EFFECTS OF FLY ASH AS A CEMENT REPLACEMENT MATERIAL FOR SELF-HEALING CONCRETE

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SCHOOL OF CIVIL ENGINEERING UNIVERSITI SAINS MALAYSIA

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FOR SELF-HEALING CONCRETE

By

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

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ABSTRAK

Disertasi ini membentangkan tinjauan literatur mengenai kesan abu terbang dalam konkrit penyembuhan sendiri. Objektif kajian ini adalah untuk menyiasat kesan abu terbang dalam konkrit penyembuhan sendiri dan mengkaji prestasi abu terbang dalam konkrit penyembuhan sendiri. Kajian ini juga membezakan jurang pengetahuan dalam aplikasi abu terbang dalam keupayaan penyembuhan konkrit secara sendiri. Penyembuhan diri adalah keupayaan konkrit untuk membaiki kerosakan dalaman tanpa campur tangan luar. Namun, pembentukan etringit akan membantu keupayaan penyembuhan diri konkrit untuk mengisi retakan. Oleh itu, terdapat 12 artikel telah dikenal pasti dalam semakan ini daripada pangkalan data Scopus dan ScienceDirect setelah memenuhi kriteria kemasukan. Menggunakan strategi carian yang sistematik, kertas yang tidak berkaitan telah disaring keluar, dan penilaian kualiti artikel digunakan untuk mengelakkan penerbitan dengan kualiti metodologi yang lemah. Dalam tinjauan ini, kesan dan prestasi abu terbang telah dibincangkan. Dalam ulasan ini, abu terbang menjejaskan daya serap air, kebolehtelapan, lebar retak, kekuatan mampatan dan produk dan persekitaran penyembuhan diri. Prestasi abu terbang dipengaruhi oleh keadaan pendedahan, masa pengawetan, lebar retak awal dan kandungan abu terbang.

ABSTRACT

This dissertation presents a systematic literature review on the effect of fly ash in self-healing concrete. The objective of this review is to investigate the effect of fly ash in self-healing concrete and studies the performance of fly ash in self-healing concrete. This review also distinguishes the gap of knowledge in the application of fly ash in the autogenous self-healing ability of the concrete. Self-healing is the capacity of the concrete to repair internal damage without outside intervention. Yet, the formation of ettringite will help the self-healing ability of the concrete to fill the cracks. Therefore, there were 12 articles had been identified in this review from Scopus and ScienceDirect database after meeting the inclusion criteria. Using systematic search strategies, irrelevant papers were screened out, and the article quality evaluation was employed to avoid publications with poor methodological quality. In this review, the effect and performance of fly ash were discussed. In this review, fly ash affects the sorptivity, permeability, crack width, compressive strength and self-healing product and environment. The performance of fly ash was influenced by the exposure condition, curing time, initial crack width and the content of fly ash.

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CHAPTER 1
INTRODUCTION

1.1 Background

For decades, a lack of durability has been recognized as a major concern in construction practices. One of the most serious concerns is the sharp decrease in durability caused by concrete cracking, which can be caused by external factors such as harsh environments, poor workmanship, or concrete itself in the case of restraining conditions. The brittle nature of concrete contributes to the low durability of many concrete structures. Thus, the development of ductile concretes is highly desirable. Self-healing concrete has been developed in this vein over the last two decades (Sahmaran et al., 2013).

Self-healing concretes are becoming increasingly important as a means to enhance the durability of concrete. Self-healing concrete is defined as the ability of concrete to autonomously repair its small cracks. The concept of self-healing concrete was inspired by natural phenomena such as tree or animal healing. Tree and animal skin that has been damaged can be restored on their own. Shan et al. (2018) described that the process of self-healing can be categorized into three major processes which are further hydration of unhydrated cement at the cracked surface, recrystallization of portlandite leached from the bulk paste, and formation of calcite ($CaCO_3$).

Self-healing ability is essential for restoring the original performance of damaged concrete since it is a more cost-effective solution than standard repair methods. Fly ash, which has been increasingly used as a concrete admixture in the last decades, has such a kind of appropriate self-healing ability in the presence of $Ca(OH)_2$.

