

INNOVATION IN RECYCLING SHELLS AS AN ADDITIONAL MATERIAL IN THE CONSTRUCTION OF HOLLOW CONCRETE WALLS

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ABSTRACT

The use of shellfish waste as an alternative material in construction is an innovative effort to reduce environmental pollution while increasing the economic value added by coastal communities. This study aims to assess the potential of recycled shellfish as an aggregate substitute in the construction of hollow concrete walls, applied to fishermen's groups in Cilincing, North Jakarta. The research method uses a laboratory experimental approach with quantitative methods, through the process of waste collection, cleaning, crushing, mixing, and molding various hollow concrete mixtures with shellfish substitution proportions of 0%, 10%, 20%, and 30%. The results of the initial research stage indicate that all mixture variations can be produced well, although with higher substitutions the dough texture tends to be coarser and requires adjustment of the water content. From a sustainability perspective, this innovation contributes to the reduction of coastal waste, the creation of economic added value, and the empowerment of fishing communities. This study provides an initial basis for further testing related to the technical performance of hollow concrete made from shellfish.

Keywords: Cilincing, Clamshell, Hollow Concrete, Material Innovation, Recycling,

1. INTRODUCTION

Environmental problems resulting from organic and inorganic waste are increasingly becoming a global concern, including in Indonesia. One often overlooked waste is shellfish waste generated from fishing activities and seafood consumption. In large quantities, poorly managed shellfish can pollute coastal environments, produce unpleasant odors, and become a breeding ground for disease. Chemically, shellfish contain calcium carbonate (CaCO_3), which has the potential for reuse. A pressing issue concerns the accumulation of shell waste. Due to the shape of the green mussel and the slow biodegradation of its shell, an estimated 25% of the total annual marine production weight is discarded as unused waste. ((Hou et al., 2016)(Zahroh et al., 2025).

The rapid growth of the construction industry is driving an increasing demand for building materials, particularly natural aggregates such as sand, gravel, and limestone. Excessive exploitation of natural resources not only accelerates the limited availability of materials but also has negative impacts on the environment, such as land degradation and ecosystem damage (Ministry of Public Works and Public Housing, 2022). Furthermore, coastal areas in Indonesia produce large amounts of shellfish waste as a byproduct of fishing activities and public consumption. Data from the Ministry of Maritime Affairs and Fisheries (Ministry of Maritime Affairs and Fisheries, 2021) records that shellfish production in DKI Jakarta, including the Cilincing area of North Jakarta, reaches more than 5,000 tons per year. Most shellfish waste is simply dumped into the coastal environment without treatment, causing pollution, unpleasant odors, and potential public health problems (Ria Kusumaningrum et al., 2021).

On the other hand, the construction industry is one of the sectors that contributes the most carbon emissions and high consumption of natural resources, especially in the use of natural aggregate materials (sand and gravel) for making concrete. Continuous exploitation of natural aggregates causes environmental damage such as abrasion, damage to river ecosystems, and scarcity of raw materials. For this reason, the need for innovation in environmentally friendly construction materials arises, one of which is by utilizing waste as a substitute for aggregates, to support the principles of sustainable development. The results of research conducted by Topić Popović, N.; Lorencin, V.; Strunjak-Perović, I.; Což-Rakovac (Topić Popović et al., 2023) are the environment: as organic water purification materials, exhaust gas treatment, roof coating materials, and others; 2) Construction Industry: as cement and concrete aggregate additives, asphalt binders, noise barriers, and others; 3) Food and feed additives: as calcium supplements, protein supplements, food antibacterials, and Nutraceuticals/bioactive molecules; 4) Biomaterials: Biomimetics, biocomposites, polyester, biofillers, sunscreens, wound healing, and biopackaging. According to Ichsan (2019), shells can also be used as a mixture for making paving blocks because they have the same chemical compounds as sand ((Ichsan, 2019)(Alfian & Indria, 2024)). The results of research that has been conducted show that shell waste has the potential to be developed for diversification of building materials. The utilization of shell waste is expected to reduce the impact of damage to the marine environment, while reducing dependence on conventional natural resources.

Several previous studies have shown that shellfish have a high calcium carbonate (CaCO_3) content, so it has the potential to be used as an alternative material in the construction sector, either as a partial substitute for aggregate or as a cement mixture ((Nedeljković et al., 2021)(Rahmadani et al., 2025)). Utilization of shellfish waste in the manufacture of hollow concrete can improve thermal insulation properties, reduce environmental burdens, and support the concept of a circular economy in the construction industry. In the context of fishing groups in Cilincing, the utilization of shellfish waste not only serves as an environmental solution but also opens up opportunities for economic empowerment of coastal communities through building material innovation. Therefore, this study focuses on the innovation of recycling shellfish in the manufacture of hollow concrete wall materials, with the aim of studying the physical and mechanical characteristics of the material while assessing the socio-economic potential of fishing community involvement.

