SOIL STABILIZATION METHOD BY USING NATURAL BAMBOO FIBRE

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SOIL STABILIZATION METHOD BY USING NATURAL BAMBOO FIBRE: A REVIEW

By

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ABSTRAK

Buluh adalah salah satu tumbuhan yang boleh cepat bercmbah di dunia, dengan spesiesnya yang julat dari sentimeter hingga beberapa inci dari ketinggiannya. Buluh adalah tumbuhan unik yang boleh mencapai ketinggian sehingga 30 meter dalam 2 hingga 4 bulan. Walaupun buluh telah digunakan sebagai bahan binaan sejak beribu-ribu tahun, namun terdapat sedikit kajian mengenai sifat mekanikal buluh itu sendiri di Malaysia. Buluh telah dikenal pasti sebagai bahan pengukuhan semula jadi yang berpotensi untuk pembaikan dan penstabilan tanah. Tingkah laku kekuatan ricih dan kekuatan mampatan tanah bertetulang gentian buluh dikaji dalam kajian ini . Kajian menunjukkan peningkatan peratusan gentian dalam tanah meningkatkan parameter kekuatan ricih ke tahap yang lebih baik untuk tujuan pembinaan. Apabila dua panjang gentian berbeza dipertimbangkan dalam kajian, kekuatan ricih dan parameter kekuatan mampatan meningkat apabila panjang gentian bertambah.

Telah didedahkan dan dilaporkan bahawa kesan kegagalan penindasan tanah adalah luar biasa dalam penambahan gentian buluh dengan panjang gentian panjang, yang mana penulis meneliti ketersediaan gentian buluh untuk meningkatkan penstabilan tanah dan sebagai hasilnya, ia telah didedahkan bahawa spesimen yang dicampur dengan gentian buluh mempunyai rintangan hakisan yang tinggi dan kekuatan ricih dan mampatan yang lebih baik berbanding kaedah konvensional yang lain. Dengan data yang tersedia ada mengenai sifat buluh, jurutera harus pertimbangkan pengunaan buluh sebagai bahan binaan dalam process pembinaan bangunan mahupun sebagai bahan untuk mentabilkan tanah bagi tujuan pembinaan.

ABSTRACT

Bamboo is one of the fastest growing plants in the world, with species ranging in size from a few centimeters to inches tall. Bamboo is a unique plant that can reach its full height of up to 30m in 2 to 4 months. Despite the fact that bamboo has been used as a construction material for thousands of years, there have been few studies on the mechanical properties of the bamboo itself in Malaysia. Bamboo has been identified as a potential natural reinforcing material for soil improvement and stabilization. The shear strength behaviour and compression strength of a bamboo fibre reinforced soil are investigated through the systematic literature review sysnthesis. The literature review shows that increasing the percentage of fibre in the soil increases the shear strength parameters to an optimum level for construction purposes. When two different lengths of fibre are considered in the study, shear strength and compression strength parameters increase as the length of the fibre increases.

It was revealed that the cracked area ratio decreased by increasing of the added amount of the fibre reinforcing material regardless of that type and species. In particular, it was reported that the effect of soil suppressing failure was remarkable in the additional of the bamboo fiber with long fiber length, which the author examined the availability of the bamboo fibre to improve the soil stabilization and as a result, it was revealed that the specimens mixed with the bamboo fibre had high erosion resistance and better shear and compressive strength compared to other conventional method. With the available data on bamboo properties, structural engineers should consider bamboo as a construction material in modern engineered buildings, in addition to a soil stabilizing method for construction.

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

Malaysia is known as tropical country which according to the World Bank, Malaysia is an upper-middle income country (Anon., 2021). The production and export of the primary industries such as crude oil, tin, palm oil, and rubber have contributed significantly on the socio economic development of the country in last many decades. Forest plantations have been established since the 1950's (Ratnasingam, et al., 2020), during recent years, the forest industries have been rapidly and actively promoted while some baby-steps that have been taken into consideration as to encourage the setting up of small scale and also rural based industries using forest produce such as rattan and bamboo as raw materials to produces commercial products besides also to be used as construction material such that for soil strengthening.

Recently, Malaysia is researching on the possible utilization of the bamboo fibre to be used for soil strengthening which is in the early phase of construction along with Lembaga Perindustrian Kayu Malaysia (MTIB), Bamboo Jungle Adventures Sdn. Bhd. (BJA), Forest Research Institute of Malaysia (FRIM) and other related parties (Zolkiply, 2020). There are many methods to improve soil stabilization such as electro osmosis, lime stabilization, stone columns, soil nailing, grouting and preloading with vertical drains and other. However, these methods is quite costly and require a lot of time to strengthen and stabalized the soft soil. To overcome these, soil reinforcement has been introduced as one alternative method which is a technique where soils are strengthened by tensile elements such as using non-biodegradable fabrics such as geotextile, granular materials and green natural materials like jute and bamboo.

Bamboo is commonly used as traditional sources for construction used for centuries due to its availability all over the globe. These natural material commonly grows in abundance in the tropical and sub-tropical regions. Major part of bamboo can also be used for soil alteration and stabilization after landslide occurs, controlling settlement and soil erosion, and is widely used in other neighbor Asian country like India and China (Khoiriya Latifah, 2021). It is a green natural element due to the biodegradable characters besides was seen as an efficient material to adopt in decreasing the global warming effects and to save the environment from chemical waste (Othman, 2011). This study is a review on the bamboo fiber characteristics and the ability to be used as soil strengthening which may significantly increase the soil strength and overall performance of the soil and reduce the settlement of the soil.