Based on previous research, there is a lack of information about long-term behaviour of hydration process, hydrated products and self-healing ability in fly ash blended cement mixtures for different types of fly ash and cement. Although self-healing concrete has been studied for decades, self-healing of cement-based materials at the current levels of advancement is characterized by significant limitations and its effectiveness depends on several key factors determined by the material properties. Hopefully, by doing this review, it may help people understand more about the effect of fly ash on the self-healing ability of concrete.

1.2 Review questions

1) What is the effect of fly ash on self-healing concrete?

2) How is the performance of fly ash as self-healing concrete?

3) What is the next journey or direction of research in this field?

1.3 Objectives of the systematic review

1) To investigate the influence of fly ash on the self-healing ability of concrete.

2) To review the performance of fly ash as self-healing concrete.

3) To identify the gap of knowledge in the application of fly ash in self-healing concrete.

1.4 Problem statement

In Malaysia, reinforced concrete structures are the main type of building facade due to their low construction cost, durability, and availability of raw materials. However, the crack in the concrete will influence the durability of the structure. For decades, a lack of durability has been recognised as a major concern in construction practises. People are not serious about taking care of concrete at an early stage of maturity, and they are only

aware of the crack after the task is completed. Therefore, a new generation of concrete which is self-healing concrete was introduced. Fly ash as self-healing agent is used in concrete to help the concrete to close the crack by itself. Therefore, this study is focusing on the effect of fly ash in self-healing concrete, the performance of the fly ash and the gap of knowledge in the application of fly ash in self-healing concrete. Therefore, this study would be able to provide a better understanding of the effect of fly ash on the crack in the concrete.

1.5 Significance of the systematic review

The overall aim of this study is to understand the effect of fly ash as a cement replacement material applied in self-healing concrete. This study can help to determine the grade and percentage of fly ash used in the concrete mix to reach the optimum self-healing behaviour in the concrete. Lastly, the information of the literature review about fly ash in self-healing concrete can be used as guideline and reference in designing the concrete mixtures.

1.6 Organization of the report

This dissertation consists of 5 main chapters, each chapter discusses a different topic related to the title. Through the sequence of the chapter, the reader can understand the dissertation from shallow to deep. The following is the summary of these chapters in this dissertation from chapter 1 to chapter 5.

Chapter 1 consists an outline of the study. The background of the study, review questions, objectives, problem statement, and significance of the study will be discussed in this chapter.

Chapter 2 discusses the methodology part of the study. It will discuss the planning process of the systematic literature review before conducting this review. In this chapter,

it will mention the protocol, review question, searching strategies, quality assessment, data extraction, data synthesis and the reporting of the review.

For the deeper explanation of data extraction and data synthesis, they will be discussed in Chapter 3. This chapter addresses some overview and the method used when conducting extraction and synthesis. These processes are crucial as they are the last process before making the summary or conclusion for the review.

Chapter 4 shows the discussion and analysis of the information obtained from the research article studied. Information obtained from the article will be arranged to answer the review question in this review. Besides, the divergences of the articles will be discussed and also the gap of knowledge of those articles.

Lastly, chapter 5 presents the conclusion of the study after reviewing the articles and interpretation of the gap of knowledge found in this study. Recommendation for future study is also stated in this chapter.

CHAPTER 2
SYSTEMATIC LITERATURE REVIEW: A METHODOLOGY

2.1 Introduction

A literature review is a discussion or summary of previously published information in a particular field. The literature review can be thought of as a simple overview of the sources, but it also includes a summary and synthesis. A summary extracts the most important information from the sources, but a synthesis reorganises and reshuffles the material. Through information synthesis, a new opinion or argument might be inspired by or merged with older materials. Additionally, the researcher who is an expert in his subject or capable of interpreting the existing knowledge can bring out contradictions and gaps in the evaluated information through the literature review. Thus, a literature review can assist the reader in locating the most pertinent and reputable sources of information.

