STUDY ON THE MECHANICAL PROPERTIES OF TWO SPECIES OF BAMBOO (Gigantochloa Ligulata and Gigantochloa Scortechinii): A SYSTEMATIC LITERATURE REVIEW

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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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ABSTRACT

This research reviews on the studies that have been done by previous researchers on the anatomical and mechanical properties of bamboo. Bamboo is the best choice for replacing timber because of its high strength and rapid growth. Bamboo grows in a wide range of climates, from the coldest mountains to the hottest tropical regions. Bamboo covers approximately forty million ha of land, mostly in Asia. Nowadays, with the current emphasis on environmental friendliness and sustainability, natural fibre composites are more preferred over conventional fibre which is normally non-biodegradable. Bamboo is a type of natural fibre composites that are widely used in many industries such as in construction. Hence, it is crucial to study the mechanical properties of bamboo to make sure it is safe for certain applications. However, there are many factors that determine the anatomical and mechanical properties of bamboo such as species, age and density, moisture content, etc. This research reviews on some of the research on the mechanical properties of pure bamboo and bamboo composites such as their tensile properties, compressive properties, impact strength and fracture toughness. The research includes how the researchers set up their experiments, the bamboo species used, and the results obtained. Bamboo has no standard building codes in most countries, making it nearly impossible for those who choose to use it in construction. There is some legal ambiguity concerning the determination of certain bamboo properties including fire resistance, strength properties, and longevity implying that regulations and standards are urgently needed. Bamboo's strength properties have already been checked, and the findings are excellent, in many cases of traditional building materials. However, building code regulations need more than a material's strength properties; other properties to consider include durability, fire safety, environmental impact, usability, and energy efficiency.

ABSTRAK

Penyelidikan ini mengkaji mengenai kajian yang telah dilakukan oleh penyelidik terdahulu mengenai sifat anatomi dan mekanikal buluh. Buluh adalah pilihan terbaik untuk menggantikan kayu kerana kekuatannya yang tinggi dan pertumbuhannya yang cepat. Buluh tumbuh di berbagai iklim, dari pergunungan paling sejuk hingga ke daerah tropis terpanas. Buluh merangkumi kira-kira empat puluh juta hektar tanah, kebanyakannya di Asia. Pada masa kini, dengan penekanan pada kebolehkerjaan dan kelestarian alam sekitar, komposit gentian semula jadi lebih baik daripada serat konvensional yang biasanya tidak terbiodegradasi. Buluh adalah sejenis komposit gentian semula jadi yang banyak digunakan dalam banyak industri seperti dalam pembinaan. Oleh itu, sangat penting untuk mengkaji sifat mekanik buluh untuk memastikannya selamat untuk aplikasi tertentu. Walau bagaimanapun, terdapat banyak faktor yang menentukan sifat anatomi dan mekanikal buluh seperti spesies, umur dan ketumpatan, kandungan kelembapan, dan lain-lain. Penyelidikan ini mengkaji beberapa penyelidikan mengenai sifat mekanik buluh dan komposit buluh seperti daya tegangan, daya mampatan, kekuatan impak, dan ketahanan fraktur. Penyelidikan ini merangkumi bagaimana para penyelidik membuat eksperimen mereka, spesies buluh yang digunakan, dan hasil yang sukar. Buluh tidak mempunyai kod bangunan standard di kebanyakan negara, sehingga sukar bagi mereka yang memilih untuk menggunakannya dalam pembinaan. Terdapat ketaksaan mengenai penentuan beberapa sifat buluh iaitu ketahanan api, kekuatan buluh, dan umurnya yang memerlukan peraturan dan piawaian. Dalam beberapa kes bahan bangunan tradisional, kekuatan sifat buluh yang diperiksa menunjukkan ianya sangat baik. Walau bagaimanapun, peraturan kod bangunan memerlukan lebih daripada sifat kekuatan bahan; sifat lain yang perlu dipertimbangkan termasuk ketahanan, keselamatan kebakaran, kesan persekitaran, kegunaan, dan kecekapan tenaga.

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CHAPTER 1

INTRODUCTION

1.1 Background

Bamboo is one of the world's oldest construction materials (Sharma, 2019). Bamboo is widely used for bridges, scaffolding, and housing in Asia, but it is typically used as a temporary exterior structural material. Certain bamboos provide the only suitable material that is sufficiently cheap and plentiful to satisfy the extensive need for affordable housing in many overpopulated tropical regions (Xuesong, 2015). Therefore, bamboo's use has progressed from conventional to more products. According to (Xing, 2015), bamboo is the best choice for replacing timber because of its high strength and rapid growth. Bamboo grows in a wide range, from the coldest mountains to the hottest tropical regions. Bamboo covers approximately forty million hectares of land, mostly in Asia. Bamboo is a high-growth rate plant that can grow in a wide range of climates, making it a sustainable and versatile resource. Bamboo is a form of agricultural crop that is grown on many continents around the world. Bamboo is divided into seven to ten genres, with 1575 different species. Malaysia has about eighty bamboo species, with fifty percent in peninsular Malaysia, thirty percent in Sabah, and twenty percent in Sarawak according to (Wong, 2017). The 10 available genera of bamboo are Bambusa, Dinochloa, Yushania, Chusquea, Gigantochloa, Phyllostachys, Dendrocalamus, Racemobambos, Thysostachys and Schizostachyu, (Wong et al., 2017). Bamboo is easily accessible globally, 64% of bamboo plantation originated from southeast Asia, 33% grown in South America and the rest comes from Africa and Oceania (Bonilla, 2012). Figure 1 shows the provided data of bamboo mainly dominated in six Asian countries as India, China, Indonesia, Philippines, Myanmar, Vietnam (Lobovikovet, 2014).