1.1.1 Bamboo Type

Malaysian bamboos grow copiously and generously in ex-logging areas throughout the country, on hilly area, slope, riverbanks and also flat land. The vegetation can be pure or mixed with other tree species in the forest due to it adaptability and flexibility for living (Ng and Shamsuddin, 1980). The total estimated area of bamboo by forest compartments is 421,722 ha accounting for 6.9 percent of the total forested land in Peninsular Malaysia (Mohamed, et al., 2007). The mechanical properties of bamboo depend on the species or types, age, moisture content, density and culms height. These situations had been confirmed by the research conducted to evaluate the mechanical properties on selected Malaysian bamboo in 1995 (Mohamed & Appanah, 2019). Some of the species which is commonly used in construction locally such as *Gigantochloa scortechinii*, *G. levis*, *G. ligulata*, *Dendrocalamus asper*, *Bambusa blumeana*, *Schizostachyum grande* and *S. zollingeri*. The characteristics of the species tabulated in table 1.1.

Table 1. 1: Characteristics some of the commonly used species of Bamboo in construction (Mohamed & Appanah, 2019)

SPECIES NAME	LOCAL NAME	Normally found in states of Malaysia	Height (m) /Internode Length (cm) /DBH (cm) /Wall thickness (mm) /No. of culm or clump	Branch cutting with percentage of sprouting (%)	Type of construction
Gigantochloa Scortechinii	Buluh Semantan	Terengganu, Kedah, Selangor, Kelantan, Perak	17-20 /42 /9-11 /7-12 /50-80	85	Heavy
G. Levis	Buluh Beting	Pahang	18-23 /35 /11-13 /11-15 /40-50	85	Heavy
G. Ligulata,	Buluh Tumpat	Perlis, Kedah, Kelantan	7-10 /35 /2.7-3.5 /9-11 /30-40	40	Light
Dendrocalamus Asper	Buluh Pering	Kedah, Melaka, Pahang, Selangor, Terengganu	18-23 /35 /9-13 /10-14 /33-35	65	Heavy
Bambusa Blumeana	Buluh Duri	-	16-18 /35 /7-9 /12-18/ 40-60	80	Heavy
Schizostachyum Grande	Buluh Semeliang	Kedah, Melaka, Pahang, Terengganu, Selangor	18-21 /85 /8-11 /6-10 /40-60	-	Light

1.1.2 Soil Stabilization

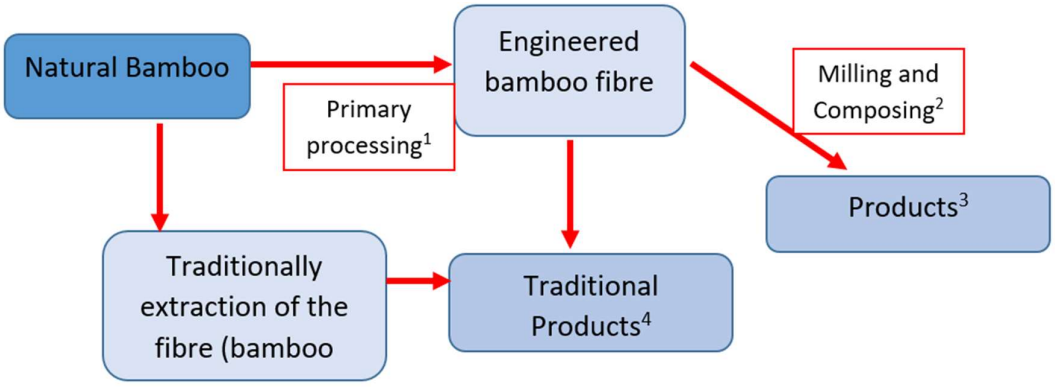
The soil or soil bed often is weak and has no enough stability for supporting the designated heavy loading such as the building or other man-made structure. Soil stabilization or strengthening is a process by which a soils physical property are transformed to provide long-term permanent strength gains. Stabilization is accomplished by increasing the shear strength and the overall bearing capacity of a soil. In this regard, it is mandatory to reinforce and stabilize the soil. To design the soil stabilization reinforcement, natural or synthesized additives are used to improve the properties of soils.

The decision of ground improvement or soil stabilization is taken for a site area when it needs in order to improve the overall soil performance such that the treatment methods will be designed based on the project design performance and survivability requirements that will dictate some of design parameters including the required stability and capacity, the allowable deformation and settlements of the specified related soil under different loading of static or dynamic. Different types of structures and man-made design structure tend to have different stabilization requirement. The well calculated and designed stabilization technique induce stress-strain states of the soil that are either in the linear elastic range or in the range that usually also associated with plasticity condition of the soil. Thus, in order to predict the soil stabilization accurately, an analysis that is realistic are required. Since in Geotechnical Engineering field, bearing capacity is the capacity of soil to support the loads applied to the ground. Thus, the bearing capacity of soil that being stabilized can be also said as the maximum average contact pressure between the structure and the soil which should not produce shear failure in the soil.

