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EXPLORING PORCELAIN TABLEWARE WASTE AS A SUSTAINABLE MATERIAL FOR INTERNAL WALL CONSTRUCTION IN SRI LANKA

W.M.N.D. Ranasinghe[1], S.M. Manawadu[2] and R. Poovahiya[3]

ABSTRACT

Industrial waste has a significant impact on the environment. This research introduces a sustainable solution for industrial waste management. Porcelain tableware waste is a landfill problem, so this research proposes reusing biscuit waste from tableware to support sustainable practices. This research aims to explore the feasibility of using bisqueware waste for internal wall construction. Bisqueware waste is a fired clay material with good strength and workability. It can be used as a composite material to develop new materials. This research is based on an experimental approach; earthenware red clay is used as an additive, mixed with porcelain bisqueware powder to increase plasticity and develop a new material. To achieve different material behaviors, different clay compositions and firing conditions were tested. These conditions provide varying workability and natural qualities. The proposed sustainable material has the qualities of workability, flexibility, strength, and heat absorption. This material can be introduced for modular development in interior partition applications. The design also reflects cultural and traditional aesthetics. The findings provide practical recommendations for sustainable interior construction and further innovation in this field. The developed modular unit is sustainable and eco-friendly, featuring indoor cooling and partition units that create a sense of cultural and traditional vibrancy. The findings offer practical recommendations for enhancing interior partitions and underscore the potential for sustainable interior constructions and continued innovation in this field.

Keywords: *Bisqueware waste; Construction materials; Porcelain tableware; Product innovation; Sustainability.*

1. INTRODUCTION

Solid waste generation has increased significantly in Sri Lanka due to urbanisation, rising consumption, and rapid technological advances. The country faces ongoing challenges in waste management, particularly in handling non-biodegradable materials commonly disposed of in landfills (Menikpura et al., 2012). Among the different types of waste deposited, some stages of porcelain tableware waste can be identified as reusable

[1] Senior Lecturer, Department of Integrated Design, University or Moratuwa, Sri Lanka, dilshanir@uom.lk
[2] Professor Emeritus, Department of Architecture, University or Moratuwa, Sri Lanka, samithama@uom.lk
[3] Professor, Industrial Design Center, Indian Institute of Technology, India, ravi@iitb.ac.in

material. Rapid urbanisation and changes in consumption patterns have contributed to this rise in solid waste. These waste streams, including discarded tableware such as ceramic bisque products, glazed ware, and fired ceramic items, receive limited attention in recycling or reuse processes, despite their advantageous material properties, including high compressive strength and durability.

In the Porcelain Tableware sector, bisque waste comprises large volumes of damaged bisque ceramic ware disposed of in Sri Lanka's landfills daily. Some broken bisque ware is used to produce glaze, and a small percentage of bisque is recycled to create clay pug rolls, but neither amount exceeds 5% of the total waste (Liyanage & Ranasinghe, 2019). The research aims to conserve resources or reuse them through sustainable production methods. Porcelain Tableware waste is classified as either low-temperature-fired(850°C) or high-temperature-fired (1300°C). Low-temperature-fired porcelain has the potential to be classified as sustainable waste. This research tests whether bisque waste, which solidifies after low-firing and becomes insoluble for reuse, can be recycled. Because it has already been fired at 850°C, this study aims to explore the feasibility of using bisqueware waste for internal wall construction.

The objectives are as follows.

1. To evaluate the most suitable clay body mixture and firing temperature for the use of bisqueware waste in internal wall construction.
2. To design a suitable modular unit using bisqueware waste for internal wall construction.

This innovative approach aims to repurpose waste streams into useful resources to minimize the ecological footprint of construction activities and promote the principles of the circular economy within the built environment by converting them into environmentally friendly building materials. Dankotuwa Porcelain PLC was selected as the context for this study. Waste bisque clay materials and red earthenware clay were used in the experimental approach to achieve sustainable reuse for new production. Only the industrial background, material attributes, and behavior of the bisque ware were evaluated to inform the development of an innovation for interior construction.