Systematic literature review is contrast with the traditional review. It requires reviewing a large amount of the information to determine the answer to the questions. To address the review question, relevant info from the research paper will be discovered, selected, and synthesised. In contrast to a traditional review, a systematic review follows a rigid and well-defined procedure for conducting the review. It contains clearly stated objectives, review questions, method of searching, and inclusion and exclusion criteria, among other things, in order to develop a qualitative review article. Because of reviewing a large amount of the papers or articles based on the review questions, the contradiction and gap of knowledge can be easily known as well as clarify where the research is needed to further undergo in future (Jesson et al., 2011).

2.2 Planning of SLR

This systematic review is to review the effects of fly ash on self-healing concrete. Some prior knowledge or understanding of the title is essential because it can assist in forming a concise summary of how to build the sections such as objective, review question, protocol, and methodology. Systematic review has its strict method to conduct the review which means a clear review protocol must be developed before the starting of the review. In this review protocol, three stages can be summarized from the starting of the review to the end of the review, which is the planning stage, conducting stage and reporting stage. Through those stages, it specifies the procedures for each stage so that the review can carry on smoothly and minimize the author bias when presenting the discussion.

2.2.1 Review protocol

Before conducting the systematic literature review, a clear protocol is needed as it can be a guide to carry out the review. Protocol preparation is a crucial part of the systematic review process. It ensures that a systematic review is thoroughly prepared and that what is scheduled is communicated prior to the review's start, promoting transparent review team behaviour, reliability, scientific credibility, and the final finished review's transparency (Moher et al., 2016). By following the protocol, the objectives, review questions and purpose of the project can be easily identified. The protocol specifies all the steps to be followed by researchers in the review to minimize the threats to validity as well as neutralizing the author bias. The protocol is separated into three stages which are planning stage, conducting stage and reporting stage (Figure 2.1).

Figure 2.1: Flow chart of the review protocol (Hussain et al., 2019).

In the planning stage, once the title of the study has been determined, a review protocol must be formulated. Then, the objectives of the review will be specified to provide a clear statement question or review question. Further discussion of the review question is provided in section 2.2.2.

In this conducting stage, it is more focused on the searching and processing of the research article. Systematic searching strategies are used to finding the related article from the database by using the main term from topic and objective. Then, the filtering process for the articles is carried out to exclude the irrelevant and duplicated article, left only the vital article. After retrieving the article from the database, it will be subjected to a quality assessment. Quality assessment is one of the article appraisal methods used to determine how closely an article's sensitivity and accuracy match the review question or objective. As a result, the review is less biased and more credible. For the data extraction section, it is the technique for extracting data from each article, such as the author, the study's purpose, and the study's outcome. Meanwhile, the data synthesis part is in charge of coordinating all the articles in order to arrive at an answer to the review question. Since this systematic literature review is qualitative, the combined result will be categorized under major themes or subthemes (Bettany-Saltikov, 2016). Therefore, the

information extracted from each article will be present in a table so that the contradiction and similarity of each article can be easily shown and reviewed.

In the reporting stage, it is the process to summarize, synthesize, and present the answer to the review questions. The report will be examined under the themes or categories of thematic analysis in this study. A thematic analysis of literature is a method of evaluating qualitative data that involves thoroughly examining the material in order to identify recurring themes, concepts, thoughts, and contextual tendencies. A table of thematic synthesized information from each article will be formed. Hence, it will be easy to answer the review question that is set at the planning stage and can interpret the gap of knowledge among the articles. Apart from this, the recommendation can be done for future researchers about the topic or field to improve their future work.

2.2.2 Formulation of review questions

A review question should be well formulated, answerable, and focused. The review questions will be defining which studies to be included, what type of searching strategy to be used to identify the relevant primary studies, also which data is needed to be extracted from each study. A poor question will result in a poor review. Moreover, a systematic review is based on a predefined specific review topic and objectives.

2.3 Conducting the SLR

A systematic review is a comprehensive examination of the literature with the goal of identifying, evaluating, and synthesising the best available data on a particular subject in order to provide helpful and evidence-based answers (Boland et al., 2017). When doing a systematic review, it is critical to collect as many studies as possible that are relevant to the review objectives or questions. To broaden the search, a synonym for

the objective and the review question will be defined, and then the eligibility article will be filtered.