1.2 Scope of Systematic Review

As aforementioned, soil stabilization using Bamboo fibre is actually a wide range studies due to many factors such as the variability of the species used and the method of strengthening the soil using these natural fiber. Additionally, the usage of the Bamboo fibre for soil stabilization is more convincing to be discovered by researchers in engineering field studies due to its flexibility and adaptability in the variation of soil type, in addition to having high compressive strength and tensile strength as well as ease of obtaining in a lower cost (Latifah, et al., 2021). Development of bamboo fibre in construction approaches are summarized in Figure 1.2. Although, there are many method of soil stabilization, but bamboo fibre usage had been proposed in the recent few years back, thus many researchers had diverted the interest focusing on the usage of bamboo fibre as soil stabilization method as help gaining more information and proper engineered information on the ability of the bamboo fibre to help achieve better soil stabilization.

It is actually the Government's objective to make Malaysia a major producer of high value added wood and fiber based products in the world market. Whereby it can be seen stipulated clearly even under the Second Industrial Master Plan of 1996-2005 and also in the New Industrial Master Plan (NIMP), which will chart the future direction of industrial development in Malaysia, for the period 2021 to 2030 (Guie, 2021). Therefore, in this review, only soil stabilization using bamboo fibre will be emphasized regardless of other natural fibre and methods. As to narrow down the scope, the review will be also focusing on the ability of the bamboo fibre for soil stabilization which in other world the increasing of the soil bearing capacity or the ability for the fibre to decrease settlement occurs in the soil.



Remarks;
[1]: cutting ➡ splitting/ ripping ➡ knot removal ➡ crushing and silvering ➡ treatment or preservation ➡ weaving
[2]: drying ➡ rough milling ➡ composing ➡ finish milling
[3]: Examples: Hardware, Construction Products, Commercial Products, etc.
[4]: Examples: Floor mat, Jug, Roof, etc.

Figure 1. 1: The development flow of bamboo fibre in construction (Glenn, 2018)

1.3 Review Questions

The review question was initiated by the researcher as per described in the sub-chapter 2.2.2. Soil stabilization is an important factor to be considered in construction. This is because the serviceability of the man-made structure is directly proportional to the soil underneath the constructed structure. However, the bamboo fiber properties and character plays vital role on the suitability to be used as the soil stabilization techniques. Additionally, there are also external factors which could affect and interrupt the fibers flexibility and adaptability in executing and conquering the soil stabilization. Findings from several researchers, the Unconfined Comprehensive Strength (UCS) and modulus of rigidity were found to increase with the increase in number of bamboo specimen due to the friction between the soil sample and the rough surface of the bamboo fibre (Devi & Jempen, 2016) .

Otsubo et al. used the bamboo fiber as the base material for the sprayer in the greening plant of the slope, and investigated the erosion preventing the effect of the base material itself. The researchers showed that utilizing the bamboo fiber resulted in less erosion than the conventional methods. Sato et al. have extensively investigated the improvement of soft clay by incorporating bamboo chips and flakes that have high water absorption characteristic of bamboo material (Kanayama & Kawamura, 2019) and conducted test with the number of soaked and unsoaked CBR value tests for ordinary soil and soil mixed with different quantity of bamboo fiber, and concluded that both unsoaked and soaked California Bearing Ratio (CBR) value of soil increases due to the addition of bamboo fiber.

Although stabilization is important and using natural fibre might be in lower in cost, but the existence of the operational cost cannot be neglected besides the potential on increased of the cost for this application after being commercialized for future soil stabilization. It has also been reported that the current studies of soil stabilization using bamboo fibre are still unconvincing due to lack of past historical data from geotechnical engineering field. According to the analysis done, the method to evaluate the performance of the stabilized soil using bamboo is crucial as to identify the potential of the fibre for suitability and as to address the method accurately and consistently in terms of its usefulness. To tackle this, this review will systematically analyze all the possible studies for the soil stabilization using bamboo fibre only. The related issue mentioned above is converted into the review question as follows:

1) RQ 1: What are the factor that will influence the performance of the bamboo fibre to be used as soil stabilization?
2) RQ 2: How the reinforcement of the bamboo fibre as soil stabilizer effecting the shear strength of the soil?

3) RQ 3: How the reinforcement of the bamboo fibre as soil stabilizer effecting the compression strength of the soil?
4) RQ 4: What are the potential of the bamboo fibre to minimize the possibility of settlement as soil stabilizer?

1.4 Objectives of the Systematic Review

2.3.1a To identify on how the reinforcement of the bamboo fibre as soil stabilizer effecting the shear strength of the soil.

2.3.1b To determine on how the reinforcement of the bamboo fibre as soil stabilizer effecting the compression strength of the soil.

1.5 Significance of the Systematic Review

The method of the soil stabilization using bamboo fiber is suitable to be executed as bamboo availability of the resources and suitable environmental condition to grows in Asian country like Malaysia and the use of bamboo had also been experienced by (Loke, 2010) in which they claimed that it could give saving of up to 45%-65% compared with using high strength geotextile alone and conventional filling method. With the application of soil stabilization technique in construction process the overall cost may get reduced by using bamboo fibre when compared to the ordinary method of construction (Kakadiya, et al., 2019). This review will disclose and disseminate the mechanism of the soil stabilization besides also reveal the ability of the bamboo fiber as soil stabilization method and its recommendation and suggestion to provide better environmental condition to use the bamboo as soil stabilization. Moreover, this review will provides a guideline in establishing some intervention and experimental information

that had been carried out by other researchers over the past years regarding the usage of bamboo fiber. In addition, the reader can obtain information about the evaluation of the fiber used and its performance as to improve the soil stabilization and reducing the settlement in soil.