Based on this background, the problems identified in this study can be formulated as follows: 1) How is the process of making variations of hollow concrete walls with partial substitution of shellfish shells as aggregate?; 2) What are the potential environmental, social, and economic benefits of utilizing shellfish shell waste in construction material innovation?; and 3) What are the opportunities for this research to be continued to the material performance testing stage. This study aims to create variations of hollow concrete wall mixtures made from shellfish shell waste as a partial substitute for aggregate; describe the initial technical aspects in making shellfish shell-based hollow concrete; and examine the potential for sustainability from an environmental, social, and economic perspective, as well as provide directions for further research. Thus, this research is expected to contribute to the development of science in the field of sustainable construction material technology, while providing practical solutions to environmental and socio-economic problems in coastal communities.

2. METHOD

This research uses a laboratory experimental approach with a quantitative method to produce hollow concrete wall materials based on shell waste. Shell waste was obtained from a group of fishermen in Kali Bari, Cilincing, North Jakarta, then processed through stages of cleaning, drying, and crushing. The quantitative method is considered appropriate because it allows for measurable testing and statistical analysis of the data obtained ((Creswell, 1994)(Creswell & W, 2015)). The research stages in the flow diagram were carried out by involving the entire research team according to their respective fields of competence. The following is a flow diagram of the research "Innovation of Shell Recycling as a Substitute for Aggregate in Hollow Concrete for Environmental Sustainability" presented in the following figure:

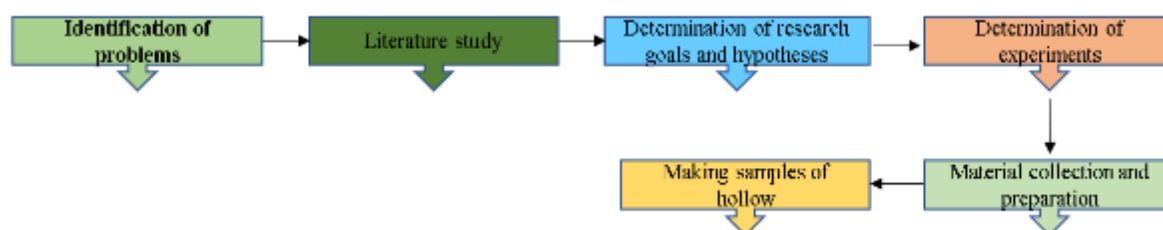


Figure 1. Research Stages
Source: Research Team, 2025

Figure 1 explains the steps of experimental research according to Soekidjo (2010), namely; 1. Identification and limitation of research problems; 2) Literature study according to the research topic, 3. Formulation of research hypotheses; 4. Preparation of experimental steps and material preparation, 5. Determination of independent and dependent variables, 6. Creation of experimental models and measuring instruments used. This research stage only focuses on the process of making variations of hollow concrete without conducting compressive strength, absorption, or thermal conductivity tests. The data obtained are analyzed descriptively to describe the initial feasibility of mixing and molding hollow concrete made from shells.

The materials used in the study included Portland cement type I, fine aggregate (clamshell flour), coarse aggregate (coarsely ground clamshells), and clean water. The clamshells were obtained from fishermen groups in the coastal area of Cilincing, North Jakarta. Data from the Ministry of Maritime Affairs and Fisheries (Ministry of Maritime Affairs and Fisheries, 2021) shows that clam production in DKI Jakarta reaches more than 5,000 tons per year, most of which leaves unused shell waste. This shell waste was processed through stages of cleaning, drying, and crushing to resemble the size of fine and coarse aggregates according to SNI 03-2834-2000 standards. Mixture variations were; Clamshells were used as a partial substitute for coarse aggregate with varying percentages, for example 0% (control),

10%, 20%, and 30% of the total aggregate volume (Indonesian National Standards Agency, 2002). This variation was intended to determine the effect of the proportion of clamshells on the quality of hollow concrete. The process of making hollow concrete includes: 1) All materials are weighed according to the mixture proportions; 2) The mixing process is carried out using a mixer to ensure homogeneity; 3) The concrete mixture is then molded using a standard hollow concrete mold (hollow block); and then the molded concrete is conditioned in a curing chamber. The experimental design was carried out with variations in the percentage of shell substitution to coarse aggregate, namely 0% (as a control), 10%, 20%, and 30%. Each variation of the mixture was molded in the form of a hollow concrete wall (hollow block) with standard dimensions. In this study, laboratory testing has not been carried out, but has only reached the stage of diversity in the shape of the hollow concrete wall.

