THE INFLUENCE OF PALM OIL FUEL ASH AND METAKAOLIN ON THE STRENGTH OF CONCRETE AND CRACK RESISTANCE OF REINFORCED CONCRETE BEAM: A REVIEW

SHANEEZ CHRISTIE ANAK NYANDAU

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2021

THE INFLUENCE OF PALM OIL FUEL ASH AND METAKAOLIN ON THE STRENGTH OF CONCRETE AND CRACK RESISTANCE OF REINFORCED CONCRETE BEAM: A REVIEW

by

SHANEEZ CHRISTIE ANAK NYANDAU

This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

JUNE 2021

Appendix A8

UNIVERSITI SAINS MALAYSIA

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2020/2021

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: The influence of palm oil fuel ash and metakaolin on the strength of concrete and crack resistance of reinforced concrete beam

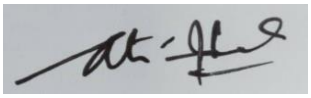
Name of Student: Shaneez Christie Anak Nyandau

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature:

ShaneezChristie

Date : 4 August 2021

Endorsed by:	Approved by:
	
(Signature of Supervisor)	(Signature of Examiner)
Name of Supervisor:	Name of Examiner:
Assoc. Prof. Ts. Dr Fatimah De'nan	Ir. Dr. Shaharudin Shah Zaini
Date: 4 August 2021	Date: 5 August 2021

(Important Note: This form can only be forwarded to examiners for his/her approval after endorsement has been obtained from supervisor)

ACKNOWLEDGEMENT

Foremost, I would like to thanks Universiti Sains Malaysia for giving me the opportunity to conduct this research as my final year project. After all of the hard work that has gone into this year, I feel obligated to convey my gratitude to everyone who has backed me up and helped me complete my research on time. Besides that, I also like to express my sincere gratitude to my supervisor, Assoc. Prof. Ts. Dr. Fatimah De'nan and my co-supervisor, Professor Dr. Megat Azmi Megat Johari for continuous support of my research, for their patience, motivation, enthusiasm and immense knowledge. As well as, Assoc. Prof. Dr. Noor Faizah Fitri Md. Yusof and Dr Noorhazlinda Abd Rahman for finishing this research. Their guidance helped me in all the time of research and writing of this research.

Special thanks to USM Library team, Mdm Jamilah Hasaan Basri and Mdm Mazainun Aini Mohd Zain who had given the full commitment, patience in giving knowledge and guidance on thesis template as well as database and endnote. My heartfelt gratitude to my parents, Mr Nyandau Kampit and Mdm Dorrit, for their unwavering support throughout my study, making me feel cherished and blessed. And not to forget, thank you to all my friends especially Nurul Arisya and Mohammad Shazarul whom I had referred with and help me a lot in completing this research.

Last but not least, I owe a debt of gratitude to everyone who has provided me with bravery, drive, and moral support in this final year, whether directly or indirectly.

ABSTRAK

Simen Portland biasa telah digunakan dalam konkrit pengeluaran, ia adalah bahan penting yang harus dijaga kerana sifatnya bertindak balas dengan setiap bahan yang ada. Semasa pengeluaran simen, sejumlah besar karbon dioksida dipancarkan dari pengeluaran klinker dalam tanur putar dan keperluan tenaga tinggi dari keseluruhan proses pengeluaran. Kejadian seperti itu dapat dicegah dengan mengganti bahagian simen dengan Metakaolin (MK) dan Palm Oil Fuel Ash (POFA). Selain menjadi alternatif yang bersimen, bahan-bahan tersebut juga dapat menyumbang kepada persekitaran yang lebih hijau dan bangunan yang lebih lestari, kerana POFA tersedia di Malaysia dan dapat digunakan untuk menggantikan simen dan meminimumkan pencemaran. Kajian ini menilai kesan MK dan POFA pada konkrit dari segi kekuatan mampatan dan corak retakan dari balok konkrit bertetulang berdasarkan kajian sebelumnya yang relevan. Dari penyelidikan, kekuatan mampatan konkrit yang mengandungi MK dan POFA lebih tinggi daripada campuran kawalan dengan peratusan peningkatan dalam julat 0,8% hingga 78,2% untuk MK dan 0,5% hingga 14% masing-masing. Kandungan MK dan POFA yang optimum masing-masing antara 10% hingga 15% dan 10% hingga 20% untuk mencapai kekuatan konkrit yang tinggi. Selain itu, kemasukan MK ke campuran konkrit meningkatkan kekuatan balok konkrit bertetulang dan mengurangkan retakan pada permukaan balok konkrit bertetulang, sedangkan kemasukan POFA ke campuran konkrit meningkatkan retakan pada balok konkrit bertetulang. Retakan muncul di zon lenturan setiap rasuk yang mengandungi MK dan POFA. Dari kajian ini, didapati juga bahawa kehalusan MK dan POFA mempunyai pengaruh yang signifikan terhadap sifat mekanikal konkrit.