2. LITERATURE REVIEW

2.1 CONCEPT OF WASTE

Waste comprises materials, substances, or products that are no longer useful, wanted, or needed and are discarded after use. Waste is any substance or object that the holder discards, intends to discard, or is required to discard (United Nations Environment Programme, 2011). Waste is defined as materials that are not prime products for which the generator has no further use in terms of production, transformation, or consumption, and which the generator discards or intends to discard. In the industrial context, waste comprises materials, energy, or resources that are lost, unused, or rejected during manufacturing and production, or consumption. Waste is typically classified into five categories: solid waste, industrial waste, organic waste, hazardous waste, and production waste (Organization for Economic Co-operation and Development, 2025). This study specifically addresses industrial waste, with an emphasis on waste from tableware production and from factories and manufacturing operations.

2.2 SUSTAINABLE WASTE

Sustainable waste management involves reducing and disposing of waste in ways that protect the environment, conserve resources, and support long-term ecological balance. It focuses on minimizing waste generation and promoting practices such as reuse, recycling, and responsible disposal, according to the United Nations Environment Programme. Sustainable waste management can be defined as the systematic management of waste through reduction, reuse, recycling, and recovery of materials to minimize environmental impacts and conserve natural resources (UNEP, 2011). Similarly, the World Bank describes sustainable waste management as the collection, treatment, and disposal of waste in ways that protect human health, preserve the environment, and promote resource efficiency. In research and industrial contexts, sustainable waste practices aim to transform waste materials into valuable resources, reduce landfill disposal, and support environmentally responsible production systems.

2.3 APPLICATION OF SUSTAINABLE MATERIALS FOR CONSTRUCTION

Sustainable materials are widely promoted in interior construction because they reduce environmental impacts, conserve natural resources, and improve indoor environmental quality. Sustainable building materials are those that have minimal environmental impact throughout their life cycle, including extraction, processing, use, and disposal (Kibert, 2016).

Reusing existing materials reduces resource extraction and keeps valuable materials out of the waste stream (McDonough & Braungart, 2002). Cork is a renewable material harvested from the bark of cork oak trees without harming the tree. According to the Forest Stewardship Council, cork is a sustainable, renewable natural material widely used in flooring and insulation for its durability and thermal properties. Recycled glass is used in tiles, decorative panels, and countertops. According to UNEP (2011), recycling materials such as glass reduces landfill waste and decreases demand for virgin raw materials in the construction industry. Sustainable materials used in interior construction include bamboo, reclaimed wood, cork, recycled glass, clay-based materials, and recycled ceramics. These materials contribute to resource efficiency, reduced environmental impact, and improved indoor environmental quality, supporting sustainable building practices

2.4 APPLICATION OF CLAY AS AN INTERNAL WALL CONSTRUCTION MATERIAL

There are various types of environmentally friendly materials used in building solutions. Clay plaster and terracotta are environmentally friendly and help regulate humidity. Earthen materials provide sustainable building solutions due to their low energy requirements and natural thermal regulation properties (Houben & Guillaud, 1994). Waste ceramics and porcelain materials can be reused in interior construction as aggregates or decorative materials. According to the United Nations Environment Programme, the reuse and recycling of industrial waste materials support sustainable resource management and reduce environmental impacts (UNEP, 2011). Clay is a popular material that was used in ancient civilisations in equatorial regions. There is substantial evidence that clay was used as a firing material in Sri Lanka even seven decades ago (Ariyapala, 1956). Both domestic and construction use can be identified in the history of Sri Lankan clay. Clay has served many purposes. Cooling was one of the purposes of clay, as seen in the use of *Gurulethththuwa, Pinthaliya, Piliheliya,* and wattle. As a construction material, "further, *walauwas* often had thick mud walls, which would transmit less external heat than stone walls" (Uragoda, 2000, p. 216).

