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Exploration of Material Manipulation: Utilizing glass wool residue as aggregate material in ceramic works

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Abstract
Ceramic production generates various waste materials such as clay, glaze, glass wool, bisque, glazed shards, and gypsum, all of which present disposal challenges and potential groundwater contamination. This study investigates the reuse of residual glass wool as an aggregate in ceramic bodies through a practice-based research approach. Despite being commonly discarded due to its fragility, glass wool was incorporated into different clay compositions from pre- to post-production stages to examine its material behaviour. Findings indicate that small additions enhance structural strength and produce unique surface textures, demonstrating a sustainable and innovative material strategy in contemporary ceramic practices.

Keywords: Ceramic; waste; glass wool; aggregate; contemporary arts

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1.0 Introduction

The ceramic industry, whether at the artisanal or industrial level, inevitably generates waste in both solid and liquid forms in varying quantities (Souza et al., 2025). Common types of waste include clay scraps, glaze waste, gypsum waste, bisque ceramic waste, glazed ceramic waste, and glass wool waste originating from kiln insulation systems. Kilns insulated with glass wool require periodic maintenance or replacement once the material degrades, in order to ensure safe operation and maintain optimal thermal efficiency during production.Glass wool is a heat-resistant, non-combustible material composed of glass fibres, capable of withstanding temperatures of up to 1400°C (Rywotycki et al., 2024). High-quality glass wool typically exhibits fibre densities ranging from 64 kg/m^3 to 160 kg/m^3. Variations in density influence gas leakage during firing, mechanical durability, and the overall lifespan of the material, thereby significantly affecting production efficiency, operational costs, and firing performance (Lemougna et al., 2023). Recent studies have primarily examined glass wool in relation to thermal performance, insulation efficiency, and material durability. However, limited attention has been given to its post-use phase and its potential reuse within ceramic production systems. This gap becomes particularly relevant in small-scale and artisanal studios, where standardised waste management infrastructures are often absent. In the Indonesian context, this issue has been reflected in the prolonged accumulation of discarded glass wool within artist studios, in some cases stored for decades. Drawing upon concerns reported by local ceramic practitioners (Lim et al., 2023), the present study positions glass wool waste not only as a technical by-product but also as a material resource requiring further investigation. This condition forms the basis of the

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current research, which explores alternative approaches to managing and reprocessing glass wool residue through experimental ceramic practice.

In previous research, the author experimented with processing glass wool waste into an alternative material for ceramic kiln construction. However, during the process, unusable glass wool residue remained. This research focuses on identifying how such residue might be repurposed as an additive in clay formulation. The clay used in this study is also industrial waste material from a local factory. A significant drawback of this reclaimed clay is its lack of structural strength, due to contamination with waterglass (sodium silicate), which causes the clay to appear solid while retaining excessive moisture. Therefore, the study aims to reformulate a mixture using different types of waste clay, raw materials, and glass wool residues to evaluate the structural integrity of the resulting material and assess its artistic potential when applied to ceramic artwork. The goal is to develop a sustainable new material that merges technical feasibility with aesthetic exploration. This study focuses on the residual glass wool waste that remains after previous utilisation efforts. Building upon earlier research that used glasswool to construct alternative ceramic kilns, this paper explores the feasibility of repurposing glasswool residue as an aggregate material in ceramic works. The residue will be tested in several clay formulations, and the most suitable formula will be applied in the creation of ceramic pieces. By employing a practice-based research method, this project aims to uncover new material potentials while contributing to environmentally responsible ceramic practices. In recent decades, the global ceramics industry has experienced rapid growth in both artistic and industrial domains, leading to an increase in material waste generation. This includes not only the commonly recognised clay and glaze waste but also insulating materials such as glass wool, which are often overlooked in discussions about sustainability. As environmental awareness intensifies, artists and researchers are increasingly challenged to address the environmental impact of their material practices (Suharson & Fitiani, 2024).

Within this context, waste from ceramic production is not merely an operational concern but also an ethical and ecological issue that demands critical intervention through creative research. In Indonesia, the problem is further compounded by the lack of standardised waste management systems, especially in small-scale ceramic studios and independent artist workshops. Many ceramicists are forced to accumulate waste in their studios for extended periods or dispose of it through informal means such as open dumping or burial. This creates long-term environmental risks, particularly when dealing with materials that contain fibrous or chemical components, such as glass wool. The situation highlights a systemic gap between material consumption and responsible waste management, underscoring the urgent need for localised, practical, and innovative solutions. Researchers have explored the recycling of clay and glaze waste within studio practices and investigated the role of sustainable design in reducing ecological footprints. There is a growing interest in integrating non-conventional materials into ceramic processes. Studies involving paper, textiles, and organic matter have demonstrated that material manipulation can lead to aesthetic innovation while also promoting sustainability.