ABSTRACT

An ordinary Portland cement has been used in the production concretes, it is an important material to be kept in check due to its nature to react with every substance present. During the production of cement, a significant amount of carbon dioxide is emitted from the clinker production in rotary kiln and high energy requirement of the overall production processes. Such an event can be prevented by replacing the part of cement with Metakaolin (MK) and Palm Oil Fuel Ash (POFA). Aside from being a cementitious alternative, the materials can also contribute to a greener environment and more sustainable building, as POFA is available in Malaysia and may be used to substitute cement and minimize pollution. The study assesses the effect of MK and POFA on the concrete in terms of compressive strength and cracks pattern of the reinforced concrete beam based on relevant previous studies. From the research, the compressive strength of concrete containing MK and POFA was higher than the control mix with the percentage of improvement in the range of 0.8% to 78.2% for MK and 0.5% to 14% respectively. The optimum content of MK and POFA is between the range of 10% to 15% and 10% to 20% respectively to achieve high strength of concrete. Other than that, the inclusion of MK to the concrete mix improves the strength of reinforced concrete beams and reduces cracks on the surface of reinforced concrete beams, whereas the inclusion of POFA to the concrete mix increases cracks on reinforced concrete beams. The cracks appeared within the flexure zone of every beam containing the MK and POFA. From this study, it was also found that the fineness of MK and POFA has a significant influence on the mechanical properties of concrete.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

ECC	Engineered Cementitious Composite
EPS	Expanded Polystrene
ES	Eggshell
FC	Foamed Concrete
GPOFA	Ground Palm Oil Fuel Ash
HSG	High Strength Green concrete
MK	Metakaolin
NMK	Nano Metakaolin
NPOFA	Nano Palm Oil Fuel Ash
POFA	Palm Oil Fuel Ash
UPOFA	Ultrafine Palm Oil Fuel Ash
USM	Universiti Sains Malaysia

CHAPTER 1

INTRODUCTION

1.1 Background

Concrete, as one of the materials used in building construction, is a porous material, and its physical and mechanical properties play an important role in determining the materials strength and toughness, as well as the characteristics of concrete in building structural members such as beams. Some of the similarities in many of the concrete types that exist today are the materials used to make the concrete. Cement, aggregates, and water are the main materials in traditional concrete. Many improvement techniques have been implemented in the recent years to create excellent concrete that saves energy and money. Such methods are needed in today construction industry to increase production. In this research, cement in the concrete were replaced in order to strengthen the concrete further.

Metakaolin (MK) and Palm Oil Fuel Ash (POFA) are two materials that have been introduced and studied for many years. The materials have been used in a variety of industries, including the construction of industrialized buildings and the medical industry. To minimize the porosity of concrete, the materials were added to the mix as an additive and as cementitious substitute materials. According to Mohd Sam et al., (2017), concrete porosity can be minimized by mixing cement with a pozzolana additive like Metakaolin. Metakaolin and POFA have been used in concrete on rare occasions and have shown to improve the mechanical properties of the material (Siddique & Klaus, 2009).

Aside from additives, the effect of application of concrete mixtures to structural behavior has been studied for a long time to see whether the mixtures substance can boost

structural properties or not. Aside from that, the building industry has been focusing on sustainability and green issues. With the increased use of waste in the sector, it was expected that project productivity and sustainability would improve.

In this research, the concrete performance has been evaluated in term of crack pattern that occur on the concrete surface. According to Dejian & Liu (2019), the presence of cracks reduces the mechanical properties and brings potential safety hazard to structures. Concrete cracks can be caused by a variety of factors. Constructional movement, settlement shrinkage, and plastic shrinkage all trigger cracks until they harden.

1.2 Review Questions

Concrete is a type of construction material made from a certain proportion of water, aggregate, and cement depending on the type of structure and its intended use. It has the potential to be extremely long-lasting if it is properly planned and sufficiently supervised during the on-site casting process. According to Peng (2017), conventional concrete needs a precise amount of compaction to reduce porosity in the structure.

Other than the research about the effects of MK and POFA materials towards mechanical properties of the concrete, the behavior of structure made from the concrete mixed with MK and POFA will also be considered especially in beam structure since it was one of the critical parts in the building. The performance and structural behavior of concrete made from the mixture have been researched for quite a while and some mechanical properties have been found out and it may affect the usage of concrete in structures. The existence of cracks on the flexural member or structures are serious problem in the construction industry that can negatively affect aesthetic, durability and structural characteristic. Thus, it is important to review the mechanical properties of

concrete that contains MK and POFA as cement replacement because in recent years, the performance of a structure that utilize MK and POFA has gained attention especially toward its compressive strength and cracking behaviour of the structure.

In the perspective of the environment, the activities of industrialization and daily activities, especially in disposal activity have led to environmental damage. The damages keep increasing due to production and construction. With the standard mixture of cement, Fantilli et al (2019) said that the production of cement produced carbon dioxide gas by 7% into the atmosphere. One of the alternatives to solve the problem is by reducing the amount of cement and adding MK or POFA in the mixture of concrete due to its efficiency to replace cement in concrete.