2.4.1 The Usage of Ceramic Waste

Environmental protection is a growing concern in the twenty-first century, and demand for it is increasing as China implements its sustainable development policy. Reducing environmental pollution and reusing ceramic waste are examples of industrial environmental protection (Shuying et al., 2015). Reducing manufacturing waste can benefit individual enterprises, the global economy, and the environment. Manufacturing companies will experience lower costs, fewer overtime hours, and higher-quality goods by minimizing waste in operations and manufacturing. Pollution and carbon footprints will be reduced simultaneously, improving the environment for everyone (Sable & Dakhore,2014). According to the research paper (Andres et al., 2010), ceramic aggregates were recycled for use in the construction and civil engineering industries after being crushed to reduce their size, sieved, and subjected to laboratory analysis.

2.4.2 Material Behaviour of Porcelain Tableware Products

Tableware comprises a range of ceramic products used for serving and consuming food and beverages, including teacups, saucers, teapots, creamers, sugar bowls, plates, platters, and dishes (Tea set & Dinner set). These items are commonly used in domestic settings and in the hospitality sector, including hotels and restaurants. Porcelain is a type of ceramic material consisting of inorganic, non-metallic solids produced at high temperatures. Ceramic materials, including porcelain, are typically composed of oxides, carbides, and nitrides, which confer heat-resistant and refractory properties (Midwest Research Institute, 1996). During firing, temperature, kiln atmosphere, and firing duration significantly influence the chemical reactions and microstructural development of the ceramic body. Tableware manufacturer Dankotuwa Porcelain is known for its cutting-edge designs. Although the methods used centuries ago seem relatively primitive by today's standards, they still convey a level of creativity that was essential to the business of the time. The people are inspired to give our items an elegant touch by their creativity and passion. Quartz, feldspar, talc, bauxite stone, Bentonite, Alumina, Kaolinite (China clay), Water, and bisque (3%) are the clay body materials used in porcelain.

Variations in kiln conditions can therefore affect the final qualities and performance of porcelain products. Within the ceramic industry, porcelain is commonly associated with whiteware production, where firing processes play an important role in determining product quality and production efficiency. Optimising firing conditions can help reduce production costs by improving energy efficiency (Carty & Senapati, 1998). Porcelain is typically produced from a composition of quartz, feldspar, and clay (kaolin). In this composition, clay provides plasticity and mechanical strength during forming and contributes to the formation of mullite and the glassy phase during firing. Feldspar acts as a flux, forming a liquid phase at lower temperatures, thereby aiding densification and reducing porosity. Quartz, with its high melting point, contributes to the final product's dimensional stability and thermal resistance (De Noni et al., 2009).

2.5 Dankotuwa Porcelain PLC and Tableware Production Process

The study was based on Dankotuwa Porcelain PLC in Sri Lanka, which has a 38-year history and is the largest tableware manufacturer with a well-known brand reputation in the country's porcelain tableware market. The company has a diverse portfolio of designs and ever-evolving items to satisfy consumer demand. In line with industry best practices and worldwide standards, the company offers its products to domestic and global markets. The business is an ISO 9001:2008-certified maker of premium porcelain tableware. Buyers for Dankotuwa come from 25 different nations, including Belgium, the Czech Republic, Colombia, Dubai, Germany, Greece, India, Iceland, Italy, Kuwait, Norway, Pakistan, Poland, Russia, Spain, Switzerland, the United States, the United Kingdom, and Ukraine, among others (Export Development Board Sri Lanka, 2020). Due to the increasing volume of industrial waste, recycling has become a major environmental concern worldwide. This study focuses on the waste generated from damaged bisque ware in porcelain manufacturing. In large-scale production processes, a significant number of items pass through the factory daily, resulting in unavoidable defects. According to statistics from the bisque ware department, approximately 5–6% of the total production is damaged at the bisque stage. Figure 1 and 2 presents the tableware manufacturing and firing process.