CHAPTER 2: SYSTEMATIC LITERATURE REVIEW (SLR): A METHODOLOGY

2.1 Introduction

In this chapter, the process of producing this paper will be discussed in detail from the planning, conducting, and reporting stages (***refer Figure 2.1***). The researcher will formulate the review question and develop a review protocol that fits the review question during the planning stage, as described in sub-chapter 1.3. After assessing and finalizing the planning stage, the researcher conducts the SLR by scheduling a search strategy, performing a quality assessment on each of the papers to be included, extracting the data needed based on the review question, and synthesizing the data carefully, methodically, and systematically. Finally, the researcher will report the findings from the literature review of the papers that will be included.

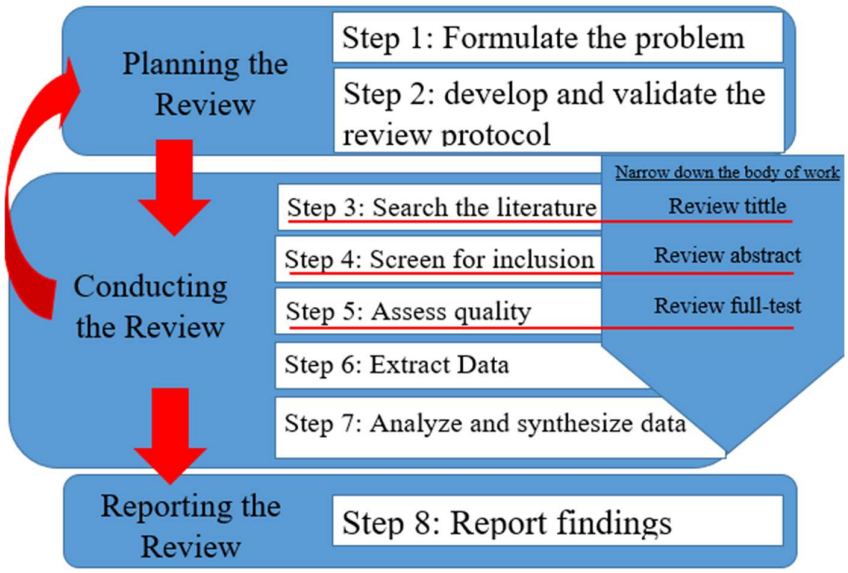


Figure 2. 1: Process of producing the Literature Review (Xiao & Watson, 2019)

2.2 Planning of SLR

The main component of structuring the SLR at the beginning stage is the formulation of review questions and the development of a review protocol. The researcher will discuss the method of formulating the review question from the review objectives in the following sub - section, as well as how it relates to the topic "Soil Stabilization Using Bamboo Fibre: A Systematic Literature Review." In a systematic review, making a plan of what to be include as writing items the researcher wants to include is critical and crucial. A plan is frequently used to refer to a review protocol in SLR, which describes the various types of studies that will be found to be evaluated, and synthesized.

The purpose of the planning is to reduce the possibility and percentage of bias by developing a standard procedure when encountering any conflict during the search, extraction, and analysis of the results. The protocol for this review is carried out in accordance with the widely accepted Preferred Reporting Items for Systematic Review and Meta-analysis statement (PRISMA checklist 2020) (Moher, et al., 2020). The PRISMA checklist referred has been modified to fit the purpose of this engineering systematic literature review.

2.2.1 Formulation of Review Question

The objective of the systematic literature review is to answer a clear and explicit research question by converting the gap of knowledge into an answerable and deeply constructed research question. The review question should be well-defined since during at the beginning your systematic review since a well formulated review question will help determine the SLR inclusion and exclusion criteria for the collection of data and the

presentation of review findings. A sound clinical question or research question help to ease the researcher for data extraction, data synthesis, and reporting during the inclusion and exclusion phase (Kitchenham, 2007).

As mentioned in Chapter 1, there are many types of soil stabilization but the only method for soil stabilization that will be discussed in the SLR is by using natural fibre known as bamboo specifically. According to the PRISMA checklist 2020 which relatable to the checklist 2009 item number 4, the explicit statement of the question is developed from the four major components which are participants, interventions, comparisons, outcomes, and study design (PICOS) (Moher, et al., 2020). However, the above mentioned element might not suitable for the engineering research systematic specifically in the geotechnical research study review as the initiative of the PRISMA was to assist the development of healthcare intervention (Liberati et al., 2009). Therefore, some alterations on the PRISMA checklist in developing the review question had done by researchers.

A broad research question may result in an unmanageable review, but this can be avoided by implement a more narrow review topic (Snyder, H. 2019). As mentioned earlier, research questions are developed from the gap of knowledge, in this paper timeline is narrowed to the latest 5 years (2018 to 2022) for studying the trend and insufficient research regarding the development of the bamboo fibre as soil stabilization. The researcher uses one database such as Scopus and Springer for searching the related paper to review the trend and the gap of knowledge other than websites. To identify the relevant publications, a string was developed (“bamboo fibre” AND “soil stabilization”) to search within article title, abstract and keyword in Scopus, and Springer additionally some inclusion criteria is imposed as follows:

I. Written in English

II. Published between 2018 and 2022

III. Document type: Article, Conference paper, and Review

IV. Source type: Journal

All the result in the data base is extracted in the form of references to Mandeley as to ease the referencing and topic summarization besides differentiating the data that might from same sources. There are about 250 publications throughout the five years with the abovementioned criteria however after re-assessing the paper in the piloted form there are only 45 data publications that is valid to be assessed for the SLR. From the illustration graph in Figure 2.2, even though there is a small fluctuation in the years 2020, it might due to the Covid-19 Pandemic that having Movement Control order (MCO) and resulted into minimization of publication of research and 2022, it is considered an increasing trend for the number of papers with a related topic whoever the trend is not increasing due to the early phase of the year. Thus an overall of increasing trend for the bamboo fibre related topic throughout these five years.

