Literature Review: Enhancing the Quality of Wall Panel Components for Houses (Case Study of the Construction of the Polsri Puzzle House)

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Abstract. In 2021, Sriwijaya State Polytechnic began using pre-cast technology to reduce the costs of construction, especially for affordable housing. The next phase of this initiative involves the development of materials for the components/items that make up puzzle houses. The puzzle house component being developed is the wall panel, aiming to eliminate challenges encountered in the field by making the component lighter and improving its quality. The research aims to summarize academic papers on the components of lightweight concrete and alternative materials that enhance the flexural strength of concrete. It concluded that the use of a foam agent meets the criteria set by the research team. Additionally, coconut fiber is proposed as an alternative component to improve the flexural strength of the concrete while keeping it lightweight.

Keyword: puzzle house, wall panel, coconut fiber, and foam agents

1. Introduction

It is clearly mandated in Article 28H, paragraph (1) of the 1945 Constitution, which states; Everyone has the right to live in both physical and spiritual well-being, to have a home, to enjoy a healthy environment, and to access healthcare services. The constitution's mandate poses a significant challenge for the government, particularly given Indonesia's nearly 300 million people. This large population directly impacts the rising demand for housing. In 2020, data from the Ministry of Public Works and Housing (PUPR) revealed a backlog of 12.75 million housing units, highlighting that many people still face difficulties in obtaining adequate housing (Bramantyo, 2012).

The concept of affordable housing is a key component of the government's 2020 vision, driven by the National Housing and Settlement Development Control Policy Agency. One approach to achieving this goal is the use of pre-cast technology, which has been shown to reduce costs by up to 6.44%, ensure structural reliability, and enable mass production (Wasino, 2005). In 2021, Politeknik Negeri Sriwijaya

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began adopting pre-cast technology for building simple houses, with the puzzle house components made of reinforced concrete.

The Puzzle House utilizes precast technology to reduce construction time and costs. It incorporates a marketable design, with parts of the house built using conventional methods. Reinforced concrete is used for both structural and non-structural parts, yet this construction approach has drawbacks. Components are heavy, requiring substantial resources for installation, and cracks frequently appear during manufacturing and installation in certain areas.

Fig 1. Puzzle house building on Musi II Campus of Polsri, Source: author, 2023

In 2023, a study on housing financing efficiency was conducted, comparing subsidized housing with developer-built homes using conventional methods (Putra, Syapawi, Sastra, & Putri, 2024). This research focuses on material development for the components/items that form the puzzle house. It aligns with the puzzle house development roadmap, as illustrated in the image below.

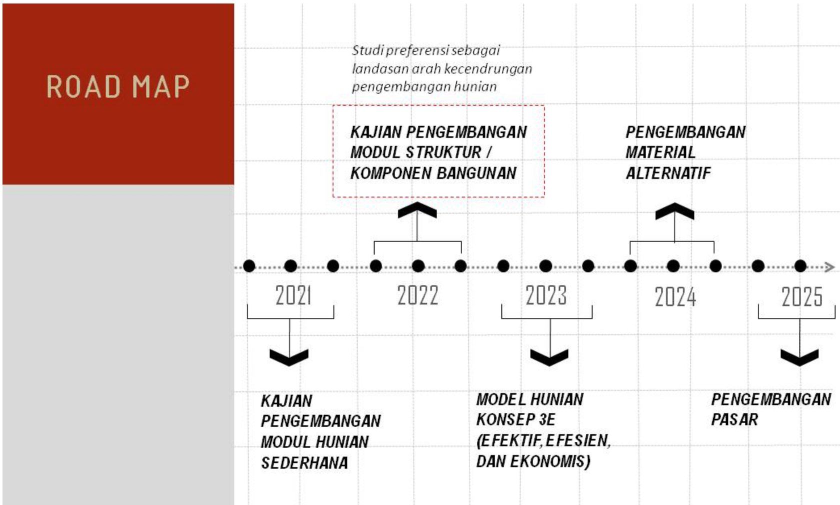

Fig 2. Road Map

The building components produced directly by the puzzle house team include: first, reinforced concrete columns with K300 grade concrete (standard concrete), available in three types of different sizes and shapes; second, reinforced concrete beams, also with the same concrete grade as the columns, available in three beam types; and third, reinforced concrete wall panels, offered in four types with varied sizes and shapes. Among these puzzle house components, the wall panel has been selected for development, considering the potential for quality improvement.