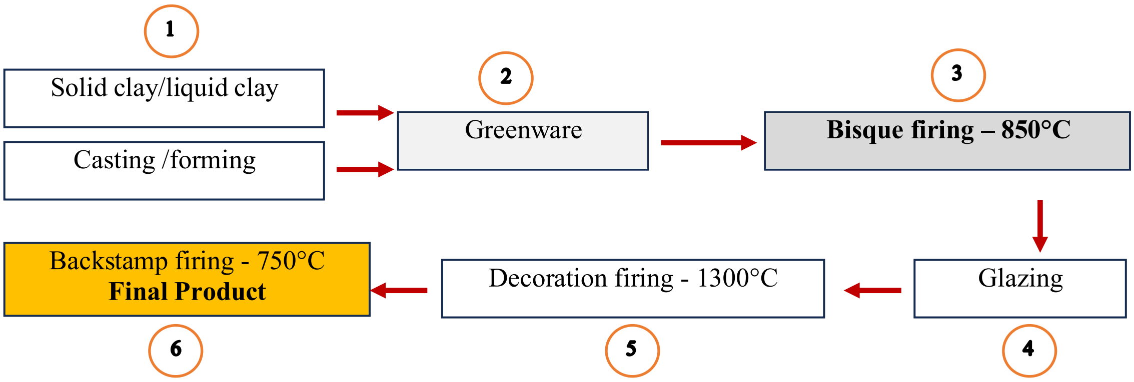

Figure 1: Production process of the tableware industry

Figure 2: Greeware production process and greenware cart [Source: Dankotuwa Porcelain PLC]

Four firing processes can be identified in porcelain tableware manufacturing. A special reason is that the product from the clay stage to the bisque-ware firing can be reused as waste, but after glazing and back-stamping firing, the body cannot be reused easily and is difficult to crush or grind due to its hardness and altered composition.

2.6 BISQUEWARE WASTE IN DANKOTUWA PLC

Bisque, bisqueware, or biscuit ware refers to pottery that has undergone the first low-temperature firing in a kiln (750°C to 850°C), during which the clay becomes partially matured but remains porous, making it suitable for further processes such as glazing. After the firing, the clay particles are bonded together, a process known as sintering; the particles become slightly attached, which strengthens the whole piece so that the clay itself, the body of clay, becomes stronger, more robust, and more handleable, which is one of the main reasons for the bisque firing. At this stage, the ceramic body becomes durable enough for handling and glazing while maintaining sufficient porosity to absorb glaze materials. After the bisque stage, products are inspected for defects before proceeding to glazing and final firing (Shears, 2020). Bisqueware has a soaking quality. It will soak up water and glaze over after being dipped in glaze. The pottery transforms from greenware to bisque when the temperature climbs from 0°C to 850°C. Materials become less porous; bisque firing will cause them to lose at least 16% of their weight. This is consistent with the research paper (Carty & Senapati,1998). The following images show the types of damage that occur during firing (Figure 3).

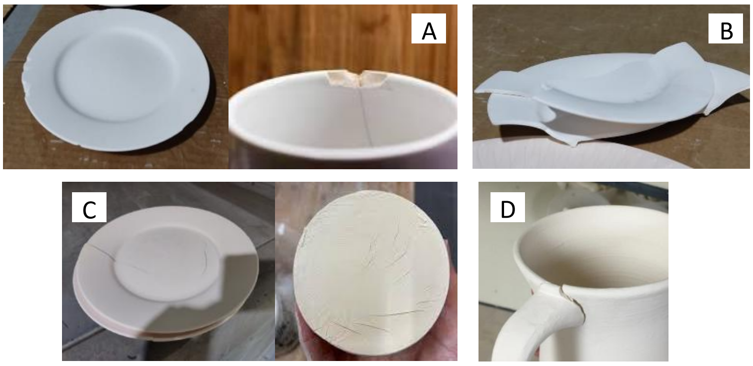

*Figure 3: Tableware bisque ware waste: **A**-Edge Crack, **B**-Body Crack, **C**-Bottom Crack, **D**-Handle Crack [Source: Dankotuwa Porcelain PLC]*

Ceramics have a long history and continue to evolve as important materials in modern industries. Porcelain, a refined ceramic, has been developed and refined over many generations, resulting in distinctive physical and aesthetic qualities. These products are exported worldwide and contribute to the national economy (Export Development Board Sri Lanka, 2020). However, large-scale production also brings challenges, including high resource consumption and increased industrial waste (Figure 4).