When constructing the review question, the objectives of this systematic review are examined. One review question will be applied to each aim, for a total of three review questions in this systemic review. Therefore, a question format known as PICO is utilised to frame a review question in order to facilitate a search. "P" represents the patient, "I" represents the intervention, "C" represents the comparison, and "O" represents the outcome. However, the PICO framework is typically utilised to construct clinical questions for quantitative literature reviews; afterwards, a modified PICO framework, PICo, is employed.

As stated previously, PICo is a version of PICO that is ideal for qualitative systematic reviews, and the meaning of each letter in PICo differs from that of PICO. In PICo, "P" represents population, "I" represents interest, and "Co" represents context. Tabular comparison of PICO and PICo is shown in Table 2.1. (LIBGUIDES, 2021). Table 2.3 displays the review questions for each target based on the PICo framework.

Table 2.1 Description of PICO and PICo

PICO	Meaning	PICo	Meaning
P- population	What are the characteristics of the patient or problem?	P - population	What is the Problem, condition or disease you are interested in?
I - intervention	What do you want to do with this patient?	I – interest	What are the phenomena of interest?
C – comparison	What is the alternative to the intervention?	Co - context	What is the setting or distinct characteristics?
O - outcome	What are the relevant outcomes?		

Table 2.2 Relationship of the review question with the PICo framework

Objective 1 (RO1)	To review the effect of fly ash on the self-healing ability of concrete.	
Review question (RQ1)	What is the effect of fly ash on self-healing concrete?	
P	I	Co
Effect	Fly ash	Self-healing concrete

Objective 2 (RO2)	To review the performance of fly ash as self-healing concrete.	
Review question 2 (RQ2)	How is the performance of fly ash as self-healing concrete?	
P	I	Co
Fly ash	Performance	Self-healing concrete

Objective 3 (RO3)	To identify the gap of knowledge in the application of fly ash in self-healing concrete.	
Review question 3 (RQ3)	What is the next journey or direction of research in this field?	
P	I	Co
Research (application of fly ash in self-healing concrete)	next journey or direction	Review (systematic literature review)

2.3.1 Systematic searching strategies

In this systematic review, systematic searching strategies aim to identify potential articles from the electronic database and then filtering the unwanted articles. There are three stages of conducting the strategized searching, which are identification, screening and eligibility stage.

During the identification stage, the electronic database used in this review is Scopus, which is owned by Elsevier and is the largest abstract and citation database of peer-reviewed literature. In this review, there are 4 searching statements based on the topic, objectives and review questions. To achieve the sensitivity and specificity in searching, topic, objectives and review questions are used by differentiating the keyword or main term from the sentences and then enriching them for the synonym, related and variation terms so that can retrieve a high portion of the relevant article and less portion of the irreverent article (see Table 2.3). When executing a search in Scopus, the Boolean operator is used to connect keywords with the enhanced keyword to generate a searching string. The Boolean operator "OR" is used to connect synonym, related, and variant terms, whereas the Boolean operator "AND" is used to connect the main term. After all the keywords and the enriched term is confirmed, the searching string is applied in Scopus to perform searching. For the information, the searching strings for each statement can be referred to Table 2.4.

In the screening stage, it is to filter out the irrelevant articles which are from the identification stage based on the inclusion and exclusion criteria (see Table 2.5) and has two phases. The first step of the article screening process is limited to the most recent five years of publishing (2018-2022), the article type document, the final publication document, and English. The second part is combing through the titles and abstracts of the remaining articles, and, if necessary, reading the full text of the articles to ensure that they adequately address the review questions. Since there are 4 searching statements in this review, therefore the screening stage is done for each searching statement. Throughout both phases, it is helpful to establish an acceptable research paper selection form to standardize the papers that match the predetermined criteria.

Overall, the number of articles in each stage (identification, screening, eligibility) is recorded down (see Figure 2.1). These searching strategies can ensure the review is transparent and neutral without bias on one side. As a result, these will improve the validity or truthfulness of the results in the review.

Overall, the number of articles in each stage (identification, screening, eligibility) is recorded down (see Figure 2.2). These searching strategies can ensure the review is transparent and neutral without bias on one side. As a result, these will improve the validity or truthfulness of the results in the review.