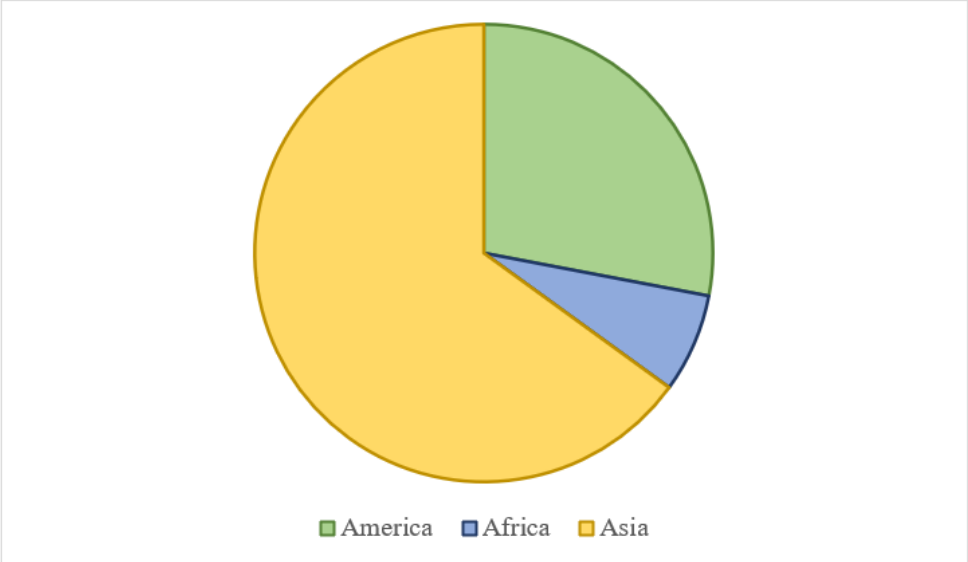

Figure 1.1 World percentage of bamboo from different continent (Bonilla,2012).

Bamboo is a grass that belongs to a taller grass family and can exist in tropical and high temperature locations. Bamboo has a natural shape that consists of a culm, which is a hollow pole with a large, jointed stem (Chapman, 2015). Bamboo reaches maximum heights of 15-30 metres in two to four months. Each species can be distinguished by its root system, which can be classified into three types: sympodial, monopodial, and amphidal (Gutierrez, 2018). The thickness of a bamboo culm decreases as it grows taller, while the density value of the fibres raises from the inner walls to outer walls. In contrast to spruce forest, bamboo has a faster reaping period and 4 times the carbon density per hectares (Sharma, 2016).

Bamboo uses in building has always been neglected due to a lack of knowledge of its properties. There are two species available in Malaysia, Gigantochloa Ligulata (buluh tumpat) and Gigantochloa Scortechinii, (buluh semantan) are being investigated and their mechanical properties will be defined (Trujillo, 2016). The compressive strength, tensile strength, shear strength, and bending strength of these bamboo species were tested mechanically in different sections along the culm to show if they distinguished (Sharma, 2012). In second aspect, the growth and moisture content use to investigate mechanical properties of two bamboo species.

The research will reviews that Gigantochloa Scortechinii and Gigantochloa Ligulata that have great mechanical properties in compression, tensile, bending, and shear strength and which represent that they are suitable for use as building materials (Xiao,Ma, 2012). Bamboo is ideal to be used as a replacement for structural timber in construction because it provides promising benefits, which indirectly aims to protect the global environment (Mena, 2012). In comparison, even though there is a large supply of bamboo, bamboo is rarely used as a building material in other developing countries (Chapman, 2015).

One of the reasons related to minor use of bamboo as structural material is a lack of research into its mechanical properties (Roberts, 2016). The ability of bamboo to maintain the force that is applied to it is critical. The bamboo's strength and moisture content are two of the most important factors that decide the full bamboo culm's ability and capacity (Kaminski, 2016). Bamboo with a moisture content of fifteen percent or less has better mechanical properties and is less susceptible to environmental attack. A minimum of 12% moisture content in air-dry condition has been used to determine bamboo strength. In terms of durability, it changes according to species type and age period. It is noticeable that an untreated bamboo has a long and durable life of approximately ten to fifteen years if it is stored accordingly, while a treated bamboo will have longer life (Shah, 2016). When bamboos reach green age of about three to four years, their strength is determined by age of growing and species type, which determines their suitability for use as timber material for construction.

Bamboo’s extent their maximum strength at maturity and are suitable for dense applications. It has also been noticed that the compressive strength of bamboos raises along their height, as well as from the inside to the outside parts of their culm. The aim of this research is to explore into the mechanical properties of two bamboo species found in Malaysia.