Figure 4: Tableware Bisque Ware Waste [Source: Dankotuwa Porcelain PLC]

It examines sustainable manufacturing practices in the ceramic sector. It explores the historical context of porcelain production in Sri Lanka, the material characteristics of bisque ware, and effective strategies for managing resources and waste sustainably. Every industrial sector is increasingly adopting sustainable production practices to protect the environment for future generations.

Table 1: 6 Months of bisque damage in Dankotuwa porcelain plc

Month	Total Bisque Issued	Damaged Bisque Ware	Damaged Percentage
Jan-22	4 31 261	16 540	3.69%
Feb-22	4 00 534	13 737	3.31%
Mar-22	5 21 341	19 584	3.62%
Apr-22	3 23 801	13 109	3.89%
May-22	4 63 031	18 261	3.79%
Jun-22	4 34 098	15 177	3.37%
Total	***2 104 066***	***96 408***	

The table (Table 1) above shows bisque ware waste at Dankotuwa Porcelain PLC over 6 months in 2022. The term was broadened to encompass the art and science of producing and using solid products made from earthy raw materials (Richerson & Lee, 2018). This definition states that a ceramic is anything other than an organic substance or a metal. Sustainable materials play an important role in interior construction by helping reduce environmental impacts and promoting efficient resource use. Sustainable building materials have minimal environmental impact throughout their life cycle, from extraction and processing to use and disposal (Kibert, 2016). The use of recycled and waste materials in construction is increasingly encouraged as a strategy to reduce industrial waste and conserve natural resources. Reusing existing materials prevents valuable resources from entering the waste stream and supports circular material flows in sustainable design (McDonough & Braungart, 2002).

In the ceramic industry, waste materials such as damaged porcelain and bisque ware offer opportunities for reuse as alternative construction materials. Recycling and reusing industrial waste can significantly reduce landfill disposal while contributing to sustainable manufacturing practices (UNEP, 2011). Therefore, incorporating bisque-ware waste into clay-based materials can offer a sustainable solution. Researchers also emphasize that sustainable production practices in the ceramic industry include improving kiln efficiency, optimizing raw material usage, and reusing ceramic waste such as damaged bisque ware (Dornfeld, 2009; Carty & Senapati, 1998). These strategies contribute to environmental protection while maintaining efficient and economically viable porcelain manufacturing. According to the Dankotuwa porcelain annual report for 2022/24, the company sold leftover clay to local small-scale manufacturers at a nominal price. It implemented strategies to optimize material efficiency and reduce waste, which are the main concerns of the company's decisions. Not only that, but they are also concerned about Industry Innovation and Infrastructure Development, which are expanded and enhanced through research and technological advancements. Measures were implemented to enhance production efficiency and minimize waste and defects. Proper waste disposal and reprocessing of materials to minimize solid waste are the main considerations. As a result, the company is willing to sell its leftovers, such as bisque ware and plaster moulds, to outsiders and researchers for innovation rather than landfill them.

Bisque-ware waste has been identified as a promising material to address the research gap. Research idea to fill the gap, as it is often discarded without effective long-term solutions despite its valuable properties. As a first-fired ceramic material, bisque ware has distinctive characteristics, including porosity, light weight, surface gaps, and water absorption. These properties present opportunities for material developments and innovations. Therefore, further research is needed to explore new materials or recycling methods to provide sustainable solutions for managing bisque-ware waste.

3. METHODOLOGY

The table (Table 1) above shows bisque ware waste at Dankotuwa Porcelain PLC over 6 months in 2022. The term was broadened to encompass the art and science of producing and using solid products made from earthy raw materials (Richerson & Lee, 2018). This definition states that a ceramic is anything other than an organic substance or a metal. Sustainable materials play an important role in interior construction by helping reduce environmental impacts and promoting efficient resource use. Sustainable building materials have minimal environmental impact throughout their life cycle, from extraction and processing to use and disposal (Kibert, 2016). The use of recycled and waste materials in construction is increasingly encouraged as a strategy to reduce industrial waste and conserve natural resources. Reusing existing materials prevents valuable resources from entering the waste stream and supports circular material flows in sustainable design (McDonough & Braungart, 2002).