Table 2.3: Searching statement with the main term and the enriched keyword in identification stage

Searching statement	Main keywords	Enriched keywords
Topic: Effects of Fly Ash as a Cement Replacement Material for Self-Healing Concrete	• Fly ash • Effect • Cement replacement • Self-healing concrete	• Result • Material, admixture • Self-repairing concrete
RO1: To investigate the effect of fly ash on the self-healing ability of concrete.	• Effect • Fly ash • ability • Self-healing concrete	• Result • capability • self-repairing concrete
RQ1: What is the effect of fly ash on self-healing concrete?	Refer to RO1	Refer to RO1
RO2: To review the performance of fly ash as self-healing concrete.	• Performance • Fly ash • Self-healing concrete	• behaviour • self-repairing concrete
RQ2:	Refer to RO2	Refer to RO2

How is the performance of fly ash as self-healing concrete?		
RO3: To identify the gap of knowledge in the application of fly ash as cement replacement in self-healing concrete	• Application • Fly ash • Cement replacement • Self-healing concrete	• Adoption, implementation • Material, admixture • Self-repairing concrete
RQ3: What is the next journey or direction of research in this field?	Refer to RO3	Refer to RO3

Table 2.4: Searching string for each statement and its number of articles found.

Section	Search String (Scopus)	Number of the article (identification stage)
Topic	TITLE-ABS-KEY ((“Fly ash” OR “supplementary cementitious material”) AND (“effect” OR “result”) AND (“Cement replacement” OR “material” OR “admixture”) AND (“self-healing concrete” OR “self-repairing concrete”))	117
RO1& RQ1	TITLE-ABS-KEY((“effect” OR “result”) AND (“fly ash” OR “supplementary cementitious material”) AND (“ability” OR “capability”) AND (“self-healing concrete” OR “self-repairing concrete”))	90
RO2& RQ2	TITLE-ABS-KEY((“performance” OR “behaviour”) AND (“fly ash” OR “supplementary cementitious material”) AND (“self-healing concrete” OR “self-repairing concrete”))	118
RO3& RQ3	TITLE-ABS-KEY((“application” OR “implementation” OR “adoption”) AND (“fly ash” OR “supplementary cementitious material”) AND (“cement replacement” OR “material” OR “admixture”) AND (“self-	88

	healing concrete" OR "self-repairing concrete"))	

Table 2.5: Review criteria

Criteria	Inclusion	Exclusion
Timeline	2018-2022	Before 2018
Document type	Article	Conference paper, review, book chapter, conference review, book, note, short survey, editorial and report
Publication stage	Final	Article in press
Language	English	Non-English

