much affordable. Due to significant to low cost building materials, coir fiber reinforced cement has been used especially as roofing materials (Cook et al., 1978).

Large demand in construction materials in building industry has brought a chronic shortage of building materials (Algin & Turgut, 2008). Thus, the civil engineers have been challenged to convert the agricultural waste to useful building materials. Agricultural waste such as bagasse, cereal straw, corn stalk, corn cob, cotton stalks, kenaf, rice husk, rice straw, coconut coir, bamboo, durian peel and oil palm leaves were used as building materials which include particleboard, hardboard, fiber board and brick (Pinto et al., 2012). Utilization of natural fibers increasingly adopted to replace man-made fibers in building due to their advantages which are renewable and biodegradable. Furthermore, natural fibers have low density, high toughness and acceptable strength properties, plentifully available, energy-efficient, economical, and eco-friendly (Sarikanat & Demirci, 2014).

Housing and building construction industries have become importance especially wood-based materials and composites panel products. Due to the increasing scarcity of wood raw materials, a non-wood lignocellulosic material has been considered as alternative to produce various building materials. All natural fibers generally consist of long cell with relatively thick cell walls, which make them stiff and strong (Fiore et al., 2016). Natural fiber cement composites are exceptional in this respect, not only for their eco-friendly nature but also because they are an economic and socially useful outlet for wood residues and agricultural wastes (Xiong et al., 2012).

1.2 Problem Statements

Malaysia is a country that is suitable for agricultural sector, due to its strategic location on tropical region. Hence, Peninsular Malaysia generates large amount of wood and agricultural residues. Those agricultural wastes are not being currently fully utilized for further downstream operation. They are burned in the open atmosphere which caused air pollution that may induce environment impact. By recycled these wastes into useful product, the wastes can be disposed of safely and easily which significantly reduce the damage to the environment.

Basically, low toughness, brittle and minimum ductility and flexural capacity are the common drawback of non-fiber reinforced cement based-materials. Literature has enclosed that utilization of agricultural waste in cement-fiber brick (CFB) will encourage enhancing its physical and mechanical properties (Vajje & Krishna, 2013). Due to rapid development in construction sector, the shortage of raw material has become the challenge. Thus, the used of those agricultural waste will reduce the use of ordinary concrete materials such as sand, cement and concrete.

Nowadays, fiber-reinforced cement has been widely implemented in construction and building sectors. However, there is still contains some degree of defect in term of fiber-reinforced cement quality such as low strength and poor bonding behaviour. Therefore, proper fiber's surface treatment and modifier should be applied suitably according to their application in order to increase the strength and bonding behaviour.

1.3 Research Objectives

The main objective of this research is to fabricate cement-fiber brick (CFB) utilizing rice husk (RH), corncob (CB) and coconut coir (CC) to enhance the physical and mechanical properties intended for building applications. The specific objectives are summarized as follows:

- i. To study the influence of mechanical and chemical treatment on fiber structure.
- ii. To analyse the effect of fibers treatment on physical and mechanical properties of the CFB.

1.4 Scope of the Research Study

This research is focus on water absorption & dimension stability (Physical properties) and compressive & flexural strength (mechanical strength) of CFB which containing rice husk (RH), corncob (CB) and coconut coir (CC). Fiber was treated mechanically (through grinding & screening) and checmically treated with organics and inorganic substance which are gelatin-hexamine (GH), linseed oil (LO) and sodium metasilicate-aluminium sulphate (AL-SM). Effect of treatment on surface morphologies and Water Retention Value (WRV) of the natural fibers was studied. The CFB will prepare by utilizing 10% wt, 20% wt and 30% wt of fiber.

1.5 Significance of Study

This research study can provide additional research information of agricultural residues in production of CFB in building construction. As agricultural waste effect the environment, the utilization of these wastes into useful products will reduce the environmental effects.

This research is expected to get better performance of bricks in term of physical properties (water absorption, dimensional change and density) and mechanical properties (compression and flexural) of the CFB produced. It can be guideline in production of useful product by utilizing agricultural wastes.

1.6 Thesis Organization

Chapter 1 presents the background of the research study, problem statement, objectives and scope of study. Subsequently, the significance of research study is also defined in this chapter.

Chapter 2 in this dissertation presents the related literature review. This chapter explained the utilization of natural fibers in building materials construction. Type of fiber's treatment and Water Retention Value (WRV) of the fiber are discussed. Afterwards, production's method of CFB by utilizing different natural fiber and wastes are explained in details.

Chapter 3 describes the overall research methodology. It is included experimental procedure from the preparation of raw materials, mechanical and chemical treatment of the wastes, WRV and manufacturing of the CFB. The CFB is characterized under compressive, flexural, water absorption and dimensional stability test.

Chapter 4 elaborates the experimental results of the research study. Parameters that affect the results of physical and mechanical properties of CFB are analysed.