All the papers are arranging according to the year of publication so that the development of the bamboo fibre can be studies easily based on the traced data. The researcher had gone through the abstract, objectives and conclusion of each paper to have a summary of a problem statement, objective, discussion or findings and suggestion. After that, all this information in every paper is summarized according to years as shown in Table 2.1. The mentioned subtopic and description in each year are almost varied, only a few topics are in common such as encapsulation. From the compiled topic review (***refer Appendix 2***), most of the researchers are shifting their direction on the effectiveness of the bamboo fibre for construction material which can be alternately used for the soil stabilization.

There are some remarkable topics in the recent year 2022 that would be publish due to the encouragement of the bamboo fibre usage as an implementation for soil stabilization and construction material. However, the identification of the bamboo fibre is developing in Malaysia (Zolkiply, 2020). Thus, it is crucial to know more information about the bamboo fibre strength and adaptability so that the researcher can enhance the application of bamboo fibre usage in soil stabilization into more practical. This issue is also mentioned in the two most citation papers (Srinivasan, A., Tejaswini, V., Vinay, H., Vipin, S., & Hn, S. 2021). Hence, this review addresses the following primary research question:

1) What are the factor that will influence the performance of the bamboo fibre to be used as soil stabilization?
2) How the reinforcement of the bamboo fibre as soil stabilizer effecting the shear strength of the soil?
3) How the reinforcement of the bamboo fibre as soil stabilizer effecting the compression strength of the soil?
4) What are the potential of the bamboo fibre to minimize the possibility of settlement as soil stabilizer?

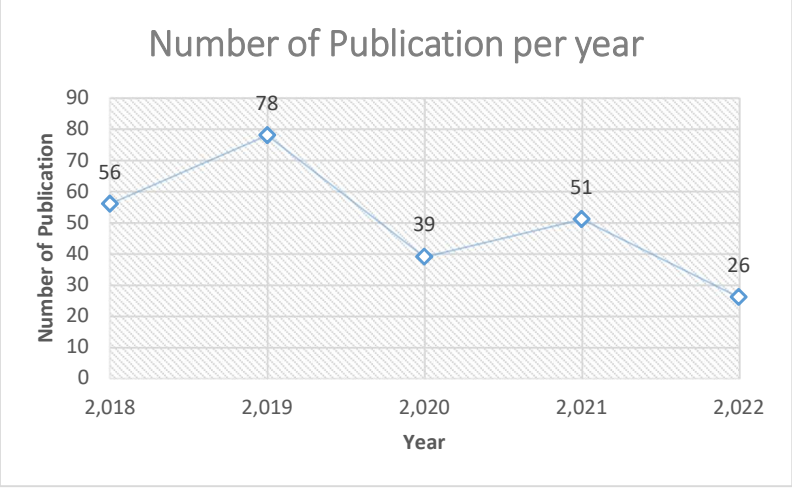


Figure 2. 2: Number of Papers over Five Year with Search String for Topic Review Purpose

Table 2. 1: Review topic summary related to bamboo fibre

Year	Publication
2018	1. Experimental evaluation of bamboo reinforced concrete slab panels
2019	1. Improvement of Clayey Soils by Combined Bamboo Strip and Flax Fiber Reinforcement 2. Influence of a Novel Mold Inhibitor on Mechanical Properties and Water Repellency of Bamboo Fiber-based Composites 3. Effect of bamboo fibres and lime on engineering properties of expansive soil 4. Seismic strengthening of masonry walls using bamboo components 5. Enhancing bamboo reinforcement using a hose-clamp to increase bond- stress and slip resistance 6. Effect of Waste Bamboo Fiber Addition on Mechanical Properties of Soil 7. Soil Stabilization Using Geosynthetic Material
2020	1. Flexural strength improvement in bamboo reinforced concrete beams subjected to pure bending 2. Experimental evaluation of bamboo reinforced concrete beams
2021	1. Influence of resin molecular weight on bonding interface, water resistance, and mechanical properties of bamboo scrimber composite
2022	-

2.2.2 Review Protocol

Review protocol is a preset plan that reduces the researcher bias in conducting the review, thereby improving the quality of the SLR. The review protocol is absolutely crucial for rigorous systematic reviews (Okoli and Schabram 2010; Breretona et al. 2007). The review protocol should describe all the elements of the review, including the purpose of the study, research questions, inclusion criteria, search strategies, quality assessment criteria and screening procedures, strategies for data extraction, synthesis, and reporting

(Gates 2002; Gomersall et al. 2015). Moreover, a review protocol raises the percentage of reliability of the review as other researcher or reader that interested in this paper can repeat the procedure to cross-check for validation (Xiao & Watson, 2019).