However, research on the use of glass wool residue in ceramic production remains limited and requires further exploration. A relevant study by Adediran et al. (2021), titled *"Recycling Glasswool as a Fluxing Agent in the Production of Clay and Waste-Based Ceramics,"* examined the inclusion of 10% glass wool in a mixture of kaolin and industrial residue fired at 950°C. The findings confirmed that glass wool can act as a flux, beginning to melt at around 700°C. Another study by Rywotycki et al. (2024), titled *"Thermal Removal of Binder from Waste Glasswool Intended for Recycling,"* investigated the thermal treatment of glass wool at various temperatures to eliminate organic compounds, successfully reducing carbon content from 5.3% to 0.7%. Based on these conditions, this study aims to explore the potential of glass wool residue as an alternative ceramic material through experimental and practice-led research. The objectives of this study are to investigate the material behaviour of glass wool when incorporated into clay bodies, examine its thermal response and fluxing potential during firing, and assess its feasibility as a localised and practical waste-management strategy for small-scale ceramic studios and independent artist workshops.

2.0 Methodology

This study employs a Practice-Based Research (PBR) approach, as defined by Linda Candy (2006), which emphasises original investigation conducted through creative practice, where the resulting artefacts function as a primary contribution to knowledge. In this context, the ceramic artefacts produced through the exploration of glass wool residue are not merely visual outcomes but also operate as material evidence for understanding transformation processes, material behaviour, and sustainability-oriented practices. The PBR approach was selected to enable iterative experimentation and embodied material inquiry, allowing the researcher to observe changes in texture, vitrification, and structural response that cannot be fully captured through theoretical analysis alone. To strengthen methodological rigour, the practice-based exploration was supported by basic material observation and physical documentation, including changes in density, surface characteristics, and absorption behaviour. Microstructural observations were used to support interpretation of the interaction between clay bodies and glass wool residue, particularly at the surface and vitrification interface. The PBR model adopted in this research is divided into three main stages: pre-production, production, and post-production. Each stage involves systematic documentation and reflective evaluation, following Donald Schön's (1983) principles of reflection-in-action and reflection-on-action, which support continuous critical engagement throughout both the making process and the evaluation of completed artefacts.

As illustrated in Fig. 1, the pre-production phase involved a literature review conducted in parallel with the identification of physical characteristics of glass wool residue sourced from previous ceramic kiln construction processes. This stage was designed to establish an informed experimental framework, ensuring that material selection and formulation were grounded in existing thermal and material studies. Based on this analysis, several clay–glass wool mixtures with varying ratios were formulated. The gradual variation of composition was intentionally applied to observe material response, structural stability, and fluxing behaviour across different proportions, thereby providing comparative insight into the feasibility of utilising glass wool residue as an aggregate material in ceramic art production. Considering the fibrous and potentially hazardous nature of glass wool, material preparation and handling were conducted following basic studio safety protocols. These included the use of respirators, protective gloves, and controlled material processing in ventilated environments to minimise airborne fibre exposure during experimentation.

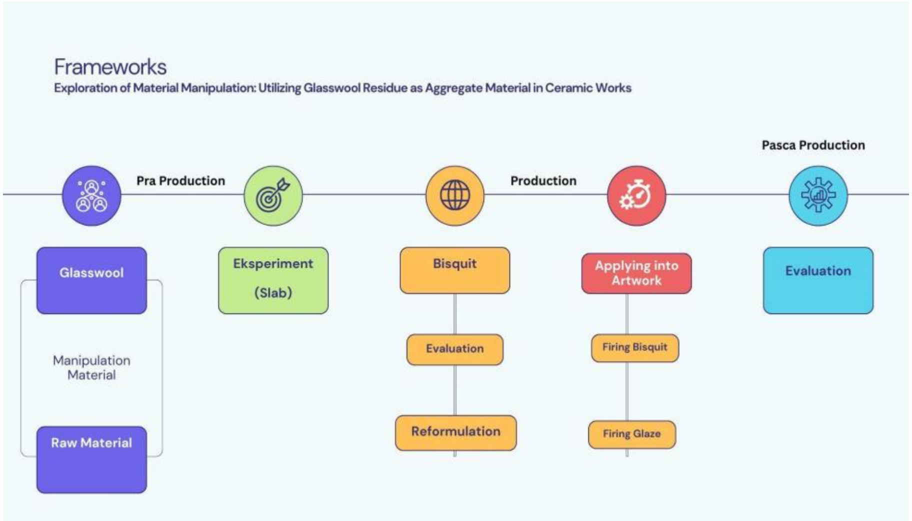


Fig. 1 Framework
(Source: Fitriani, et al., 2025)