The initial consideration in selecting parts of the house for development focused on non-structural components. In the puzzle house production process, which is directly handled by the team, the components include columns, beams, and walls. Of these, the non-structural part is the wall. Additionally, field experience shows that installing this part requires significant resources and takes considerable time. In the initial development, the wall panel was made from reinforced concrete, which naturally made this component heavy. This research aims to make the component lighter and find alternative materials to replace the reinforcement without compromising its flexibility, thereby reducing the need for extensive resources during installation. Due to the stacked nature of the wall installation, certain requirements must be met, including compressive and flexural strength, while maintaining a lightweight structure.

2. Method

Before proceeding to the next stage, a comprehensive and structured review of academic literature is necessary. This article will employ a literature review method, focusing on journals related to lightweight concrete and alternative reinforcement materials. The goal of this literature review is to explore alternative materials for the wall components already produced. The findings will serve as a foundation to support subsequent research.

3. Result and Discussion

The definition of concrete has become broader, as concrete is a material made from various types of cement, aggregates, and pozzolanic materials, fly ash, sulfur, and others. As it ages, concrete will harden further and will achieve the planned strength (Fc) at 28 days. The rate of concrete strength is greatly influenced by the water-cement ratio (W/C) and the temperature during curing. One of the common performance metrics for concrete is its compressive strength (Naville & Brooks, 1987). Concrete, of course, has its drawbacks, such as its inability to withstand tensile and flexural forces, making it prone to cracking, and once it hardens, concrete is difficult to reshape mengeras (Mulyono, 2004). Concrete is commonly used to withstand compressive forces but is weak in tension. In applications involving elements that experience bending forces, such as beams and slabs, tensile strength is essential. Due to concrete's weakness in tension, it is often combined with steel reinforcement, commonly referred to as reinforced concrete. The application of pre-cast technology, particularly in the production of wall panels, requires a minimum flexural strength under service loads such as mobilization, wind loads, or lateral loads from external forces that cause the panels to bend, while maintaining the properties of concrete but with a lightweight design. Here is a table of the properties that will be developed:

Table 1. The properties that will be developed

Component	Properties of materials	Properties of development
Wall Panel puzzle house	compressive strength flexural strength Heavy	compressive strength flexural strength lightweight

If it follows conventional concrete components that are widely available in the field, it will certainly complicate the planned development properties. This condition necessitates an academic review to select and determine the appropriate use of materials to ensure that the properties of the developed components meet the targeted specifications. The literature review concerning the planned development indicates that concrete must have good compressive and flexural strength while eliminating the heavy properties of traditional concrete; in other words, lightweight concrete with good compressive and flexural strength is needed. Below are some literature reviews related to lightweight concrete, along with several applications for producing lightweight concrete, as shown in the table below:

Tabel 2. Literature reviews

No	Title	Year	Finding
1	Lightweight Concrete from a Mixture of Styrofoam and Sawdust with Portland Cement250, 300 dan 350 kg/m3	2010	This study aims to measure the weight per cubic meter, focuses on determining the compressive strength and modulus of elasticity of the produced lightweight concrete.The findings revealed that using more sawdust increased the concrete's weight, while also enhancing both its compressive strength and modulus of elasticity. On the other hand, increasing the amount of styrofoam in the concrete led to a 63.2% reduction in its weight, making it significantly lighter. However, this also resulted in a decrease in both compressive strength and modulus of elasticity (A & Mustaza, 2010).
2	The production of lightweight concrete from plastic-based artificial aggregates	2013	The test results show that the plastic aggregate has a specific gravity of 1.15, a bulk density of 1378 kg/m³, and an aggregate abrasion of 29.64%, indicating its potential for use in lightweight concrete. Lightweight concrete was produced using a mix ratio of cement: sand: plastic aggregate at 1:2:1.5 and a water-cement ratio of 0.35. This mix resulted in a maximum compressive strength of 13.16 MPa, which classifies the concrete as suitable for lightweight structural applications like wall panels, concrete frames, and cladding (Rommel, 2013).
3	Engineering the job mix for lightweight concrete using Hydroton and Master Ease 5010.	2018	The composition and aggregates we used include Portland cement type I, additive Master Ease 5010, Hydroton, Gombong stone as coarse aggregate, and sand as fine aggregate. Hydroton has hard and lightweight characteristics, taking the form of small spheres measuring 1 to 2.5 cm, typically used as an alternative planting medium. With these characteristics, Hydroton is considered capable of replacing coarse aggregate in the production of lightweight concrete mix (Candra & Siswanto, 2018).