In this paper, the review protocol almost the same as the conventional SLR which describes all the aspects of the review including the objective of study, review question as per discussed in sub-section 2.2.1, searching strategy, quality assessment criteria, method of data extraction, and data synthesis (Gomersall et al., 2015;Gates, 2002; (Xiao & Watson, 2019)). The components of the protocol are in sequence and illustrated in Figure 2.3. Moreover, each of these components will be discussed in details in each of the subchapters as follows:

1. Identify review question (***Chapter 2, section 2.2.1***)
2. Define search strategy (***Chapter 2, section 2.3.1***)
3. Define quality criteria (***Chapter 2, section 2.3.2***)
4. Define data extraction (***Chapter 2, section 2.3.3***)
5. Define data synthesis (***Chapter 2, section 2.3.3***)

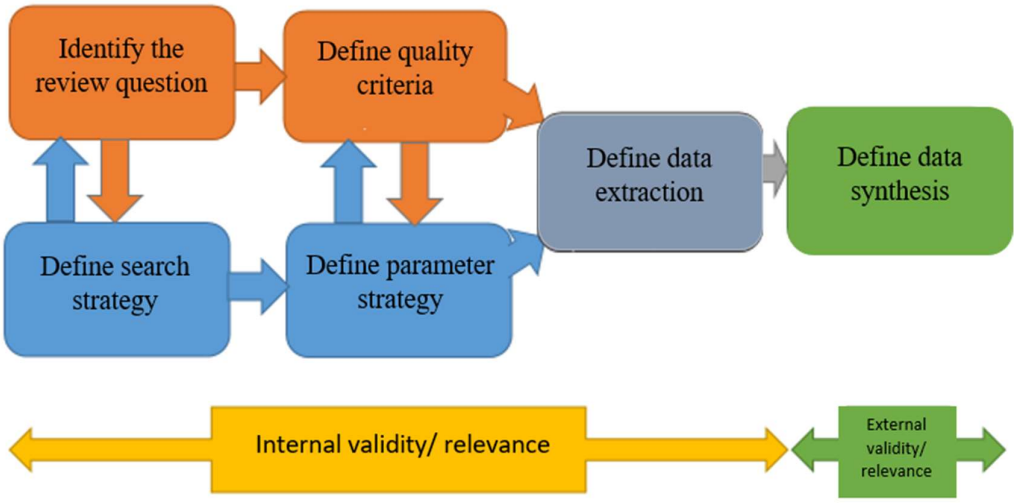


Figure 2. 3: Components of SLR Protocol (Xiao & Watson, 2019)

2.3 Conducting of SLR

During the conducting stage, the researcher will discuss the searching strategy based on the review paper's objective. The purpose of study of the review paper are derived from the review question mentioned in section 2.2.1. In addition to that, the quality criteria will be defined and establish to filter the inclusion paper in the search before data extraction and synthesis is carried out as per describe in sub-section 2.2.2.

2.3.1 Systematic Searching Strategies

The search framework is done according to the PRISMA flow diagram which is depicted in Figure 2.4 (Moher, et al., 2020). According to the PRISMA flow diagram, the initial search is made up of several databases, due to the access granted from the researcher's side. Although the final included article might source from one database, it does not influence the result of the search and this fulfills the criteria in PRISMA checklist 2020 (item no 7; 'Present the full search strategies for all databases, registers and websites, including any filters and limits used') (Moher, et al., 2020).

2.3.1a Identification

In order to develop and achieve a comprehensive search, the first phase of search strategy specific in identification aspect is sub-divided into several steps as follows;

1) Write out the objective based on the review question
2) Identify the keyword and terms
3) Develop search string based on review question

In this paper, there are two objectives related to the review questions and another additional statement that related to the research question is created to increase the range of all possibility of the search result. Subsequently, a keyword is identified based on the

concept domain and other important elements. Moreover, to make sure the keywords are working, Kitchenham and Charters (2007) suggested researchers check results from the trial search against lists of already known primary studies such as from the review question and define parameter criteria to know whether the keywords result can be used as data analysis during critical data anakysis (Xiao & Watson, 2019) . Researchers also suggested that it is very important to document the date of search, the search string, and the procedure. This allows researchers to backtrack the literature search and to periodically repeat the search on the same database and sources to identify new materials that might have shown up since the initial search (Okoli and Schabram 2010).. The identification of the main terms is listed as follows:

A) Objective:
    1) To identify on how the reinforcement of the bamboo fibre as soil stabilizer effecting the shear strength of the soil.
    2) To determine on how the reinforcement of the bamboo fibre as soil stabilizer effecting the compression strength of the soil.

B) Others
    1) The potential of the bamboo fibre to minimize the possibility of settlement as soil stabilizer.

Table 2. 2: Main terms derived from the two objectives and others

Derive the main terms (from Objective 1):	Derive the main terms (from Objective 2):	Others:
1. Soil stabilization 2. Bamboo fibre 3. Shear strength 4. Soil reinforcement	1. Soil stabilization 2. Bamboo fibre 3. Compressive strength 4. Soil reinforcement	1. Soil characteristics 2. Soil settlement 3. Minimize 4. Bamboo fibre

According to an article Rowley and Slack, 2004, the search statement listed can be spread by synonyms, abbreviations, alternative spellings, and other related terms. Basic searchers focus on the term in the search statement and priorities document in which the search statement appears are in close meaning and such searching allows researchers to obtain additional related information other than available 'basic search' (Rowley & Slack, 2004). Moreover, there are also other guidelines for enriching the keyword by free-text searching (also known as "natural language" or language use daily) (Lahlafi, 2007). The researcher uses both of these methods to generate comprehensive keywords to generate a search string using 'Boolean operators'. The Boolean operators use as a link to combine the main terms and their respective synonym to further narrow down the scope to the topic (Grewal, et al., 2016). The search string and its respective main terms are presented in the Table 2.3, Table 2.4 and Table 2.5.