The research is part of a many literatures review that examines at the feasibility of using bamboo as a building material in a variety of lab tests. In addition, it aims to define which species from 2 species that chosen is excellent and suitable to use as construction materials under different lab tests (Solarte, 2018). Bamboo and wood have a variety of distinctions. In bamboo, there are no rays or knots giving it uniformly distributed tension distribution over the length of bamboo. Since bamboo is a hollow with often thin and soft walls, joining bamboo is harder than joining wood (Bartlet, 2016). Since bamboo avoids the same mechanical performance as wood, it can be glued and connected very well. Bamboo has a macroscopically graded structure with diameter, thickness, and internodal volume, when the fibre distribution has a microscopically graded architecture, culminating in bamboo's favourable properties (Usmani, 2001).

Bamboo has excellent mechanical properties in its round shape, making it useable in building and potentially reducing the requirements of steel. Bamboo is a cylinder-shaped, lightweight, and practically graded material with ideal properties for building elements, which are commonly used in construction. In term of importance, bamboo consider as one of essential material for housing and bridge construction, according to (Xing, 2015). Scaffolding, fibre-reinforced composites, and bridges are only a few of the engineering and civil building applications for bamboo (Tan, 2011).

In addition, it is essential to know the bamboo's anatomical and mechanical properties to determine its suitability for the intended purposes. The anatomical properties of bamboo must determine to know how much mechanical properties will be affected. Also, properties of the end products, particularly in timber material, according to (Abd. Latif et al, 2017), (Razak, 2010), and (Wang, 2016). The durability, resilience, workability, and strength of bamboo can all be influenced by anatomical properties (Liese, 2010).

These results were promoted by a study by (Xin et al, 2015), which ended by that understanding the anatomical structure of bamboo is important for knowing its mechanical properties and applications. Bamboo's density and shrinkage are essential factors in deciding its suitability for different uses in constructing, with density that related to mechanical properties (Abdullah, 2017). The mechanical properties of bamboo must be determined to know how bamboo perform in structural design and industrial applications (Gutu, 2013).

In Malaysia, sixty-three species of bamboo existed. Twenty-five domestics, while the others are only grown in cultivation (Abd. Razak and Abd. Latif, 1995). Only 13 species are known to be commercially utilized, including Gigantochloa scortechinii (buluh semantan), G. ligulata (buluh tumpat) that selected by (Abd. Razak, 1995).

This research use bamboo properties to review for only two species to determine each species appropriateness for using construction material and different products. These properties were also studied as a function of bamboo culm height. It will be used to evaluate the bamboo species for suitability based on the derived properties.

1.1.1 Bamboo importance

Bamboo's importance has been defined and classified into three categories: environmental, economic, and social benefits. Bamboo is an excellent material for rehabilitating degraded lands because it provides forest cover, reduces soil erosion, and accumulates carbon dioxide in the environment (Purkiss, 2014). The benefits of bamboo as a sustainable raw material and stated that if a cluster of matured culms are cut, most younger culms are left each year. Therefore, that this is better than that of wood (plantation trees) where sometimes a whole area is cut once in 20 or 40 years (Barber, 2017). The use of bamboo in disaster avoidance is always recommended. (Solarte, 2017).

According to Arghya Das and Saikat Sarkar they describe the importance of bamboo as it is rapid growing sustainable natural building material, the material is easily available & Eco friendly, as a stand-alone building material, bamboo is a viable (if not preferable) alternative to steel, concrete, and masonry. It is adequate cost and simple to construct with it can be freely bent, shaped, and provided with joints to fit the construction. Its extreme elasticity makes it an excellent building material where earthquakes are a significant risk, as well as a locally accessible material in some areas, which tries to carry the local tradition & vernacular Architecture of that place. In addition, they mentioned various advantages of bamboo as following: It is Light, strong, and versatile, it is Environment friendly, easily accessible to the poor, self-renewing resource of nature, speedily growing, highly productive and it is low-Cost Material.

1.1.2 Various use of bamboo

Table 1.1.2 Examples of Bamboo importance and different uses of bamboo as a material.

Use of bamboo as plant	Use of bamboo as material
Ornamental horticulture	
Ecology Stabilize of the soil. Uses on marginal land. Hedges and screens Minimal land use	Local industries Artisanal Furniture A variety of utensils Houses

As shown from (Table 1) bamboo importance as plant and its uses. Bamboo has a lot of potential as a wood substitute because it is a cheap and quick-growing resource with better mechanical properties than most wood types. (Reszka, 2016).

Several bamboo species have had their mechanical properties thoroughly tested. Dynamic contact angle calculation was used to determine the angle of many layers of the bottom portion of 3 years old bamboo (Gong, 2016). Bamboo's specific gravity and bending properties were also determined at various ages, horizontal layers, and height areas. Compressive strength was also measured at various ages and heights (Bakar, 2014).

Bamboo is formed up of several different species, each with its own structural and mechanical properties, when wood from trees do not have the same properties. Furthermore, there are many factors that include age and moisture content, soil, altitude, climate condition and the part of the stem that is investigated, and that can produce very different test results in (bottom, middle or top part) (Chakraborty, 2012).