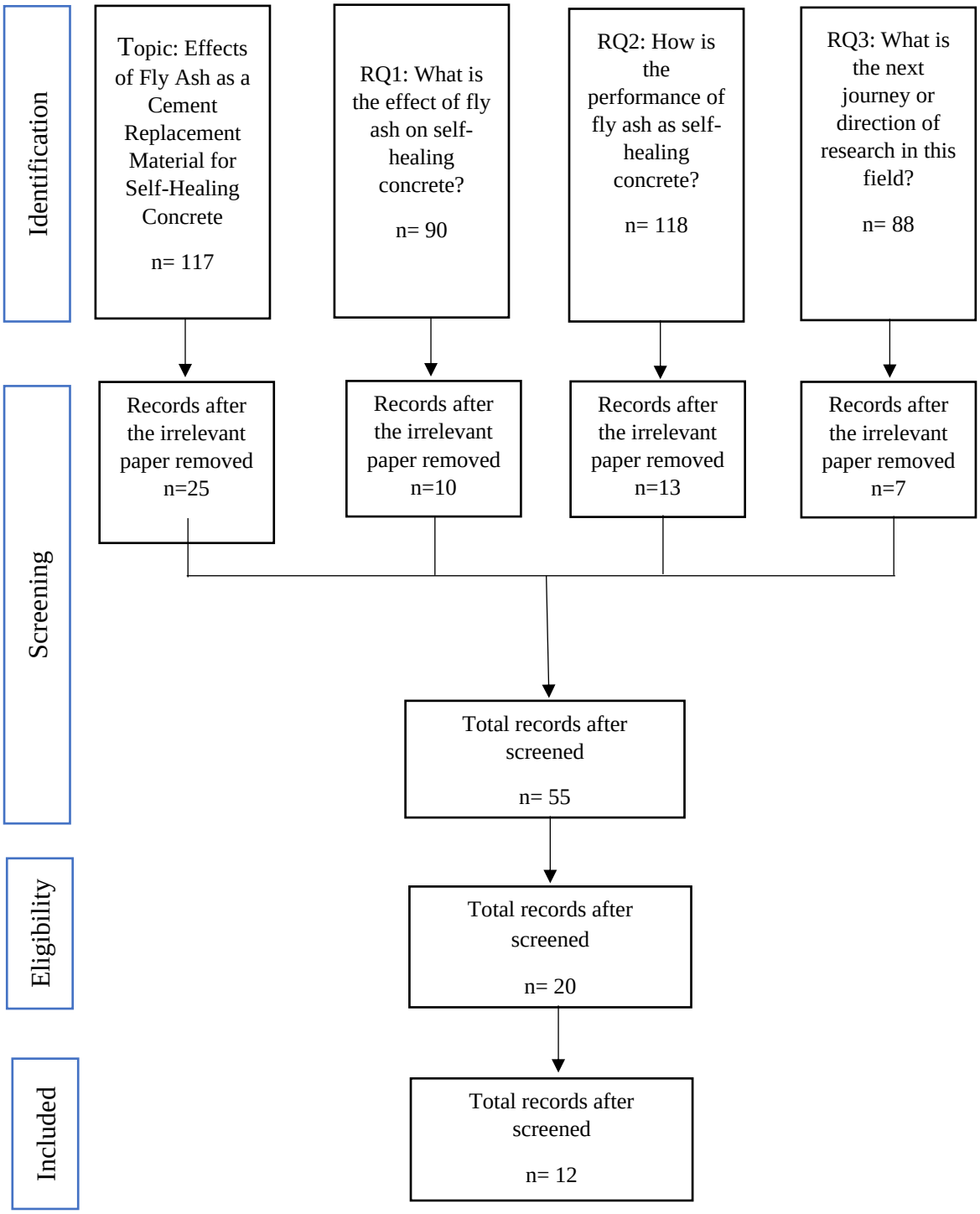

Figure 2.2: PRISMA flow diagram

2.3.2 Quality assessment

The purpose of the quality assessment is to determine the methodological quality of the selected literature and to weed out publications with questionable methodology. The validity and quality of the review studies determine the quality of the systematic review, which means that the review is devoid of bias and the conclusions are close to the truth (Bettany-Saltikov, 2012). Therefore, such poor research or study should be identified as such in the systematic analysis or completely omitted.

In this review, an assessment framework designed by Caldwell et al, (2011) had been used to assess the methodological quality of the studies. This appraisal framework can offer clarity and fairness when undertaking a review of a research paper for assessment purposes. Additionally, it is a framework that encompasses both quantitative and qualitative appraisal questions. The framework serves as a guide with detailed explanations for each item (see Table 2.6), and it begins with questions that address quantitative and qualitative investigations. However, because this is a qualitative systematic review, the quantitative question in the framework will be ignored in favour of the qualitative component.

In this assessment, the total score for each study is calculated by adding one point for each "yes" and zero point for others, such as "no", "cannot answer", and "not applicable," resulting in summary scores from 0 to 10 (see Table 2.7). To rate the quality of the articles, this assessment allocates the article into three categories: a score of 0–4 is classified as low quality, 5–7 indicates moderate quality, and 8–10 is regarded as high quality (See Table 2.8). In addition, there will be 12 articles waiting for appraising (see Table 2.9).

From the assessment, there are 12 out of 12 articles are categorized as high quality, which scores within 8 to 10 (See Table 2.10). In conclusion, all the 12 articles have a mean score of 9.67, thus those articles are suitable for review.

Table 2.6: Questions in quality assessment and its description.