1.3 Objectives of the systematic review

For the past few years, there has been a lot of research into the use of MK and POFA as partial cement replacement material in concrete. The crack pattern formed on the beam when using the concrete mixture with the two additives will be the focus of this study, which will be based on the theory of reinforced concrete design. As a guide for the study, two goals have been prepared:

1. To study the effect of the utilization of Metakaolin (MK) and Palm Oil Fuel Ash (POFA) on the compressive strength of concrete based on related previous studies.
2. To evaluate the influence of Metakaolin (MK) and Palm Oil Fuel Ash (POFA) inclusion on the cracking behavior of reinforced concrete beam.

1.4 Scope of the Systematic Review

Two key methodological methods have been established for this research. The first goal was to assess the compressive strength of concrete with MK and POFA. A systematic literature review (SLR) was conducted in order to achieve this aim. Secondly, a systematic literature review was conducted to determine the cracking behavior of concrete beams where MK and POFA were used as partial replacement of the cement.

A systematic review is a well-defined and methodological way of classifying, analyzing, and synthesizing the available evidence for a particular technology in order to explain the current course and status of research or provide background information on research challenges (BA & Charters, 2007). The SLR review protocol is specified in this section. The SLR steps as shown in Figure 1.1 were used to locate existing literature on experimental and numerical research on the crack pattern of reinforced concrete beams with POFA and MK.

In this study, there are a few steps that have been carried out to complete the systematic literature review (SLR). Firstly, there are three review questions were identified from the review topic such as how the compressive strength of concrete are affected by the utilization of MK and POFA, how the cracking behavior of reinforced concrete beam affected by the utilization of MK and POFA and what is the optimum content of MK and POFA to produce high compressive strength of concrete. After identifying review question, do some searching strategies for the review question such as identify synonyms, related phrases and keyword variants and screening, defines the inclusion and exclusion requirements for the papers. Then, collect and extract all the data needed that relevant for the review questions. Next step is defining data synthesis. Last but not least, combine the data from a number of review articles in order to draw conclusions about the research topic.