4	Utilization of Cigarette Filter Waste as a Mixing Material for Porous Lightweight Concrete.	2019	Cigarette filter waste made from cotton, which is a fiber that is lightweight, porous, and easily absorbs water, can be utilized as a complete substitute for coarse aggregate. To investigate this, research is needed to determine the compressive strength produced by replacing coarse aggregate with cigarette filter waste. The job mix follows SNI K-125, where cigarette filter waste completely replaces the coarse aggregate. For 1 m³ of concrete, the mix includes 276 kg of cement, 214 liters of water, 148.62 kg of cigarette filters, and 828 kg of sand. The research shows that the compressive strength of the concrete after 28 days reached a maximum of K-115.56, exceeding the target strength of K-100 for concrete paving. (Candra, Gardjito, Cahyo, & Prasetyo, 2019).
5	Utilization of Coal Waste (Fly Ash) as a Replacement Material for Coarse Aggregate in the Production of Lightweight Concrete.	2021	Fly ash, a byproduct of coal, is mixed with a resin chemical binder in a 60% fly ash to 40% resin ratio. Sieve analysis of the artificial coarse aggregate revealed that it is of gravel or coral type with a maximum size of 20 mm and a specific gravity of 1891 kg/m³. The concrete produced from this mixture achieved a compressive strength of 6.85 MPa after 28 days, which is a 38.55% decrease compared to normal concrete's strength of 10.92 MPa. Therefore, it can be observed with this 60% fly ash and 40% resin mix is not suitable for structural applications due to its lower compressive strength, and it is only appropriate for non-structural lightweight concrete (Firda, Permatasari, & Fuad, 2021).
6	Characteristics of Lightweight Concrete Using Foam Agent (Sodium Lauryl Sulfate) as a Foaming Agent.	2022	The concrete mixture, tested on 100 mm x 200 mm cylindrical specimens, shows an average compressive strength of 5.702 MPa, tensile strength of 0.522 MPa, elastic modulus of 3.823 MPa, flexural strength of 1.232 MPa, and an average specific gravity of 1355 kg/m³. This experimental study aims to assess the strength characteristics of lightweight concrete made with foam, following the guidelines set by the Indonesian National Standards. (Syahrul, 2022).