Another major source of knowledge deficiency is the fact that bamboo poles as a building material are still largely unknown (partly because construction grade timer bamboos primary grow in tropical countries) (Nurdiah, 2016). The mechanical properties of bamboo have only been scientifically checked in the last 30-35 years.

Bamboo has no standard building codes in most countries, making it nearly impossible for those who choose to use it in construction (Xuhe, 2016). There is some legal ambiguity concerning the determination of certain bamboo properties including fire resistance,

strength properties, and longevity implying that regulations and standards are urgently needed.

Bamboo's strength properties have already been checked, and the findings are excellent, in many cases of traditional building materials (Pawar, 2014). However, building code regulations need more than a material's strength properties; other properties to consider include durability, fire safety, environmental impact, usability, and energy efficiency.

1.2 Scope of the systematic review

The bamboo production is reducing and there is a sustainability interest to promote their agriculture for economic benefits. The restraint is several including the basic information on plant growth, its structure and function and much knowledge on bamboo anatomy as shoot apex, axillary buds, stems, culm and regular leaves and root. The various alternatives in the use of bamboo depend on the different properties of its culm. In this research two species of bamboo are studied anatomically and correlated to their mechanical properties as environment friendly timber. In addition, to review the bamboo anatomy and how anatomy of bamboo affecting the mechanical properties. In term of availability, Gigantochloa Ligulata (buluh tumpat) and Gigantochloa Scortechinii, (buluh semantan) considered as the famous and available species in Malaysia. Also, in term of suitability, these two species considered as most durable and suitable timber material in constructing and building.

In 2004, the International Organization for Standardization (ISO) established its own standard for determining bamboo's mechanical properties. This is the first and most critical step in getting bamboo approved as a building material around the world. The ISO 22157 standard describes how bending strength, compression, tension, shear, and durability must be determined by using two different species bamboos that available at Malaysia, Gigantochloa Ligulata (buluh tumpat) and Gigantochloa Scortechinii, (buluh semantan) to determine the excellent bamboo type referring to ISO to use in construction work in timber materials. It is essential to mention that not all the tests implemented the ISO 22157 standard, but they do provide an overview of bamboo's mechanical properties. Before a standard building code can be assigned to bamboo, further research is required in the areas of fire resistance and durability. Nonetheless, the implementation of an international ISO 22157 standard for the mechanical properties of bamboo has made significant progress. This research discusses the difference

between two types of anatomy according to its anatomical structure when that reflect on mechanical properties performance referring to previous researchers and experimenter mechanical properties tests that conducted in laboratories.

1.3 Review question

High mechanical performance coupled with sustainability gives to bamboo a high potential to substitute con venational construction materials in various applications. There are countries in which this material has been used in construction and represents an asset, on the contrary, there are countries where there is still not enough knowledge of the structural properties of locally grown bamboo. In these cases, it is important to extend the knowledge of the mechanical properties of local bamboo species supported by the development of suitable standardised testing procedures. In addition, there are many anatomical properties that may affect the mechanical properties of bamboo, so much know how mechanical properties affected by anatomy of bamboo. This SLR also represent the difference between two bamboo species and study the mechanical properties of each to know which one of these species most strength, durable and suitable for construction materials. In this view, the paper presents the results of an experimental study for the mechanical characterization of two bamboo species cultivated in some countries (Gigantochloa Scortechinii and Gigantochloa Ligulata) using ISO 22157 Standards. Question of this research shed light on current challenges and on the possible future steps for a wider uptake of natural materials in constructions. To solve this, offset effectively, this review will systematically analyze all the possible studies for anatomical and mechanical properties only. The related issue mentioned above is converted into the review question as follows:

Table 1.3 Questions of systematic literature review

NO.	Review Questions
RQ1	What are the differences between two bamboo species Gigantochloa Ligulata (buluh tumpat) and Gigantochloa Scortechinii, (buluh semantan) in anatomical and mechanical properties aspects?
RQ2	Which one among two species shows the excellent performance to use as sustainable material in civil engineering?
RQ3	What are the experimental tests that should use to review the mechanical properties of bamboo?

1.4 Objectives of the systematic review

1) To review the anatomy of two species of bamboo and the factors that affect mechanical properties of bamboo in systematic literature reviews.
2) To review mechanical properties of two species of bamboo according to ISO 22157.

1.5 Significance of the systematic review

The proposed research project will help us to better understand the anatomy, mechanical properties, and characteristic of bamboo. It will also help in the effort of developing the usage of bamboo as one of important material in construction timber materials. The proposed project will also help in maintaining the environment when using bamboo due to suitability of bamboo as the sustainable timber. Finally, the research helps to compared between two different spices

of bamboo that are available at Malaysia and determine which one of them is excellent to use in construction work under different laboratory tests.

CHAPTER 2

SYSTEMATIC LITERATURE REVIEW (SLR): A METHODOLOGY

2.1 Introduction

(Figure 2.1) represents the process the review and processes of research production in three stages such as planning the review, conducting the review, and reporting the review. In the first stage which is the planning review stage, the researcher prepares the review question and conduct a review protocol that reflect the review question. In second stage which represented in conducting the review, the researcher develops the SLR by schedule a search strategy, by classify a quality assessment based on each of the papers to be included. In addition, extraction of the data must apply based on the review question and synthesis the data in term of systematic literature review. At the third stage which is reporting the review the researcher will evaluate and investigate the findings from the literature review of selected and included papers (Emilio, 2020).