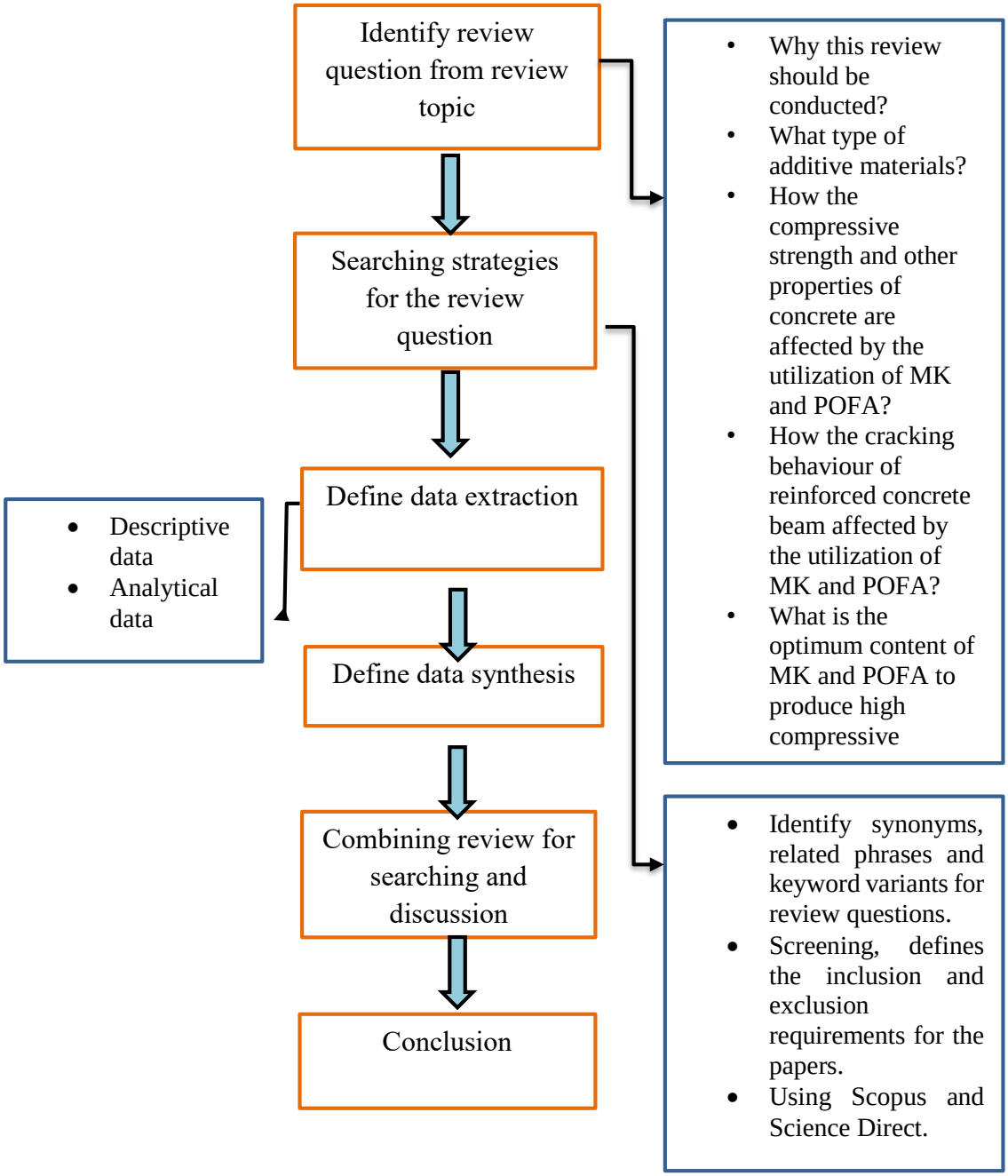


Figure 1.1 Methodology for systematic review

1.5 Significance of the systematic review

The research is important in determining and comprehending the efficiency and structural behaviour of reinforced concrete beams containing POFA and MK. From the compressive strength of concrete containing both of the materials, it has been proven that both contributed to many positive results. The incorporation of the mixtures into beam structures has the potential to improve superstructure stability and strength. It also can be enhancing sustainability and environmental friendliness.

The methodology of systematic literature review (SLR) will be further discuss on the next chapter (Chapter 2).

CHAPTER 2

SYSTEMATIC LITERATURE REVIEW (SLR): A METHODOLOGY

2.1 Introduction

This chapter explains the methodology used in this study, which focuses on the influence of POFA and MK on strength of concrete and crack resistance of reinforced concrete beam. Furthermore, the research methodology is outlined in such a way that the review questions for this study are met.

For this study, two main methodological approaches have been identified. Firstly, the objectives were to study the compressive strength of concrete that affected by inclusion of MK and POFA. In order to achieve this goal, a systematic literature review has been performed. Secondly, the systematic literature review use to identify or evaluate the cracking behaviour of reinforced concrete beam that contain MK and POFA.

2.2 Planning of SLR

The main objective of the proposed research methodology was to determine and analyse the experimental and numerical studies on crack pattern of reinforced concrete beam with POFA and MK. To this end, a systematic literature review will be carried out hereinafter. A systematic literature review (SLR) identifies, selects and critically appraises research in order to answer a clearly formulated question (Dewey & Drahota, 2016). Besides that, a systematic review also may be a high-level overview of primary research on a specific research question that systematically identifies, selects, evaluates, and synthesizes all high-quality research evidence relevant to that question so as to answer it. According to BA & Charters (2007), a systematic review is a well-defined and methodological way to classify, analyse and synthesise the available evidence for a

specific technology in order to clarify the current direction and status of research or to provide background information on research challenges.

2.1 Review protocol

First of all, the significant step in the systematic literature review process is development of the protocol as shown in Figure 2.1. The protocol points out all the approaches and methodologies that researchers will use throughout the analysis to mitigate the chances of validity and neutralise author bias. One of the main differences between SLR and standard literature reviews is the review protocol. An independent researcher has evaluated the protocol used in this report.

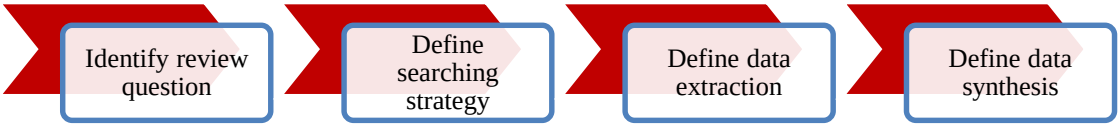


Figure 2.1: SLR protocol

The protocol starts with the specification of the search technique procedure to be used, followed by the identification of the analysis issue or review topic. The selection criteria were established to provide a method for selecting primary studies in a systematic manner. Finally, data elements obtained from the primary studies were identified to aid in the investigation of the research questions. Regarding the data collection, the qualitative approach was used to further evaluate the data that had been collected that reduce the possibility of validity.

2.3.1 Formulation of review question

In this section, focus at the issues that matter to both researchers and practitioners. As a result, the SLR highlighted the key review questions:

RQ1. How the compressive strength and other properties of concrete are affected by the utilization of Metakaolin (MK) and Palm Oil Fuel Ash (POFA)?

RQ2. How the cracking behaviour of reinforced concrete beam affected by the utilization of Metakaolin (MK) and Palm Oil Fuel Ash (POFA).

RQ3. What is the optimum content of Metakaolin (MK) and Palm Oil Fuel Ash (POFA) to produce high compressive strength of concrete?

A systematic review is based on a single review objective and priorities that have been pre-determined. Any scoping searches in a database to see if there are any reviews on the topic and if it is a different one are a good idea. The analytical questions can then be formulated.