No.	Question	Explanation
1	Does the title reflect the content?	The title should be informative and reflect the focus of the study. It should make it simple for the reader to understand the content of the study. An inaccurate or misleading title can confuse the reader.
2	Are the authors credible?	Researchers should hold appropriate academic qualifications and be linked to a professional discipline relevant to the research.
3	Does the abstract summarize the key components?	The abstract should provide a brief description of the study. It should contain the study's aim, methodology outline and main findings. The purpose of the abstract is to encourage the reader to decide if the study is of interest to them
4	Are the background and study design identified and the rationale for undertaking the research clearly outlined?	The design of the study should be identified and the background. The author should provide a clear rationale for the research and the reader needs to consider whether it is satisfied to meet the aims of the study.
5	Is the literature review comprehensive and up to date?	The literature review should present the current state of knowledge relevant to the study and identify any gaps or conflicts. It should include key or classic studies on the topic as well as up-to-date literature.
6	Is the aim of the research clearly stated?	The aim of the study should be clearly defined and should deliver what the researcher is setting out to achieve.
7	Is the methodology identified and justified?	The researcher should state clearly which research strategy is adopting. A clear rationale for the choice should also be provided so that the reader can judge whether the chosen strategy is appropriate for the study.
8	Are the results presented in a way	Data presentation should be simple, easy to understand, and consistent.

	that is appropriate and clear?	
9	Is the discussion comprehensive?	The results should be compared with previous research on the topic. The discussion should be balanced and avoid subjectivity.
10	Is the conclusion comprehensive?	Conclusions must be supported by the findings. The researcher should recognize any limitations to the study. There may also be recommendations for further research, or implications for practice in the relevant area.

Table 2.7: The article assessment scoring mark.

Answer	Score
Yes	1
No/ does not answer the question/ not applicable	0

Table 2.8: The rate quality of the articles.

Categories	Total score
Low quality	0-4
Moderate quality	5-7
High quality	8-10

Table 2.9: The articles included in the review

No	Title	Year
1	An Experimental Study on Fly ash as Self-Healing Material	2018
2	Effect of fly ash and superabsorbent polymer on concrete self-healing ability	2019
3	Investigating a new method to assess the self-healing performance of hardened cement pastes containing supplementary cementitious materials and crystalline admixtures	2019

4	The features of different mineral admixtures affecting the self-healing capacity of cementitious-based materials	2021
5	Enhanced autogenous self-healing of cement-based composites with mechanically activated fluidized-bed combustion fly ash	2021
6	Evaluation of enhanced autogenous self-healing ability of UHPC mixtures	2021
7	Environmental Life Cycle Assessment of Alkali-activated Material with Different Mix Designs and Self-healing Agents	2021
8	Evaluation of self-healing performance of concrete containing fly ash and fibres	2021
9	Effect of fly ash on the self-healing capability of cementitious materials with crystalline admixture under different conditions	2021
10	Self-Healing Products of Cement Pastes with Supplementary Cementitious Materials, Calcium Sulfoaluminate and Crystalline Admixtures	2021
11	Self-healing Behaviour of Expansive Mortars with Fly Ash and Bottom Ash	2021
12	Influence of ion chelator on pore structure, water transport and crack-healing properties of cement pastes incorporating high-volume fly ash and blast-furnace slag	2022

Table 2.10: The assessment score of the articles

No	Question	Article												Total
		1	2	3	4	5	6	7	8	9	10	11	12	
1	Does the title reflect the content?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	12
2	Are the authors credible?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	12
3	Does the abstract summarize the key components?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	11
4	Are the background and study design identified and the rationale for undertaking the research clearly outlined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	12
5	Is the literature review comprehensive and up to date?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	12
6	Is the aim of the research clearly stated?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	12
7	Is the methodology identified and justified?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	12
8	Are the results presented in a way that is appropriate and clear?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	12
9	Is the discussion comprehensive?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	12
10	Is the conclusion comprehensive?	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	9
	Total	10	10	9	10	9	10	10	10	9	10	9	10	

2.3.3 Data extraction and synthesis

Generally, data extraction occurs prior to doing a quality assessment of the studies or literature. Data extraction is the process of extracting data from an article that is relevant to the review objectives and review questions. Each article's relevant info will be collected in an extraction form or framework. Each author will have a preferred approach for emphasising crucial components of articles such as the objective, methodology, findings, and so forth. The most traditional way to begin the data extraction process is to highlight the article's essential section and then insert it into the data extraction form for each article. Additionally, revising the content further can help avoid overlooking critical material relevant to the topic.