Chapter 5 presents the conclusions drawn in this research study. Recommended future works are also proposed in this chapter. Lastly, the contribution and summary of the research is reviewed.

©This item is protected by original copyright

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

Nowadays, global environmental warming is considered to be the most important worldwide issue. Since the government is encouraging the use of sustainable materials such as those from natural resources in order to reduce the detrimental effect of synthetic materials on the environment, it has brought a challenge to investigate how it can be achieved by benefiting the agricultural wastes into useful products. Malaysia is located in a region where biomass productivity is high. As reported in the 9th Malaysia Plan, the major agricultural wastes grown in Malaysia are rubber (39.7%), oil palm (34.56%), rice (12.78%), cocoa (6.75%) and coconut (6.34%). The plan forecasted that in 2020, about 30,000 tonnes of solid waste will be generated per day if no new effort is put in place to address the ever-increasing generation of solid waste. In this regard, the Department of National Solid Waste Management has put in place two strategies: prevention at source and providing facilities for solid waste management treatment and disposal. To address this problem, high priority is given to reducing, reusing and recycling (3R) of solid waste, which included the agricultural waste (Yahaya, 2013).

2.2 Agricultural Residues

Agricultural residues such as biomass residues are abundant and cheap resources that can be used to obtain valuable renewable products. It provides 35% of all energy requirement and act as major source of energy in developing countries (Werther et al., 2000). Agricultural residues is not being competitive in food market (García-Torreiro et

al., 2016). It was being recognized as valuable renewable feedstock because they have carbon rich composition (Colantoni et al., 2016). The growing concern of resource depletion and global pollution has challenged engineers to seek and develop new materials relying on renewable resources. These include the use of by-products and waste materials in building constructions. Moreover, agricultural wastes used as supplementary cementitious materials in concrete production can contribute to the environmental friendliness and economic effectiveness of structures worldwide.

These residues have been widely used in several applications such as building and construction materials and fuel combustion. Table 2.1 and 2.2 shows the basic properties and chemical composition of some natural fibers

Table 2.1: Basic properties of some natural fibers (Väisänen et al., 2016)

Fiber type	Density (g/cm³)	Tensile strength (MPa)	Elastic modulus (GPa)	Elongation at break (%)
Softwood	1.4	100-170	10-50	8.0-14.0
Hardwood	1.4	90-180	10-70	11.0-13.0
Softwood pulp	1.5	1000	40	4.4
Jute	1.3-1.5	200-770	20-55	2.0-3.0
Sisal	1.5	100-800	9-22	3.0-7.0
Kenaf	1.4-1.5	930	53	1.6
Coir	1.2	180	4-6	30.0
Flax	1.5	350-1040	28-70	2.0-4.0
Hemp	1.5	690	30-70	1.5-4.0
Bamboo	0.6-1.1	140-230	11-17	4.0-7.0
wheat	0.6-0.8	10-200	1-12	2.7
Rice husk	0.7-1.0	55	22	2.0-5.0

Table 2.2: Chemical composition of some natural fibers (Väisänen et al., 2016)

Fiber type	Cellulose (wt%)	Hemicellulose (%)	Lignin (wt%)	Extractives (wt%)	Ash (%)	Waxes (wt%)
Softwood	40-45	30	26-34	2-5	0.2-0.8	0.4-0.5
Hardwood	40-50	23-39	20-30	2-4	0.2-0.4	0.4-0.5
Softwood pulp	77.5-78.5	19.2-19.4	7-11	0.1-0.5	0	0
Jute	45-63	14-20	12-25	1-2	0.5-2.0	0.5
Sisal	50-64	12	9.9	1-2	1	2
Kenaf	45-71	12-22	8-13	3.2	4.7	0.4-0.8
Coir	30	15-25	40-45	2-3	2.7-10.2	1.0-2.0
Flax	65-85	18.6-20.6	1-4	2.3	1.5	1.5
Hemp	60-77	15	3-10	3.6	2.6	0.8
Bamboo	26-43	30	21-31	3-5	1.7-5.0	1.0-2.0
wheat	38-41	15-31	12-16	1-3	6.0-8.0	0.5-1.0
Rice husk	25-45	18-33	8-31	2-5	10-20.	14-17

2.2.1 Rice Husk (RH)

Rice husk (RH) is the outermost layer of rice grain. It's as protection encasing a rice grain especially in growing season. It is a yellowish colour and unusual shape. The uses of RH in many industries are continually growing such as building materials, fertilizer, insulation materials and fuel. RH has been used in production of ceiling boards, particle boards, insulation boards and bricks. Table 2.3 shows the main composition of RH (percentage in weight).