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3.1 EXPERIMENTAL APPROACH TO RESEARCH

There is a significant gap in the literature on combining bisque ware and clay for sustainable material development. This research adopts an experimental approach to address porcelain bisque waste and develop new materials for sustainable interior applications. As a high-porosity by-product of porcelain manufacturing, bisque ware can potentially be used as an aggregate material when combined with clay. Its porosity and heat-absorption properties provide opportunities to develop a composite material with beneficial characteristics such as improved permeability and structural strength. Therefore, the study focuses on transforming bisque waste into a sustainable material solution for interior construction applications. An experimental process for Material Testing is presented in Figure 5.

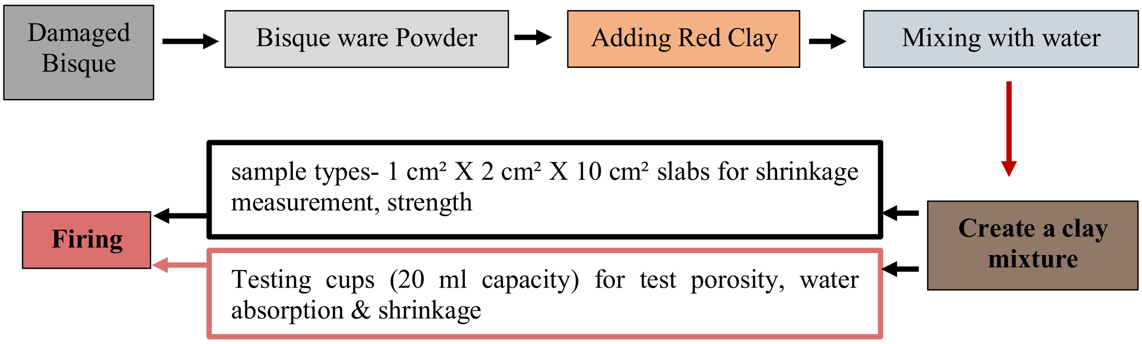

Figure 5: Design framework for material testing process [Source: Authors' Creation]

Figure 5 outlines how bisque ware can be combined with clay to create novel composite materials for interior applications. Together, these steps define the material development process and experimental conditions, ensuring alignment with the core objectives of sustainability, ecological restoration, and effective interior design practices. During the material development phase, the testing was conducted using various combinations of bisque ware and clay (Natural Red Clay) to determine the optimal mix. The bisque ware will be combined with clay in the following ratios (Table 2).

Table 2: Bisque Ware Firing Temperatures [Authors' Creation]

Porcelain Bisque ware	Red Clay	Firing Temperature			
20%	80%	500°C	650°C	750°C	850°C
50%	50%	500°C	650°C	750°C	850°C
60%	**40%**	500°C	650°C	**750°C**	850°C
80%	20%	500°C	650°C	750°C	850°C

This material-mixing process aims to identify the most effective material combination for interior applications, thereby creating new opportunities for the use of porcelain-bisque waste.

4. RESEARCH FINDINGS AND ANALYSIS

4.1 RESEARCH FINDINGS FROM BISQUEWARE WASTAGE

The study investigated several combinations of bisque ware and clay to identify the most effective mixture to improve material characteristics for interior applications. Through this experimental process, the research aimed to determine the optimal composition that enhances the strength, porosity, and overall performance of the developed material. The rationale for selecting these ratios was to evaluate how different proportions of bisque ware, which is characterised by high porosity and strength, would affect the material. In contrast, higher proportions (50%, 60%, and 80%) were anticipated to increase porosity and water absorption capacity, potentially enhancing the material's suitability for moisture absorption in interior environments. The objective of testing these variations was to identify an optimal balance between structural integrity and functional performance, ensuring that the developed material possesses both durability and beneficial characteristics for interior applications. This study's findings indicate apparent new material experimental findings from bisque waste.