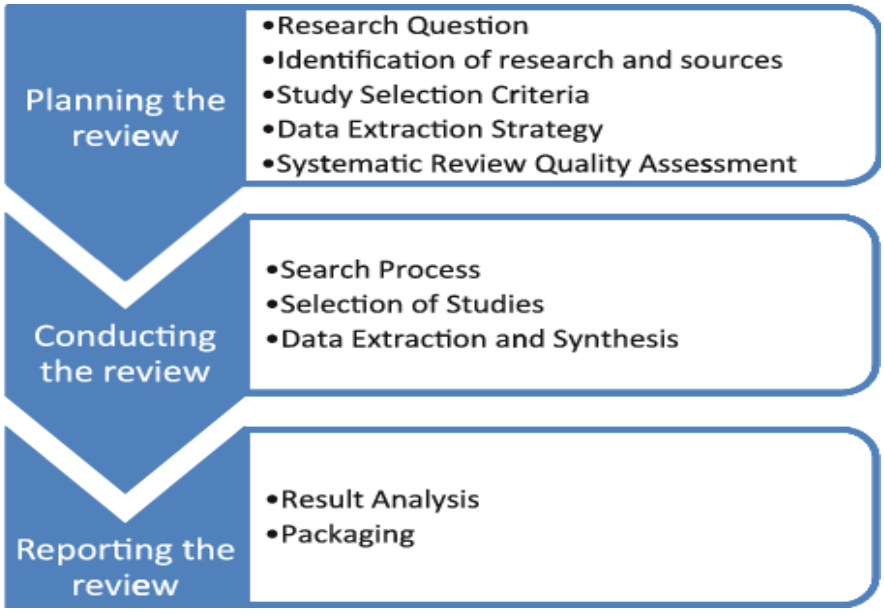

Figure 2.1 Process of Literature Review (Emilio, 2020).

2.2 Planning of SLR

The objective of this systematic review is to obtain and analyse the quality attributes and measures proposed for assessing the quality. The study will identify gaps and new areas of research for further investigation. Development review protocol is coming after review question to introduce the path of researcher developments. In this section researcher will shows how review question and protocol of SLR related to identify the mechanical and anatomical properties of bamboo and which bamboo species is suitable to use as structure material. Planning stage is significantly essential in SLR and review process to demonstrate the steps and way of SLR. Planning stage also include the protocol of many studies, papers and reviews that must evaluated and estimated. Planning stage aims to decrease the tendentious by establish measurement process when confronting any discrepancy through other process such as data extracting, searching review papers and result analysis (Silvia, 2016). Referring to Reporting Items for Systematic Review and Meta-analysis statement (PRISMA checklist 2009) ,the researcher follow the protocol and checklist as mentioned (PRISMA, 2015a) and correction mentioned in PRISMA chart in order to suits the review field with PRISMA procedure.

2.2.1 Formulation of review question

The purpose of a systematic review is to answer a clear and focused review question. Translating a knowledge gap into an answerable and soundly constructed review question is essential. The review question should be defined at the beginning systematic review. A well formulated review question will help determine inclusion and exclusion criteria, the creation of search strategy, the collection of data and the presentation of findings. Review questions must allow researcher to find information quickly, find information that is relevant and applicable to be valid accurately measures stated objectives (Simmi, 2018). In addition, must

provide researcher checklist for the main concepts to be included in your search strategy. The criteria of review question should always be clear, unambiguous, structured. Review questions may be broad or narrow in focus. It is important to formulate research question with care to avoid missing relevant studies or collecting a potentially biased result set.

Protocol research is useful tools for defining clear, focused review questions and developing a review protocol (Tanu, 2018). Before defining review question using protocol research, must check question has not already been the subject of a systematic review. A protocol for a systematic review should only be modified if it becomes clear that there are outcomes or study designs (John, 2017).

Referring to chapter 1, there are many anatomical properties of bamboo and that may affect the mechanical properties of bamboo that it led to recognize the suitable and excellent species or type of bamboo to use as timber material that will be considered in this SLR research.

According to the PRISMA checklist 2009 item number 4, when devising a search strategy, a search tool is used as an organising framework to list terms by the main concepts in the search question, especially in teams where it is not possible to have an experienced information specialist as a member of the review team (Abigail, 2014). The PICO tool focuses on the Population, Intervention, Comparison and Outcomes of a (usually quantitative) article. It is commonly used to identify components of clinical evidence for systematic reviews in evidence-based medicine and is endorsed by the Cochrane Collaboration. Due to its target literature base several of these search terms such as “control group” and “intervention” are not relevant to qualitative research which traditionally does not utilise control groups or interventions, and therefore may not appropriately locate qualitative research (Stephen Campbell, 2016). However, these terms may become more relevant in the future as more trials and interventions

incorporate qualitative research. As the PICO tool does not currently accommodate terms relating to qualitative research or specific qualitative designs, it has often been modified in practice to “PICOS” where the “S” refers to the Study design, thus limiting the number of irrelevant articles (Sudeh, 2017). However, the abovementioned element might not be suitable for the engineering research systematic review as the initiative of the PRISMA was to assist the development of healthcare intervention. Therefore, there are some alterations on the PRISMA checklist in developing the review question (Carolyn, 2017).