Following data extraction, data synthesis is usually the most difficult element of the systematic literature review. The data synthesis process is a section in which the review question is answered. The data extracted from the data extraction form must be connected together to create a new order that will allow the review question to be answered. Synthesis of information in a new order might contribute to or fill a knowledge gap (Jesson et al., 2011). A suitable synthesis method adapted such as a chronological method or thematic analysis just can present a meaningful summarized output for the review

2.4 Reporting the SLR

Following data extraction and synthesis, a discussion of the articles' principal findings is required to address the review questions at the reporting stage. This section

of the review will explain the overall interpretation of the results for each review question, as well as the strengths and weaknesses of each article. Due to the fact that it is a thematic analysis, the information obtained from the article will be analysed under

the same theme or issue, allowing for the interpretation of the data to demonstrate the inconsistency of various articles. Additionally, it is beneficial for authors or readers to identify knowledge gaps and make recommendations for future research.

Finally, a conclusion is required after each review question has been discussed. This section will provide a summary of the major points and the entire review. Then, an integrated conclusion will explain the study's purpose and significance by connecting it to a bigger picture that will help clarify the paper's arguments (CENTER, 2020). As a result, the reader can skim the conclusion to be reminded of the review's central finding or argument in this section.

2.5 Summary of the chapter

This chapter discussed the planning, conducting, and reporting stages of a literature review. It described the review methodology and the design of review questions during the planning stage. The conducting stage describes the articles' systematic search tactics, quality assessment, data extraction, and synthesis. Finally, the reporting stage clarified the summary of the articles' findings in relation to the review questions. The reporting step also discusses the overall interpretation of the results for each review question.

CHAPTER 3
DATA EXTRACTION AND SYSNTHESIS

3.1 Introduction

Data extraction and synthesis are the crucial parts of the systematic review. The data extracted from the screened studies are synthesized, and the conclusions of the review are based on this synthesis. Normally, data extraction occurs before the synthesis part. It requires reading through the studies and summaries the relevant information into a table. Besides, synthesis of the data can be done by using a formal statistical technique to combine the results of two or more studies, then producing an overall summary or new knowledge of the conclusion.

3.2 Data extraction

Data extraction is the method of reading the full text of each selected article for inclusion in the analysis and extracting the relevant data. In this review, there are 12 articles required to extract the necessary information and compile them in table form.

Table 3.1: Data extraction form with different data field to be filled.

Data field	Explanation
Title	Title of the article
Author	Author of the article
Year	Published year of the article
Objective/ review question	Objective or review question that the article suit to answer in this review.
Concrete type	Type of concrete used in the article
Material used	Material used in the article other than fly ash, can be used or compared with fly ash
Experiment/ test	Experiment or test that use to determine the performance of fly ash. (Tensile

	splitting test, compressive strength test, etc)
Description	Possible information stated in the test may be useful in this review. (e.g., the result of the experiment or discussion made)
Note	The possible useful information obtained from the article except for the test/experiment section
Conclusion	The conclusion that was made by the author.
Recommendation	Future recommendation or limitation of the article stated by the author.

3.3 Data synthesis

Synthesis is the process of collection, combination and summary of the findings for individual studies in the systematic review. Planning comparisons, preparing for synthesis, doing the synthesis, and interpreting and reporting the results can all be guided by a broad framework for synthesis. There are two major analyses in the synthesis process which are quantitative and qualitative. Quantitative data are usually about quantities, which mean it can be measured, counted and expressed by using numbers. Meanwhile, qualitative data is descriptive in nature, expressed in terms of language rather than numerical values. This data is not measured using hard numbers used to create graphs and charts. Instead, it is classified according to its properties, attributes and other identifiers. This systematic literature review is conducted based on qualitative data. Therefore, the result and summary of the article will be based on the performance and effect of the fly ash in the concrete.

To conduct the qualitative systematic review, thematic analysis is adapted. It involves reading through a data set and identifying patterns in meaning across the data to derive themes. From the screening process of the articles, 12 are eligible. However, each article had gone through different tests and material when conducting the study, the