Table 2. 3: Enrich the term and search string from Objective 1

Main term	Stabilization	Bamboo fibre	Reinforced	Shear strength
Enrich term	1. structure 2. Equalizer 3. Adjust	1. Natural fibre 2. Green plant 3. Green material 4. Bamboo reinforced concrete		1. Shear force 2. Stress 3. Ability to resist
Search string: ("stabilization" OR "structure" OR "equalizer" OR "adjust") AND ("bamboo fibre" OR "natural fibre" OR "green plant" OR "green material" OR "bamboo reinforced concrete") OR ("reinforcement") AND ("shear strength" OR "shear force" OR "stress" OR "ability to resist")				

Table 2. 4: Enrich the term and search string from Objective 2

Main term	Stabilization	Bamboo fibre	Reinforced	Compressive strength
Enrich term	1. Structure 2. Equalizer 3. Adjust	1. Natural fibre 2. Green plant 3. Green material 4. Bamboo reinforced concrete		1. Compressive force 2. Toughness 3. Ability to resist
Search string: ("stabilization" OR "structure" OR "equalizer" OR "adjust") AND ("bamboo fibre" OR "natural fibre" OR "green plant" OR "green material" OR "bamboo reinforced concrete") OR ("reinforcement") AND ("compressive strength" OR "compressive force" OR "toughness" OR "ability to resist")				

Table 2. 5: Enrich the term and search string from others

Main term	Bamboo fibre	Minimize the possibility	Settlement	Soil characteristics
Enrich term	1.Natural fibre 2.Green plant 3.Green material 4.Bamboo reinforced concrete	1. Reducing 2. Prevent 3. Intercept 4. Suppress	1.Erosion 2.Downward movement 3.Movement sinking of	1.soil texture 2.soil properties
Search string: ("bamboo fibre" OR "natural fibre" OR "green plant" OR "green material" OR "bamboo reinforced concrete") AND ("minimize the possibility" OR "reducing" OR "prevent" OR "intercept" OR "suppress") OR ("settlement" OR "erosion" OR "downward movement" OR "movement" OR "sinking of") AND ("soil characteristics" OR "soil texture" OR "soil properties")				

The string above mentioned will be applied in the database like 'Scopus' and 'Springer' and search within article abstract and keyword only. Results are illustrated in Figure 2.4 where the first search string based on objective 1 are 27 articles whereas the second search string has 18 articles and the "Others 1" search string obtains 49 articles. All the information of these searches is recorded and compute in a table as shown in Table 2.6. This enables the researcher to retrace the literature search and to repeat the search on the database and source regularly to discover a new material that has surfaced since the initial search (Okoli and Schabram, 2010).

Table 2. 6: Search string information

Related statement	Search string applied	Date of search
Objective 1	TITLE-ABS-KEY (("stabilization" OR "structure" OR "equalizer" OR "adjust") AND ("bamboo fibre" OR "natural fibre" OR "green plant" OR "green material" OR "bamboo reinforced concrete") OR ("reinforcement") AND ("shear strength" OR "shear force" OR "stress" OR "ability to resist"))	18th March 2022
Objective 2	TITLE-ABS-KEY (("stabilization" OR "structure" OR "equalizer" OR "adjust") AND ("bamboo fibre" OR "natural fibre" OR "green plant" OR "green material" OR "bamboo reinforced concrete") OR ("reinforcement") AND ("compressive strength" OR "compressive force" OR "toughness" OR "ability to resist"))	18th March 2022
Others	TITLE-ABS-KEY (("bamboo fibre" OR "natural fibre" OR "green plant" OR "green material" OR "bamboo reinforced concrete") AND ("minimize the possibility" OR "reducing" OR "prevent" OR "intercept" OR "suppress") OR ("settlement" OR "erosion" OR "downward movement" OR "movement" OR "sinking of") AND ("soil characteristics" OR "soil texture" OR "soil properties"))	18th March 2022

2.3.1b Screening

The date range in the strings is not restricted to the latest years (5years) due to the research on the bamboo fibre as soil stabilization had just currently being introduced to be studied and formation of engineered bamboo in Malaysia have the least research data information (Zolkiply, 2020). However, to observe the current trend and to avoid the scope of review from going too wide the document type is restricted to the article, conference paper, review, and all papers limited from the journal and English version only. After filter from the criteria above mentioned, only 27, 18, and 12 papers are left in the string related to Objective 1, Objective 2, and Others 1 respectively.

2.3.1c Eligibility and Inclusion

The result from each search string after a filter is extracted out in the form of reference format, then transfer to EndNote to identify the duplicates. With the aid of the function applicable in EndNote, 8 duplicates paper was detected and the left will undergo last screening to obtain the inclusion paper to be reviewed in this study. Inclusion and exclusion criteria of the review often establish based on neither the review question nor objectives and any irrelevant studies will be excluded (Xiao & Watson, 2019). The inclusion and exclusion criteria need to be much focused and applied stringently (Grewal, et al., 2016). There are two key steps recommended by the researchers which can resulted in achieve the describe criteria as mentioned. To begin with, a researcher will read the title, abstract, introduction and conclusion from the article to eliminate some misleading paper that obtains from the search engine. Successively, a researcher will identify whether there is key information required for the data extraction and all the irrelevant paper (***Table 2.7***) will be precluded including papers that cannot be accessed in full.