According to formulation review, research questions are developed from the gap of knowledge, in this research the SLR developed and investigated latest 7 years (2014-2020) to fulfill the research requirement and criteria, the gap of knowledge be wider more than 5 years. The researcher only uses one database (Scopus) for searching the related paper to review the trend and the gap of knowledge. To identify the relevant publications, a string was developed (‘Mechanical properties of bamboo’, ‘Anatomical properties of bamboo’, ‘Difference between Gigantochloa Ligulata and Gigantochloa Scortechinii’) to search (access on JUNUARY 14th,2021) within article title, abstract and keyword in Scopus, additionally some inclusion criteria is imposed as follows:

- Year: 2014-2020
- Document type: conference, paper, book, Articles, review
- Source type: Journal
- Language: English

All related and relevant paper or review in the Scopus was follow data extortion method as mentioned in PRISMA flow diagram using method of references (ris format) to be related and to ease title epitomize. In this SLR review, there are about 132 publications include (paper,

review, conference, and journals) throughout the seven years within selected criteria. (Figure 2.2) shows number of publication papers that related to selected topic of SLR and represent the number of publications in each year when represented in inclusion criteria above. There is noticeable decrease between year 2015 to 2017. When 2015 illustrate the higher number of publication papers when it considered interest of researcher in mechanical and anatomy of bamboo in that year. As shown in figure 2.2, the years were arranged into linear graphical way to ease the data extraction.

Furthermore, the researcher has been read all the selected and relevant papers, abstract all the content of papers to locate each paper in inclusion or exclusion according to SLR topic and avoid the duplicate the papers. After that, all this information in every paper is summarised according to years as shown in Table 2.1.

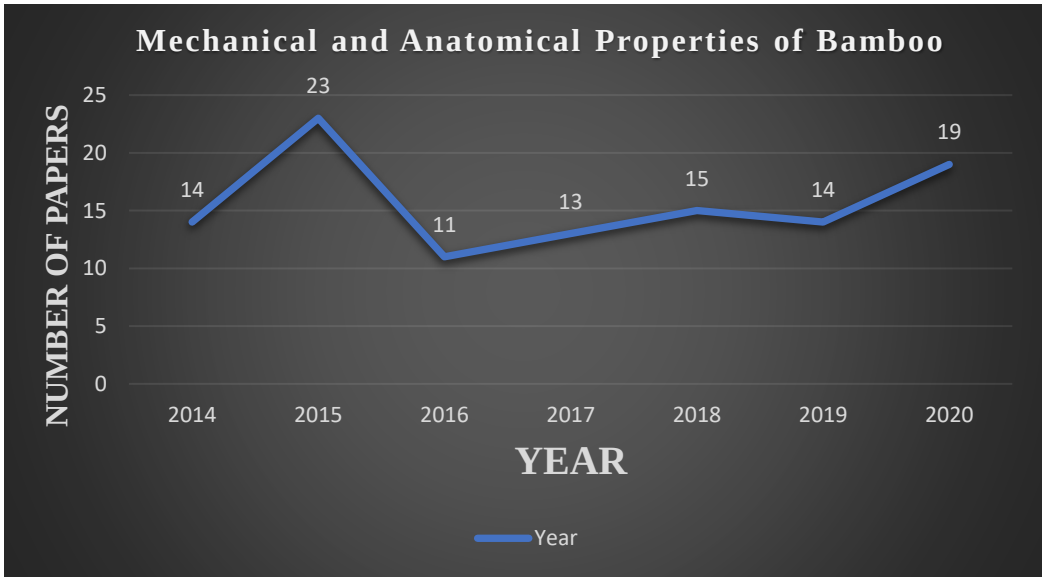

Figure 2.2 Number of Papers Throughout Seven Year

Table 2.1 Review topic summary related to mechanical properties of bamboo

YEAR	Summary
2014	• Mechanical properties of bamboo laminates with other composites. • Bamboo evaluated under different loading conditions. • Alternative to wood and wood-based composites for structural applications.
2015	• Anatomical feature and mechanical properties of three Malaysia bamboo • Feature of bamboo depends on age of bamboo • Suitability and durability of bamboo for construction and manufacturing purposes.
2016	• Natural fiber bamboo composites and alternative materials • Various advantages such as sustainable, abundant, low cost and good specific strength. • Mechanical properties of bamboo for safe for applications
2017	• Optimization on the use of bamboo and physical, mechanical, and chemical properties. • Density, stiffness, bending strength properties and nondestructive evaluation of four-year old • Bamboo culm density and dynamic modulus of elasticity and how can used to determine its strength and stiffness.
2018	• Effects of node, internode, and height position on mechanical properties of bamboo. • Anatomical properties of bamboo and how affected mechanical properties • Selected of the mechanical properties of bamboo culms, location of different height was investigated with ISO 22157 and ASTM

2019	-Mechanical Properties of bamboo through measurement of culm physical properties for composite fabrication of structural concrete reinforcement. -Physical properties of the culm, including culm diameter, wall thickness, height, moisture content and specific density. -Correlations between mechanical properties including tensile strength, modulus of rupture and modulus of elasticity in flexure and tension and culm physical properties.
2020	-Identification of the density, morphology, tensile strength, and modulus of elasticity. -Variation of the density of different types of bamboo's culm.