1	Utilization of Coconut Coir Fibers and Bendrat Fibers for Lightweight Precast Concrete Walls Reinforced with Bamboo Weaving and Pumice Stone Waste Aggregate	2004	With the addition of 0.50% coconut coir, the flexural strength increases by 13.31%, 11.45%, and 13.04%, respectively (Suparjo, 2005).
2	The effect of adding coconut coir fibers in the production of cellular lightweight concrete.	2015	This study aims to determine the effect of adding coir fiber material with addition percentages of 1.5%, 2%, 2.5%, and 3% as an alternative material for high-strength concrete. An increase in the tensile strength of concrete by 19.7% can be achieved with the addition of 2% coconut coir (Prahara, Liong, & Rachmansyah, 2015).
3	The effect of adding coconut coir fibers in the production of cellular lightweight concrete.	2019	This research involves the addition of coconut coir fibers to address the weaknesses of lightweight concrete in tension and to create lightweight concrete. The fiber addition has variations of 0%, 0.1%, 0.3%, 0.5%, and 0.7% based on the volume of the test specimen. The highest flexural strength was obtained at the 0.3% variation, measuring 0.92 MPa with a unit weight of 0.828 g/cm³ at 28 days of age (Marfranklin & Risdianto, 2019).
4	The Effect of Using Coconut Coir Fibers on the Compressive Strength and Flexural Strength of Concrete.	2021	The research method was conducted using laboratory tests based on SNI 03-0349-1989. The variations of coconut coir fiber addition in this study were 0.25%, 0.5%, 0.75%, and 1% of the aggregate weight. The flexural strength ranged from 17 to 24 kg/cm², which is still lower compared to concrete blocks without the addition of coconut coir fibers. However, the range of compressive and flexural strength values still meets the SNI requirements (Purwanto, Rahmawati, & Sutarno, 2021).
5	The Effect of Fiber Addition on the Mechanical Characteristics of Concrete Blocks.	2024	The addition of fibers (ijuk, coconut, and bendrat) was made at 0.1%, 0.3%, and 0.5% of the total volume of concrete blocks. The highest values of flexural strength, modulus of elasticity (MOE), and stiffness were found in the coconut coir fiber concrete blocks at 0.3% (Wibowo & Yoresta, 2024).

From the literature review above, there are several materials used to create lightweight concrete. The selection of materials we will use must adhere to certain binding requirements. The first filter set is the Indonesian National Standards (SNI) regarding materials, the second is the ease of availability, and the accessibility of tools for the research team, as well as the limitations of time and funding available to the research team.

Tabel 3. Component

No	Materials	Requirements Indonesian National Standards	Easily accessible	Easily accessible tools	Time and cost-efficient	Result
1	Styrofoam and sawdust	X	√	√	√	3
2	Plastic-based artificial aggregates	X	√	√	√	3
3	*hydroton* dan *master ease* 5010	√	√	√	X	2
4	Cigarette Filter Waste	X	√	√	X	2
5	*fly ash*	√	X	√	X	2
6	*foam agent* (Sodium Lauryl Sulfate)	√	√	√	√	4

From the table above, it can be concluded that for the research to be conducted, it is advisable to use a foam agent, as this component meets the criteria set by the research team. This is to ensure that the research expectations can yield concrete with good compressive and flexural strength while eliminating the heavy properties of traditional concrete, in other words, producing lightweight concrete with good compressive strength. The next requirement is the tensile/flexural strength of the concrete. The following literature review relates to the components that will be chosen to support the development of the properties of the puzzle house wall panels. This study aims to find alternative replacements for reinforcement in concrete:

The summary presented in the table above aims to find alternative replacements for the use of steel in concrete, ensuring that the concrete maintains good flexural strength when applied to puzzle house wall panels. The tabulated data provides an overview of several materials that can serve as suitable alternatives aligned with the planned development. Concrete possesses good flexural/tensile strength by eliminating the heavy properties of traditional concrete. Coconut coir fibers (coco fiber) frequently appear in the presented data tabulation, showing good performance in providing flexural strength to concrete, especially in lightweight concrete. Additionally, coco fiber is relatively affordable and abundantly available in Indonesia, particularly in Palembang.

4. Conclusion

In 2021, Politeknik Negeri Sriwijaya began utilizing precast technology, particularly in the construction of simple houses. In 2023, a study on the cost efficiency of puzzle houses was conducted (Putra et al., 2024). This research focuses on the development of materials for the components/items that make up the puzzle house. The component of the puzzle house being developed is the wall panel, which consists of concrete with reinforcement. This, of course, makes the component heavy and requires significant resources during installation. The development aims to eliminate the challenges encountered in the field. The solution being pursued by this research is to make the component lightweight, thereby reducing the resources required for installation.

The literature review conducted by the author has identified several components that have been reshuffled to meet the required criteria. It can be concluded that the use of foam agents fulfills the criteria set by the research team. The use of coconut fibers as an alternative component helps the concrete achieve good flexural strength while remaining lightweight. The selection of these components is intended to ensure that future research can produce concrete that meets the requirements for compressive and flexural/tensile strength while eliminating the heavy properties of traditional concrete, in other words, lightweight concrete with good compressive strength.

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