RQ1 was informed by the need to know the effect of the utilization of MK and POFA on the compressive strength of concrete. Next, RQ2 helps to explained the cracking behaviour of reinforced concrete beam affected by incorporating MK and POFA in concrete mixture. Lastly, RQ3 helps to evaluate the optimum contents of MK and POFA.

2.3.2 Systematic searching strategies

This process consisted of a search and delivery plan. The search strategy aids in the creation of the proper search string as well as the classification of the appropriate databases for the collection of related documents. Identification, screening, and eligibility are three sub-processes of systematic searching techniques.

First of all, the first step in the process were to identify synonyms, related phrases, and keyword variants. It was aimed to provide the chosen index more

opportunities for searching for more important research papers. The relevant keywords were first found, with the algorithm focusing on an online thesaurus, keywords used in previous studies, keywords recommended by Scopus, and the results of the search. Table 2.1 is the enriched main keywords for the review question and review objectives in the study that help to find the papers or publications that are relevant to the study.

Then, the search was performed on selected leading and supporting databases using advanced searching techniques such as the Boolean operator, phrase searching, truncation, wild card, and field code functions separately, or by combining these searching techniques into a full searching string. The produced search strings were then 'paste' into the selected databases, which were Scopus' leading database and Science Direct's supporting database, to search for the relevant papers. Table 2.2, Table 2.3, Table 2.4, Table 2.5 and Table 2.6 are the full search string for review objectives (RO1 and RO2) and review questions (RQ1, RQ2 and RQ3) that were paste into Scopus's leading database and Science Direct's supporting database to find paper that are related and relevant.

Table 2.1: Enriching the main keywords for review objectives and review questions

Section	Main keywords	Enriched keywords
RO1 To study the effect of the utilization of Metakaolin (MK) and Palm Oil Fuel Ash (POFA) on the compressive strength and other properties of concrete based on related previous studies.	Effect Utilization Compressive strength Metakaolin Palm Oil Fuel Ash	Outcome, result, consequence Usage, use Stability, toughness MK, pozzolan POFA, pozzolanic
RO2 To evaluate the influence of Metakaolin (MK) and Palm Oil Fuel Ash (POFA) inclusion on the cracking behaviour of reinforced concrete beam.	Influence Inclusion Metakaolin Palm Oil Fuel Ash Cracking Behaviour Reinforced concrete beam	Urge, instigate, impact Incorporation, addition MK, pozzolan POFA, pozzolanic Fracture, impair Performance, action, presence Flexural member
RQ1 How the compressive strength and other properties of concrete are affected by the utilization of Metakaolin (MK) and Palm Oil Fuel Ash (POFA)?	Compressive strength Affected Utilization Metakaolin Palm Oil Fuel Ash	Stability, toughness Influence Usage, use, employment MK, pozzolan POFA, pozzolanic
RQ2 How the cracking behaviour of reinforced concrete beam affected by the utilization of Metakaolin (MK) and Palm Oil Fuel Ash (POFA).	Influence Inclusion Metakaolin Palm Oil Fuel Ash Cracking Behaviour Reinforced concrete beam	Urge, instigate, impact Incorporation, addition MK, pozzolan POFA, pozzolanic Fracture, impair Performance, action, presence Flexural member
RQ3 What is the optimum content of Metakaolin (MK) and Palm Oil Fuel Ash (POFA) to produce	Optimum Content Metakaolin Palm Oil Fuel Ash	Peak, best Constitution MK, pozzolan POFA, pozzolanic

high compressive strength of concrete?	Produce High Compressive strength	Make, construct Peak Stability, toughness

Table 2.2: Full search string for the review objective 1

Database	Search String
Scopus	TITLE-ABS-KEY (("outcome" OR "effect")) AND ("compressive strength" OR "stability" OR "toughness") AND (“reinforced concrete") AND ("utilization" OR “Usage”) AND ("Metakaolin" OR "MK") AND ("Palm oil fuel ash" OR “POFA)))
Science Direct	(“effect”) AND (“compressive strength”) AND (“Utilization”) AND (“reinforced concrete”) AND (“Metakaolin) AND (“Palm oil fuel ash”)

Table 2.3: Full search string for the review objective 2

Database	Search String
Scopus	TITLE-ABS-KEY ((“Influence” OR “Impact”) AND ("cracking” OR “fracture”) AND (“reinforced concrete beam” OR “flexural member”) AND (“Inclusion”) AND (“POFA” OR “Palm oil fuel ash”) AND (“MK” OR Metakaolin”)
Science Direct	(“Influence”) AND (“palm oil fuel ash”) AND (“Metakaolin”) AND (“cracking)” AND (“reinforced concrete beam” OR “Flexural member”)