Table 3: Firing temperatures & material behaviors [Authors' Creation]

Temperature	Qualities of the Experimental Clay Body
500°C Fired Samples	These samples exhibit an earthy colour and rustic appearance with the lowest shrinkage rate, allowing precise shaping. They also demonstrate good water absorption while maintaining structural integrity. Additionally, the low firing temperature makes the process cost-effective, enhancing the material's suitability for various applications.
650°C Fired Samples	Compared to the 500°C samples, those fired at 650°C exhibit increased strength and a different colour. The material has improved fired clay qualities but experiences higher shrinkage and water absorption. This temperature enhances the material's durability but may limit its application due to these changes.
750°C Fired Samples	Samples fired at 750 °C show increased strength and reduced shrinkage compared to lower temperatures. However, they exhibit high water absorption, with some samples absorbing up to 8 ml of water in less than 10 minutes. Their darker colour and uniform appearance make them suitable for strength-focused applications, although the high-water absorption may limit their use.
850°C Fired Samples	The highest firing temperature produces materials with exceptional strength, darker colour, and a more uniform appearance. However, these samples show significant shrinkage and very high-water absorption rates, with some draining 8 ml of water in less than five minutes. While these properties may benefit certain applications, the higher production costs and excessive water absorption must be carefully considered.

Among the test pieces shown in the table (Table 3) above, the 750°C sample with a 60:40 clay composition was selected because the tested bisque ratio exhibited the most suitable properties for interior applications. It exhibited low shrinkage, allowing for accurate casting and consistent forms while maintaining a lightweight structure and a rustic aesthetic. These characteristics make it suitable for interior and penetration applications, particularly where moisture absorption and strength support are beneficial. This clay body is a newly developed material with remarkable material values. The reliability of the newly developed material provides design ideas for the construction industry and offers a solution for bisqueware waste by introducing a new system chain.

4.2 Development of a Modular Unit Using Bisqueware for Internal Wall Construction

The selected clay body offers a balance of water absorption and strength. The developed shape and form provide additional functional value, and the modules have been cast to rotate around a supporting bar, enabling flexible interior partition arrangements and improved airflow from the exterior (See Figures 6 and 7). Furthermore, during firing, the design enables efficient stacking within the kiln, maximising space utilisation and reducing wasted capacity. Unlike conventional temporary partitions, which often rely on high-cost or difficult-to-handle synthetic materials, the developed clay module serves as a non-load-bearing partition system. In addition to its individual functional role, the module can serve as an indoor partition curtain, providing flexible and sustainable spatial organisation.

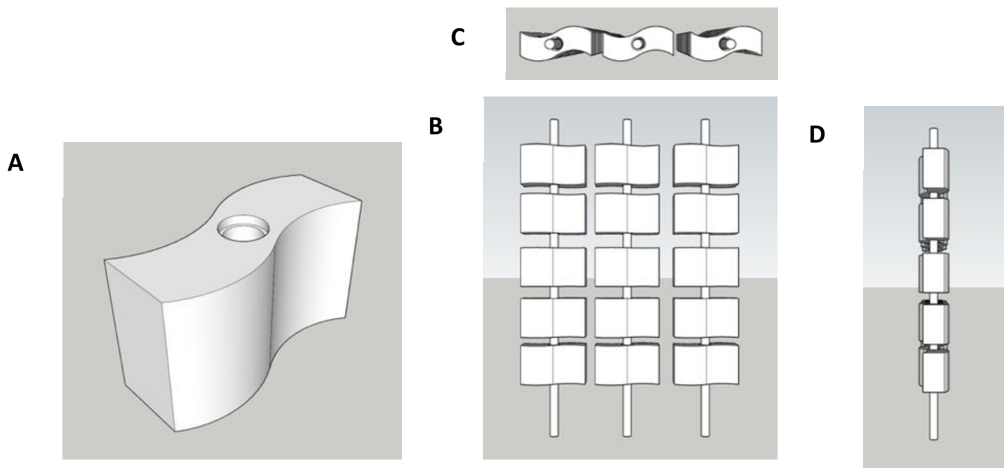

Figure 6: A-Modular unit, B-Front View, C- Top View, D-Side View [Source: Authors' Creations]

The modular units can be arranged according to specific interior requirements. They can also serve as temporary partition elements, enabling flexible spatial organisation without damaging the original building structure. It is fixed to the floor using a 1-inch diameter stainless steel bar.