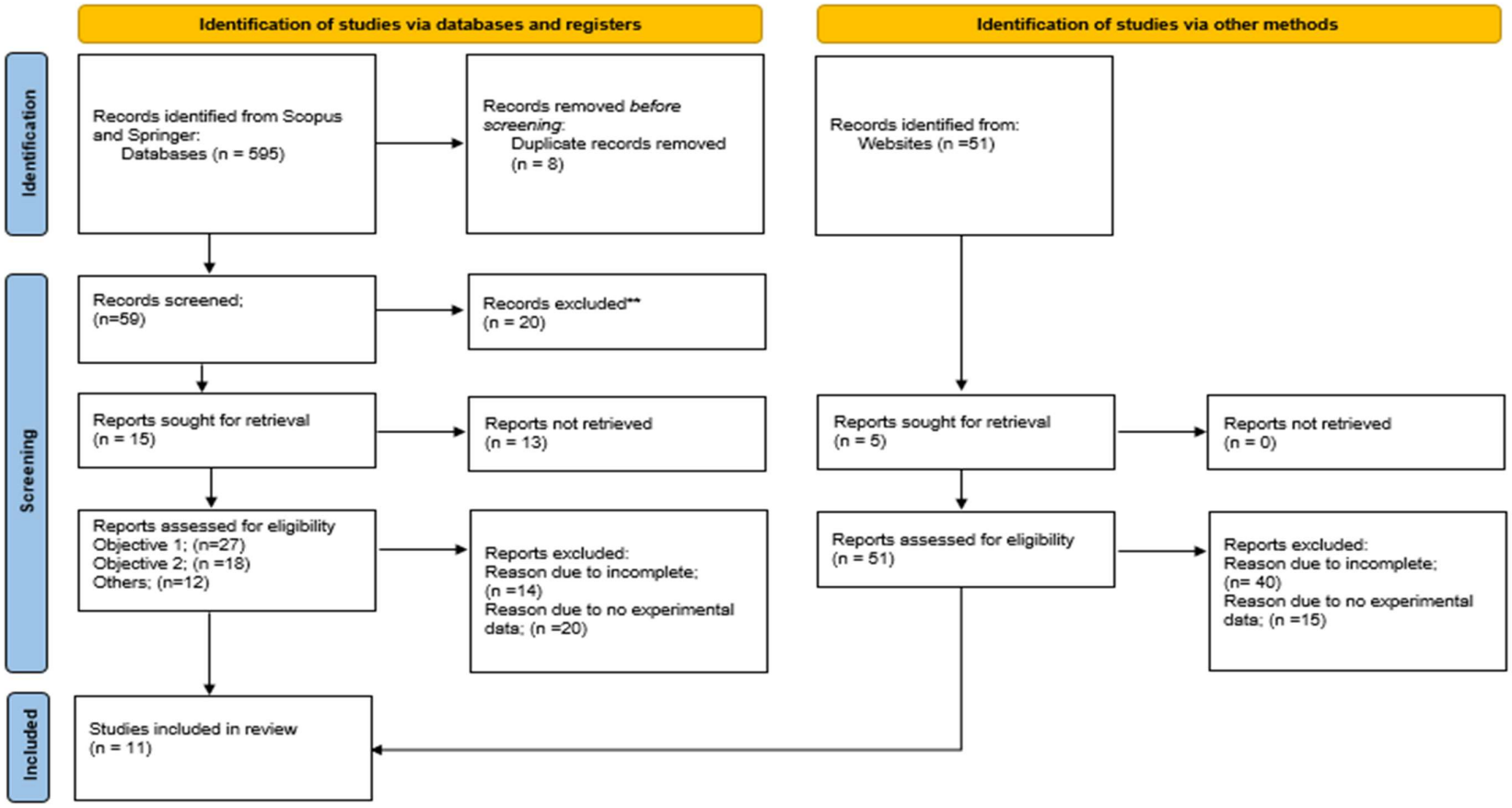


Figure 2. 4: PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources (Moher, et al., 2020)

Table 2. 7: List of inclusion and exclusion paper with criteria

NO	YEAR	COUNTRY	TITTLE	STATUS	PROBLEM STATEMENT/ OBJECTIVES /SOLUTIONS / SUDJESTION
1	2016	Japan	Invasion Of Moso Bamboo Into A Japanese Cedar Plantation Affects The Chemical Composition And Humification Of Soil Organic Matter	Excluded	Its unique root rhizome system, from which shoots and culms emerge, bamboo is one of the fastest-growing plant species in the world; It is extensive rhizome system also makes bamboo spread laterally, enabling it to invade into surrounding forests or agricultural systems
2		India	Shear Strength Behaviour Of Bamboo Fiber Reinforced Soil	Excluded	Inclusion of reinforcement substantial reduced the footing settlement and the surface deformation. The tensile strength and surface roughness of bamboo were found to be nine times and three times higher than geocell materials respectively
3		Prade	Shear Strength Behaviour Of Bamboo Fiber Reinforced Soil	Excluded	Bamboo is recognized as a potential natural reinforcing material for improvement and stabilization of soil; The increase in the length of the fiber also causes an increase in the shear strength of the soil
4	2017	Malaysi	Lightweight Bouyant Foundation On Peat Soil Using Bamboo Culms And Plastic Bags	Excluded	The effect of moisture content of peat on the capacity of the foundation model using physical modelling approach; lightweight waste material as foundation materials in order to further harness the potential of buoyancy effect on peat
5		Rajashta	Effect Of Bamboo Grid Reinforcement Using Soil Bagasse Ash Mixure	Excluded	Bamboo has excellent engineering properties and can be utilized for low cost housing project where it can mainly be used as reinforcement to the structure; Drawback of bamboo as construction material is its water absorption and moisture content properties