Table 2.4: Full search string for the review question 1

Database	Search String
Scopus	TITLE-ABS-KEY (("outcome" OR "effect")) AND ("compressive strength" OR "stability" OR "toughness") AND (“reinforced concrete") AND ("utilization" OR “Usage”) AND ("Metakaolin" OR "MK") AND ("Palm oil fuel ash" OR “POFA)))
Science Direct	(“effect”) AND (“compressive strength”) AND (“Utilization”) AND (“reinforced concrete”) AND (“Metakaolin) AND (“Palm oil fuel ash”)

Table 2.5: Full search string for the review question 2

Database	Search String
Scopus	TITLE-ABS-KEY ((“Influence” OR “Impact”) AND ("cracking” OR “fracture”) AND (“reinforced concrete beam” OR “flexural member”) AND (“Inclusion”) AND (“POFA” OR “Palm oil fuel ash”) AND (“MK” OR Metakaolin”)
Science Direct	(“Influence”) AND (“palm oil fuel ash”) AND (“Metakaolin”) AND (“cracking)” AND (“reinforced concrete beam” OR “Flexural member”)

Table 2.6: Full search string for the review question 3

Database	Search String
Scopus	TITLE-ABS-KEY ((“optimum” OR “best”) AND (“content” OR “constitution”) AND (“concrete”) AND (“palm oil fuel ash”) AND (“Metakaolin”))
Science Direct	(“optimum”) AND (“content”) AND (“palm oil fuel ash”) AND (“Metakaolin”) AND (“concrete”)

The second sub-step of the systematic searching strategy procedure, screening, establishes the inclusion and exclusion criteria for the papers to be reviewed. Many of the publications on the list were checked to see if they meet the criteria for inclusion and exclusion. This search was generated directly using the sorting feature of the databases that have been selected. Timelines, publication formats, and language were use as some of the basic requirements for inclusion and exclusion.

Since it is almost impossible for researchers to read all of the currently published articles, Okoli (2015) suggested that researchers determine the range of timelines that can read. In the Cochrane Handbook, however, Higgins and Green (2020) claimed that timeline publication restrictions could only be used if it is realized that related studies could have only been conducted within a certain time span. To ensure the quality of the study, only papers with empirical evidence and published in journals, academic articles, or review articles were considered. Furthermore, the thesis only includes papers written in English and Bahasa Malaysia to avoid any confusion. Table 2.7 lists some of the study's inclusion and exclusion requirements.

Table 2.7: Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Timeline	2000-2021	Before 2000
Publication Type	Journal, Research article, Review article, Books, Conference proceeding, Chapter in Book	Newspaper
Language	English, Bahasa Malaysia	Other than English and Bahasa Malaysia

Finally, after the screening procedure, which is the third sub-process, the researcher must manually monitor the recovered papers to confirm that all of the

surviving articles are consistent with the requirements. This can be accomplished simply reading the titles and abstracts of the articles. The quality of the articles should be examined if there is any remaining uncertainty about the validity of the articles under consideration.

2.3.3 Data Extraction and Synthesis

After identified all of the papers that will be included in the systematic review, the next step was to collect and analyse the data from those articles. Many structures and methods for data extraction and synthesis were described in the literature, but non-meta-analysis as qualitative analysis and meta-analysis as quantitative analysis are the most widely used. For a non-meta-analysis, a description of the findings tables was generated. A meta-analysis, on the other hand, entails data pooling and sophisticated statistical analysis.

Another key challenge in data extraction and synthesis is that, previous to the recent development of machine learning models, electronic text searches might be used to locate information within an article (Cochrane Handbook, 2020). Despite recent advances in machine learning models for automating data extraction in systematic reviews, data extraction is still mostly a manual process.

2.4 Reporting the SLR

Throughout this step, all processes must be recorded. The total number of articles retrieved should be properly recorded, from recognition to screening to eligibility. The number of articles recovered is suggested to be recorded using the PRISMA flow diagram, as shown in Figure 2.2. In the following chapter (Chapter 3), the data extraction and data synthesis will go through in more depth.