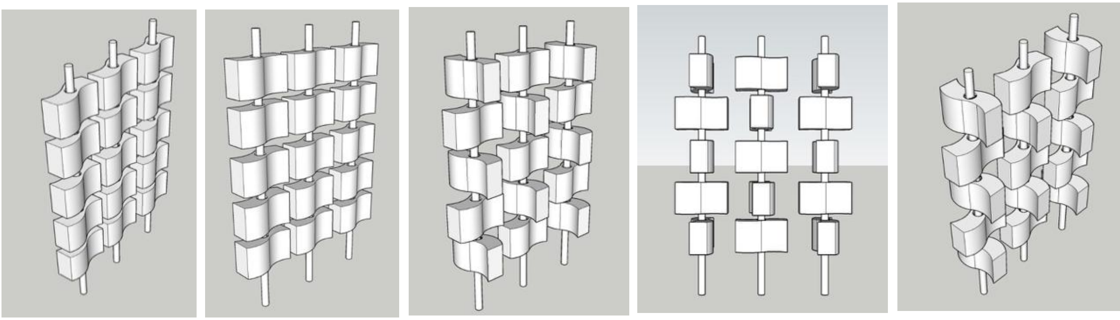

Figure 7: Interior arrangement [Source: Authors' Creations]

5. CONCLUSIONS AND SCOPE FOR FUTURE RESEARCH

This research's findings demonstrate and describe the potential of porcelain bisque waste as an environmentally sustainable alternative for interior construction, while promoting the reuse of ceramic waste and supporting circular economy practices. This research highlighted the potential of using porcelain bisque waste as a sustainable material for interior construction in Sri Lanka. This composition exhibits physical and functional properties, including water absorption, thermal performance that contributes to a cooler environment, aesthetic appeal, and good strength and flexibility. Based on these qualities, the findings indicate that combining porcelain bisque waste with red earthenware clay can produce a new modular unit. It can be introduced for non-load-bearing interior partitions fixed to the floor. The proposed modular unit can be applied to the interior partition system, offering lightweight construction, easy installation, straightforward arrangement, and replacement. The proposed material properties can be modified by altering the material composition and the firing temperature to suit the required indoor environment. As an interior arrangement, the modular configuration enables a variety of design possibilities and spatial arrangements.

The proposed design solution addresses porcelain tableware bisque-ware waste while introducing a modular system as a novel, sustainable application in interior construction. For further development, the proposed material and modular design can be enhanced by incorporating water retention within the modular units, allowing moisture to penetrate the clay structure, and promoting cross-ventilation for cooling in indoor environments. This will support evaporative cooling and improve air circulation, thereby reducing energy consumption for indoor climate control. Future research should investigate the optimal percentage of porcelain bisque waste in the material composition, as well as the feasibility of large-scale manufacturing, production processes, production costs, and market unit pricing. These aspects are essential for assessing the commercial viability and practical implementation of the proposed modular system in the interior construction industry.

The proposed solution has the potential to be adopted by other ceramic manufacturers in Sri Lanka and internationally for the sustainable reuse of porcelain bisque waste. However, further research and industry-scale validation are required to assess its technical feasibility, economic viability, and adaptability to different manufacturing contexts. The system's cooling performance has not yet been fully validated under real-world operating conditions. This area is reserved for future researchers to continue this experimental study. Further long-term assessments are required to evaluate and optimise its effectiveness under real-world conditions.

6. ACKNOWLEDGEMENTS

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