2.2.2 Review of protocol

The review protocol specifies how the review will be conducted. Decisions should be made on the review question, inclusion criteria, search technique, research selection, data extraction, quality assessment, data synthesis, and dissemination plans (Victoria, 2016). The possibility of bias in the review is reduced when the methods are specified advance. Clear inclusion criteria, for example, prevent research from being chosen based on whether their findings support a preferred conclusion. If changes to the protocol are necessary, they should be documented and justified (Hazel, 2002). Modifications may occur from a better understanding of the review question, but they should not be made based on individual study results. Protocol development is often an iterative process that requires communication within the review team and advisory group and sometimes with the funder.

Systematic reviews should begin with a series of unambiguous questions, the responses to which will provide useful information for decision-making. In the protocol, this should be stated clearly and exactly. Questions might be highly particular or very wide, but if they're overly broad, it can be better to split them down into a series of related, more detailed ones. For example, a review to 'assess the evidence on the positive and negative effects (Catherine, 2014).

Where there are several objectives, it may be necessary to prioritise by importance and likelihood of being able to answer the question. It may even be necessary to restrict the scope of the question to a level that is manageable within set resources. For clarity, the singular term 'review question' is used throughout the guidance (Jeremy, 2018).

The review question can be framed in terms of the population, intervention(s), comparator(s) and outcomes of the studies that will be included in the review. These elements of the review question, together with study design, will then be refined to determine the specific inclusion criteria that will be used when selecting studies for the review (Ben, 2011). Although both the acronyms PICO or PICOS (p) population, (I) interventions, (C) compactors, (O) outcomes, S (study design) are commonly used, here the term PICOS will be used throughout for consistency. In some situations, not all the elements will be relevant, for example not every review question will specify type of study design to be included (Patrick, 2015). The use of PICOS in the context of reviews incorporating different study designs.

Since the review protocol is well-organized, unique, and varies according to the review topic, usually the protocol will be registered under an international database called PROSPERO, but this applies to health research only (National Institute for Health Research 2021).

Therefore, the researcher has by-pass this section even it has been mentioned in the PRISMA checklist 2009 (PRISMA, 2015a).

In this research, the review protocol is like a conventional SLR in that it defines all aspects of the review, including the study's objective, review question, search strategy, quality assessment criteria, data extraction method, and synthesis (AghaKouchak, 2014). The components of the protocol are represented in Figure 2.3.

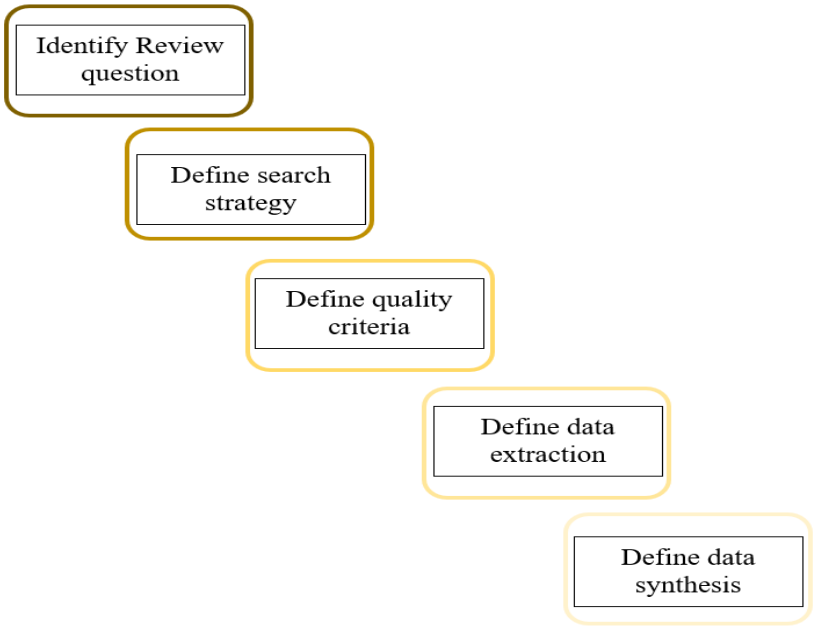

Figure 2.3 Components of SLR Protocol

2.3 Conducting of SLR

Systematic review adheres to standardized methodologies/guidelines in systematic searching, filtering, reviewing, critiquing, interpreting, synthesizing, and reporting of findings from multiple publications on a topic/domain of interest. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The PRISMA statement is an evidence-based guide consisting of a checklist and flowchart intended to be used as tools for authors seeking to write SLR and meta-analyses. In this research, will show the searching strategy based on the many objectives, journals, and review paper (Jonathan, 2012). The goal taken from the review question as mentioned before. Furthermore, the quality criteria will be determined in the inclusion paper in the search before data extraction and synthesis of reviewed paper.