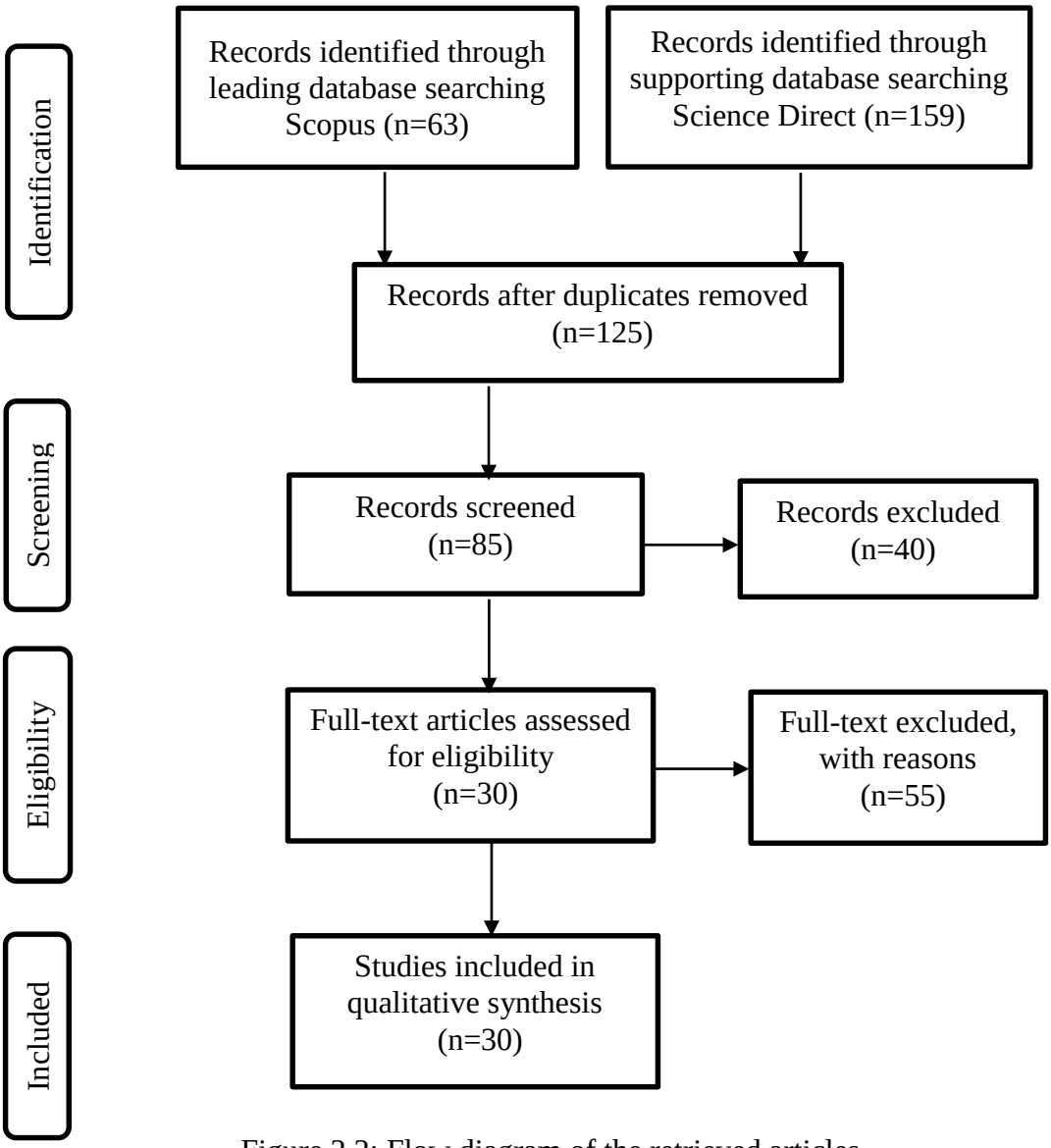


Figure 2.2: Flow diagram of the retrieved articles

CHAPTER 3

DATA EXTRACTION AND SYNTHESIS

3.1 Introduction

During the extraction and synthesis process, the relevant data from the selected papers was classified according to the knowledge and conclusions drawn. The data extraction method entailed locating and extracting relevant information from the chosen posts. Reviewing the synthesized data and extracting useful information, as well as the conclusion of the selected papers, were all part of the research process.

The variable of interest was organised on the general characteristics of the papers and the primary criteria used for the assessment in order to achieve the SLR's goal. The general details of the papers include the year of publication, the nature and scope of the research, and the country or location in which the study was done. For data processing, the data relating to each selected paper was extracted to an Excel spreadsheet. The classification stage entails classifying and analysing the collected data in order to prepare it for further analysis, with the ultimate result presented in the form of charts and graphs.

3.2 Data Extraction

This process requires the collection of data from related research in order to analyse and compare the results. Appropriate data collection techniques were used when extracting data. Data management were begin as soon as the collecting data begin, and decided which types of data that want to keep using data management tools like Mendeley.

Data extraction is the process of reading the full text of each article selected for inclusion in the study and extracting the pertinent data using a standardised data

extraction form or table. The review goals and review questions formulated in the first phase of the SLR were used to establish the data extraction type or table.

It is common for qualitative data were extracted in stages. As key themes and questions arise from the synthesis, review authors will cycle between reading primary articles, data extraction, and synthesis or interpretation (Noyes & Lewin, 2011). To summarize the literature extracted, the data extraction table is widely used in the thesis.

3.2.1 Descriptive Data

A descriptive data is a summary data that quantitatively characterizes or summarizes features from a set of data, as well as the process of generating, analyzing, and interpreting those data. The Table 3.1 represents the summary of the journal that relevant to the research topics. It is present the title of publication, year of publication, types of publication, publication outlet, research objectives, research scope, brief description and methods used for the research topic.