3. RESULTS AND DISCUSSION

Sustainability Aspects

Utilizing shell waste as a building material not only provides a solution to reduce coastal environmental pollution but also has the potential to create added economic value for fishing communities. Collaboration with fishing partners in Cilincing demonstrates that this recycling process can be carried out in a participatory manner, while also opening opportunities for the development of circular economy-based businesses in coastal areas. Research on the innovation of recycled shells in the construction of hollow concrete walls can be viewed from three main dimensions of sustainability: environmental, economic, and social.

1) Environment Aspect

The utilization of shell waste directly contributes to reducing pollution in coastal areas. Currently, most shell waste in Cilincing is simply dumped around the Fish Auction Place (FIP) or directly into the sea, causing unpleasant odors, disrupting coastal aesthetics, and even potentially becoming a source of disease (Ministry of Maritime Affairs and Fisheries, 2021). By processing shells into construction materials, the volume of waste polluting the environment can be reduced, while also supporting the reduce-reuse-recycle (3R) principle in environmental management. Furthermore, the utilization of shells can reduce dependence on natural aggregates (stone and gravel), thereby helping to curb the exploitation of non-renewable natural resources.

2) Economic Aspect

From an economic perspective, this innovation opens up opportunities to create added value from materials that previously had no commercial value. Fishermen and coastal communities can play a role in the production chain, from collecting, cleaning, and processing shell waste. This has the potential to foster environmentally-based small businesses and increase local incomes. Hollow concrete wall products made from shells can also compete as an affordable and environmentally friendly alternative building material, especially for building simple houses in densely populated urban areas.

3) Social Aspect

This research involved a group of fishermen in Kali Baru, Cilincing, as partners in providing raw materials. This collaboration emphasizes the importance of community participation in the development of environmentally friendly innovations. From a social perspective, community involvement not only raises awareness of the importance of waste management but also fosters a sense of ownership of the research findings. Furthermore, this can strengthen social solidarity and support the formation of a community-based business ecosystem in coastal areas.

Thus, this research not only contributes to the development of alternative construction material technology, but also has a real impact on environmental sustainability, improving the welfare of coastal communities, and strengthening the local economy.

Hollow Concrete Manufacturing Process

This research successfully implemented an innovative method of recycling shell waste into a partial aggregate substitute for hollow concrete walls. The stages of forming hollow concrete are as follows: 1) The first stage is the material preparation process, which begins with collecting shell waste from a fishing group in Kali Baru, Cilincing, North Jakarta. The waste is then processed through cleaning, drying, and crushing until it reaches a size similar to coarse aggregate. This process demonstrates that shell waste can be processed into a material that meets the initial standards for concrete production.



Figure 2. Green Mussel Shell Harvesting Process
Source: Research Team Documentation, 2025

Cleaning and Drying the Shells: The collection process is shown in Figure 2. The shells are cleaned of organic matter using running water. The shells are then dried in the sun for approximately 2–3 days until the water content decreases. The drying process is shown in Figure 3 as follows:



Gambar 3. Proses Pemilihan dan Pengeringan Cangkang Kerang Hijau
Sumber: Dokumentasi Tim Peneliti, 2025

The third stage of crushing and screening, the dried shells are crushed using a crusher or hammer to a size close to coarse aggregate (5–20 mm) and fine aggregate. The common standard size of fine aggregate is smaller than 4.75 mm or retained on sieve No. 4, in accordance with standards such as SNI 1970-2008. The resulting broken material is screened using a sieve to obtain a uniform size according to the needs of the concrete mixture. Based on SNI 03-0349-1989, hollow concrete bricks formed from a mixture of Portland cement, fine sand aggregate, water and or without other additives are one of the wall filler materials (Indonesian National Standards Agency, 1989). Fine aggregate is a filler used with cement to make a mixture. In addition, it also affects the shrinkage, crack resistance and hardness properties of hollow concrete walls or other cement-mixed building materials. The process of crushing shells is as follows:



Figure 4. Shell Destruction Process
Source: Research Team Documentation, 2025

The shell crushing process uses a flour-making machine equipped with a sieve with the appropriate size for fine and coarse aggregate grains as required by SNI 1970-2008. Furthermore, the raw materials, consisting of sand, cement, and water, must have a ratio of 75:20:5 (Indonesian National Standards Agency, 2008). The composition of these raw materials is in accordance with the Technical Guidelines issued by the Department of Public Works in 1986. The mixing process uses a mixer to produce a homogeneous concrete mixture (Indonesian National Standards Agency, 2002). The mixing and stirring process can be seen in Figure 5 below:



Figure 5. Concrete Mixing Process
Source: Research Team Documentation, 2025

The mixture variations developed included hollow concrete with coarse aggregate substitution of seashells of 0% (control), 10%, 20%, and 30%. Each variation was successfully cast in the form of hollow blocks with standard dimensions. From a technical perspective, the mixing and molding process did not experience significant obstacles, although at higher substitution percentages the dough texture tended to be coarser and required water content control to maintain a compact mold. The mixing process was carried out while gradually adding water with a mixing time of approximately 15 minutes. This is in line with initial findings of similar research which stated that high substitution levels can affect the workability of concrete mixes (Abdul et al., 2023). After the concrete mix was mixed, it was cast using a 30 x 15 x 10 cm brick mold, and a 30 x 30 cm lobster mold. The mold model can be seen in Figure 6 below:

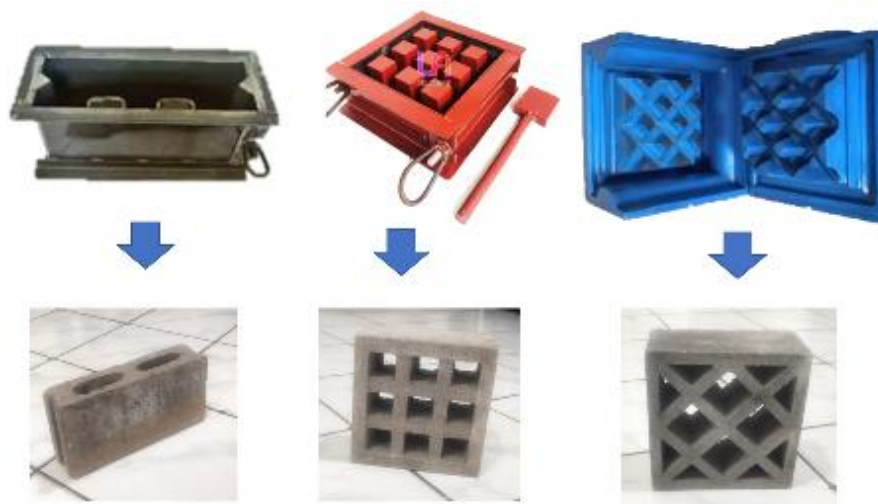


Figure 6. Hollow Concrete Molding Tool
Source: Research Team Documentation, 2025

Figure 6 shows the models and types of hollow concrete wall molds, as well as the resulting products from this study. Three different models were used to produce various shapes. Future research could include testing the hollow concrete walls for compressive strength and water absorption. The resulting product is shown in Figure 7 as follows:



Figure 6. Experimental Variants of Hollow Concrete Walls
Source: Research Team Documentation, 2025

Figure 7 shows the experimental results of creating hollow concrete variants that can be applied to building walls and fences. In addition to the various forms of concrete blocks used as infill walls, louvers are also made, which are useful for natural air circulation, natural lighting, enhancing the building's aesthetics, maintaining privacy, as well as potentially saving energy and improving the health of home occupants by reducing humidity and unpleasant odors. Louvers can also function as decorative elements for fences or room partitions, providing a modern and elegant look.

4. CONCLUSION

This research successfully developed an innovative method for utilizing shellfish waste as a partial aggregate substitute in the construction of hollow concrete walls. Experimental steps, including the creation of various mixtures, demonstrated that shellfish waste can be processed into a construction material suitable for further processing. The success of various hollow concrete wall variations (0%, 10%, 20%, and 30%) indicates that this material has the potential to partially replace conventional aggregate.

From a sustainability perspective, this research contributes to three main aspects. First, the environmental aspect, namely reducing coastal pollution caused by shell waste while suppressing the exploitation of natural aggregates. Second, the economic aspect, through opportunities to create added value and the potential for small businesses based on waste recycling in coastal communities. Third, the social aspect, by involving fishermen groups in Cilincing as partners, which ultimately increases community awareness and participation in waste management. Overall, this research can be said to be the first step in presenting innovative environmentally friendly building materials that are relevant to the needs of coastal communities, while also supporting the achievement of the Sustainable Development Goals (SDGs).

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