2.3.1 Systematic searching strategies

Creating search strategies for systematic reviews, finding the best balance between sensitivity and specificity, and translating search strategies between databases is challenging. Several methods describe standards for systematic search strategies, but a consistent approach for creating an exhaustive search strategy has not yet been fully described in enough detail to be fully replicable. The researcher has devised a method that outlines the steps involved in creating a systematic search strategy for use in a systematic review. To assure term completeness, the researchers devised an optimization technique based on comparing the results returned by thesaurus terms. Information specialists can use this strategy to create systematic reviews. The method provided here can be used to develop complex and thorough search strategies for various databases and interfaces, such as those required when searching for relevant references for systematic reviews and will benefit the researcher. In addition, The search framework is according to the PRISMA flow diagram which consists of four steps (identification, screening, eligibility, and included) as shown in Figure 2.4 (PRISMA, 2015b). The initial search, according to the PRISMA flow diagram, is made up of numerous databases; however, due to the researcher's access, Scopus will be the only database searched. Although the final included article is sourced from one database, it does not influence the result of the search and this fulfills the criteria in PRISMA checklist 2009 (PRISMA, 2015a).

2.3.1(a) Identification

In this stage there are some criteria that developed to enhance the review strategy as following:

a) Write out the objective (related to the review question) and identify the keyword
b) Enrich the terms

c) Develop search string

In this research, the two objectives are considered and included based on review questions that selected. In addition, there are one more objective statement created to relate both objectives and to compare two bamboo species to choose the excellent properties to be used as sustainable timber material. Moreover, to increase the keywords research and increase the results of publication papers. Keywords that defined by researcher is all related to title of SLR and relevant to the review questions. The identification of the main terms is listed as follows:

A. Objective:

1) To review the anatomy of two species of bamboo and the factors that affect mechanical properties of bamboo in systematic literature reviews.
2) To review mechanical properties of two species of bamboo according to ISO 22157.

B. Others

1. Difference between two species within mechanical and anatomical properties.

Table 2.2 Main terms derived from the 2 objectives and others

Derive the main terms (from O.1):	Derive the main terms (from O.2):	Others (1)
1) Anatomical properties 2) Dissection properties 3) Division properties 4) External factor 5) Water factor 6) Age factor 7) Length factor 8) Node, internode factor	1) Mechanical properties 2) Bending strength 3) Shear strength 4) Compression strength 5) Flexural strength 6) Tensile strength 7) ISO22157	1) Gigantochloa Ligulata 2) Gigantochloa Scortechinii 3) Modulus of elasticity 4) Modulus of rupture 5) MOR 6) MOE

During literature search, especially when search for articles in Scopus databases, researcher rely very much on keyword searching. To conduct a keyword search, in need to formulate a search statement. There are some steps researchers used to develop a search statement. First, Identify the keywords or the main concepts of your research topic (Chris Edward, 2012). In addition, researcher think about of similar terms (synonyms) or phrases that might also be used to describe these concepts, to ensure that you do not miss out any relevant information. Moreover, Combined search terms in a way that Scopus database can understand and relate. So, AND, OR NOT (Boolean operators) were added. The Boolean operators use as a link to combine the main terms and their respective synonym to further narrow down the topic (Donna Mertens, 2009). Besides, there are the researcher used free guidelines for enriching the keyword by free text searching to develop Scopus keywords research. The search string showed in (Table 2.3) (Table 2.4) (Table 2.5).

Table 2.3 Enrich the term and search string from Objective 1

Main Term	Method	Anatomy	Factors	Mechanical properties	Cultivation
Enrich term	1) Anatomical properties 2) Dissection properties 3) Division properties 4) External factor 5) Water factor 6) Age factor 7) Length factor 8) Node, internode factor	1) Branch node 2) Culm 3) Node 4) Internode 5) Branch growing from node 6) Branch	1) Age 2) Height 3) Node 4) Density 5) Moisture content 6) Wall thickness 7) Fiber	1) Bending test 2) Flexure test 3) Compression test 4) Shear test 5) Tensile test	1) Agriculture 2) Garden 3) Plant 4) Production 5) Bamboo 6) Gigantochloa Ligulata 7) Gigantochloa Scortechinii 8) Gigantochloa species
Search string: (‘method’ OR ‘anatomical properties’ OR ‘dissection properties’ OR ‘division properties’ OR ‘external factor’ OR ‘water factor’ OR ‘age factor’ OR ‘length factor’ OR node, internode factor’) AND (‘anatomy’ OR ‘branch node’ OR ‘culm’ OR ‘node’ OR ‘internode’ OR ‘branch growing from node’ OR ‘branch’) AND (‘factor’ OR ‘age’ OR ‘height’ OR ‘node’ OR ‘density’ OR ‘moisture content’ OR ‘wall thickness’ OR ‘fiber’) AND (‘mechanical properties’ ‘bending test’ OR ‘flexure test’ OR ‘compression test’ OR ‘shear test’ OR ‘tensile test’) AND (‘cultivation’ OR ‘Agriculture’ OR ‘Garden’ OR ‘Plant’ OR ‘Production’ OR ‘Bamboo’ OR ‘Gigantochloa Ligulata’ OR ‘Gigantochloa Scortechini’ OR ‘Gigantochloa species’)					