Table 3.1: Descriptive data for research topic

Author, Title of publication	Year of publication	Type of publication	Publication outlet	Research objective	Research scope	Brief description	Methods
Brooks and Megat Johari "Effect of Metakaolin on Creep and Shrinkage"	2001	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Autogenous shrinkage -Creep and shrinkage -Compressive strength test -Curing
Vu et al. "Strength and Durability aspects of Calcined Kaolin-blended Portland Cement Mortar"	2001	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Compressive strength test -Curing method
Vanchai Sata, Chai Jaturapitakkul, and Kraiwood Kiattikomol.	2004	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Curing method

"Utilization of Palm Oil Fuel Ash in High-Strength Concrete"							-Compressive strength test
Tangchirapat et. al. "Use of Waste Ash from Palm Oil Industry in Concrete"	2007	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Slump test -Curing method -Compressive strength test -Sulfate resistance test.
Chindaprasirt et al "Strength and water permeability of concrete containing palm oil fuel ash and rice husk-bark ash"	2007	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	Compression test, penetration and steady flow method.
Sata et al "Influence of Pozzolan from Various by-product Materials on Mechanical Properties of High-strength Concrete"	2007	Journal	Scopus	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Slump test -Curing method -Compressive strength test
Siddique and Klaus "Influence of metakaolin on the properties of mortar and concrete: A review"	2009	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	Review other paper
Tangchirapat et al "Use of palm oil fuel ash as a supplementary cementitious	2009	Journal	Scopus	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Compressive strength test

material for producing high-strength concrete"							-Drying shrinkage test -Water permeability test -Sulfate resistance test
Tangchirapat, and Jaturapitakkul. "Strength, drying shrinkage and water permeability of concrete incorporating ground palm oil fuel ash"	2010	Journal	Scopus	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Water permeability test -Compressive test
Kroehong et. al. "Effect of palm oil fuel ash fineness on the microstructure of blended cement paste"	2011	Journal	Scopus	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Compressive strength test -Curing method
Siamed et al "Influence of Metakaolin on the performance of mortars and concretes"	2012	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Compressive strength test -Curing method
Megat Johari et. al. "Engineering and transport properties of high-strength green concrete containing high volume of ultrafine palm oil fuel ash"	2012	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Slump test -Compressive strength test
Deepthi et al.	2014	Journal	Science Direct	RQ2	RQ2	RQ2	-Third point loading test

"Effect of metakaolin on the structural behaviour of normal and steel fibre reinforced concrete beams"							-Slump test
Muthusamy and Zamri "Mechanical Properties of Oil Palm Shell Lightweight Aggregate Concrete Containing Palm Oil Fuel Ash as Partial Cement Replacement"	2015	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Curing method -Compressive strength test -Flexural strength test
Islam et. al. "Durability properties of sustainable concrete containing high volume palm oil waste materials"	2016	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Compressive strength test -Curing method
Zeyad et al "Pozzolanic reactivity of ultrafine palm oil fuel ash waste on strength and durability performances of high strength concrete"	2016	Journal	Scopus	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Slump test -Compressive strength test
Mahyuddin et al "Characterization of Metakaolin and study on early age mechanical strength of hybrid cementitious composites"	2016	Journal	Scopus	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Flow test -Compressive strength test -Curing method -Shrinkage test

A.M. Zeyad et. al "Efficiency of treated and untreated palm oil fuel ash as a supplementary binder on engineering on engineering and fluid transport properties of high-strength concrete"	2017	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Slump test -Curing method -Compressive strength test
Dadsetan and Bai. "Mechanical and microstructural properties of self-compacting concrete blended with Metakaolin, ground granulated blast-furnace slag and fly ash"	2017	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Slump test -Compressive strength test
Ahmed et al "Structural performance of reinforced concrete beams with Nano-Meta-Kaolin in shear"	2017	Journal	Science Direct	RQ2	RQ2	RQ2	-Two-point loading applied -Deflection measurement
Shehab El-Din et. al. "Mechanical Performance of High Strength Concrete Made from High Volume of Metakaolin and Hybrid Fibers"	2017	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	Concrete mixtures containing Metakaolin is being tested using: -Compressive strength test

							-Split tensile test -Bond strength test
Hamada et. al "The present state of the use of palm oil fuel ash (POFA) in concrete"	2018	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	Review other paper
Malagavelli et al. "Influence of metakolin in concrete as partial replacement of cement"	2018	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-compressive strength test -tensile strength test
Tawfik et al "Hybrid effect of Nano Silica and Metakaolin on Mechanical Properties of Cement Mortar"	2019	Journal	Science Direct	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Compressive strength test -Flexural strength
Rahman et al "Flexural study of reinforced foamed concrete beam containing palm oil fuel ash (POFA) and eggshell powder (ESP) as partial cement replacement"	2019	Journal	Scopus	RQ2	RQ2	RQ2	-four point load test
Hamada et. al. "Fresh and hardened properties of palm oil clinker lightweight	2019	Journal	Scopus	RQ1/RQ3	RQ1/RQ3	RQ1/RQ3	-Curing method -Slump test