Table 2.3: The main composition of RH (Jauberthie et al., 2000)

COMPOSITION	WT%
Silica	18.80-22.30
Lignin	9-20
Cellulose	28-38
Protein	1.90-3.0
Fat	0.30-0.80
Other nutrients	9.30-9.50

Research studies on the utilization of RH in cementitious composites summaries in Table 2.4. RH was utilized in most of research study in production of cement-based composites such as board, mortar and concrete due to the its properties which are high availability, low bulk density, tough, abrasive in nature and resistance to weathering due to the high concentration of silica in amorphous and crystalline form. The presence of the amorphous silica determines the pozzolanic effect of RH and subsequently will affect the cementitious properties that increase the rate at which the materials gain strength (Jauberthie et al., 2000).

Salas et al., (1986) used RH as a lightweight aggregate for low cost housing. From the results, it can be concluded that based on specific weight and average resistance to compression, this RH concrete can classify as materials with hybrid characteristic between lightweight structural concretes and insulating concretes. Besides that, utilization of RH provided low strength even with negligible proportion of RH.

Raoul Jauberthie et al., (2003) investigated the properties of cement with addition of RH. The samples were stored in wet and dry condition. The results indicated that there is significant effect to the properties between the samples stored in wet and dry conditions. So, the storage conditions play a main role to the behaviour of lightweight RH mortar.

Furthermore, Sisman et al., (2011) studied the effects of RH on the concrete properties for farm building and stated that RH concrete could be classified as lightweight concrete with respect to their unit weights. The replacement of RH as an aggregate in concrete increased the water absorption and the thermal conductivity decreased with increasing RH content. The results concluded that structural and insulating concrete can

be produced using RH because it meets the strength, resistance and insulation requirements especially in agricultural building.

Moreover, Sarkar et al., (2012) studied the mechanical properties and dimensional stability of cement bonded particleboard from RH and sawdust, the density of RH bonded board satisfies the standard. The density of RH board increased when the ratio of cement particles increased. Increasing the RH board density, thickness swelling reduced significantly in the RH board. The thickness swelling of RH board is lower than sawdust board.

Other researcher, Yuzer et al., (2013) investigated the influence of raw RH addition on structure and properties of concrete. The concrete was produced with Portland cement, limestone coarse aggregates, crushed stone sand, natural river sand and raw RH. The results showed the addition of RH was decrease the density, but increase the porosity of the concrete samples. Small amount of RH has slightly reduced the compressive strength however it modifies physical and thermo-physical properties of concrete. Utilization of RH will release less harmful gas and will decrease casualties in case of fire when used as a coating material. RH also has been used in production of particleboard.

Chabannes et al., (2014) studied the use of raw RH as natural aggregate in a lightweight insulating concrete for an innovative application. They use a lime-based binder. From the result, RH concrete has shown good thermal properties and compressive strength.

Besides that, Chabannes et al., (2015) also studied the hardening and mechanical performances of RH and hemp-based building materials cured under natural and

accelerated carbonation. The results indicated that RH showed low bonding strength between RH and lime. The mechanical properties of hemp concrete are twice higher than RH concrete for under natural condition. The accelerated carbonation curing lead to increase the mechanical properties for both concretes in the short term which is the compressive strength approximately equivalent to those obtained under natural carbonation.

©This item is protected by original copyright

Table 2.4: Researches on cement-based composites utilized rice husk (RH) fiber

No.	Authors	Test conducted	Results
1	Salas et al. (1986)	Compressive strength	<ul style="list-style-type: none"> • Low strength even with negligible proportion of RH
2	Jauberthie et al. (2003)	Density, young modulus, compressive and flexural strength (store in wet and dry condition)	<ul style="list-style-type: none"> • Increase the content of RH will decrease the flexural strength but increase the compressive strength. • Low ambient humidity suitable to improve the flexural strength.
3	Sisman et al. (2011)	Physical, mechanical and thermal properties	<ul style="list-style-type: none"> • The unit weight decreased with increasing RH content. • The compressive strength decreases with increasing RH content. • Water absorption increases with decrease the unit weight. • Thermal conductivity decreased with increasing RH content.
4	Sarkar et al. (2012)	Mechanical properties and dimensional stability	<ul style="list-style-type: none"> • The density RH and sawdust board increased with increasing of cement ratio. • Water absorption significantly reduces with increasing of cement percentage. • Thickness swelling of RH board reduced significantly with increasing the cement percentage. • The flexural strength increased with increasing the cement percentage.
5	Yuzer et al. (2013)	Density, porosity, compressive strength and thermal conductivity,	<ul style="list-style-type: none"> • Addition of RH decreases the density but increase the porosity. • Small amount of RH addition leads to slight reduction in compressive strength but modified physical and thermo-physical properties of concrete. • High ratios of RH improved the durability rather than strength.
6	Chabannes et al. (2014)	Physical and mechanical properties	<ul style="list-style-type: none"> • RH concrete show lower mechanical properties compare to hemp concrete but can compete in term of thermal insulation.
7	Chabannes et al. (2015)	Mechanical properties (under natural carbonation and CO ₂ curing)	<ul style="list-style-type: none"> • RH concrete have lower bonding strength between the lime and lower mechanical performance compares to hemp concrete.