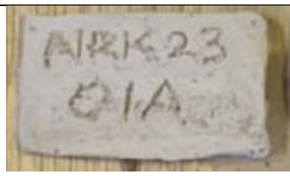
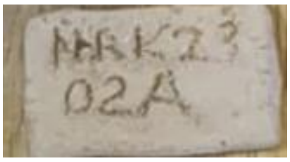
3.0 Findings

Initial findings indicate that when glasswool residue is mixed into clay at various proportions in Fig. 2, it results in distinct differences in both strength and texture. Formula 1 produced a noticeably rougher surface compared to Formula 3 but demonstrated superior structural strength. Glasswool remains safe to use at concentrations not exceeding 20%, as excessive amounts disrupt the clay's cohesion, rendering it non-plastic, difficult to form, and incapable of achieving adequate glaze adhesion, as illustrated in Fig. 4. Glasswool shows potential as a viable aggregate and can be effectively utilised at a recommended concentration of 5% of the total clay body. The incorporation of glasswool residue yields a distinct surface character, often manifesting as glaze crawling due to the clay body's inability to absorb and hold the glaze evenly. Although glass wool contributes to the structural reinforcement of the clay body, it simultaneously reduces surface porosity, hindering glaze retention and causing visible cracking across the surface. This limitation, however, produces an unexpected artistic effect that contributes to the visual identity of the works. Thus, clay formulas incorporating glasswool are suitable for decorative ceramic pieces but not for functional ware, as the chemical composition of the residue may pose risks of contamination upon use.

Fig. 2 Material from Ceramic Waste
(Source: Fitriani et al., 2025)

Table 1. Clay Formulation

No	Formula	Piece 1 (Greenware)	Piece 2 (After Firing)
	15% glasswool residue 50% clay waste 35% mix of soil		

		
10% glasswool residue 50% clay waste 40% mix of soil		
5% glasswool residue 50% clay waste 45% mix of soil		

(Source: Rahma, 2025)

Based on the trials conducted as presented in Table 1 above, the results indicate that the first formula produced a coarser texture due to the higher content of glass fibre residue. In contrast, the third formula resulted in a smoother surface. However, the clay mixture used in the first experiment, comprising Sukabumi clay, kaolin, and feldspar for plasticity considerations, was later replaced with Pacitan clay. During the production phase, the mixture incorporating Pacitan clay was preferred because of its higher plasticity and naturally darker colour. The new clay blend that most closely matched the desired quality was based on Formula 3, with 45% of the content replaced by Pacitan clay. This selected formula was then applied using hand-building techniques such as slab, pinch, and coil, as illustrated in Figure 3. At this stage, the researcher carefully documented both the visual and technical processes, as well as the intuitive responses that emerged when working with the new material. The documentation included recording changes in the clay's characteristics throughout processing from wedging to the initial drying stage in order to identify potential shrinkage, cracking, or shape deformation. In addition, the researcher observed how the natural colour of Pacitan clay influenced the aesthetic perception of the final outcome, particularly in the context of exhibitions that emphasise a sense of natural materiality. Preliminary findings suggest that this combination not only improves surface smoothness but also provides adequate structural strength for larger-scale forming experiments. This opens up opportunities for further development in the exploration of both sculptural and functional forms while maintaining the tactile quality that is central to this research.

Fig. 3 Material from Ceramic Waste
(Source: Fitriani, et al, 2025)

After the forming process, the pieces underwent a drying phase. Usually, pure clay dries within three days, but this clay formulation did not fully dry even after a week, indicating a significantly longer drying time compared to standard clay. To test the durability of the clay while still semi-wet, the works were directly fired. The firing was conducted using a single firing method; conventionally, ceramic pieces undergo two firing stages—a bisque firing at 900°C, followed by a glaze firing at 1150–1200°C. In this case, the author skipped the bisque stage: the semi-dry pieces were glazed immediately using a spray technique with two layers of colour, then fired. The firing lasted 14 hours, reaching a peak temperature of 1190°C, as shown in Fig. 3a. The post-production phase involved an analysis of the final results: surface quality, texture, structural strength, shrinkage rate, and aesthetic potential. After firing, the kiln was left to cool for

12 hours, until it reached room temperature (approximately 38°C), before being opened. At this stage, a critical reflection was carried out to evaluate the potential and limitations of incorporating glass wool residue into ceramics. Comprehensive documentation was also conducted as part of the research narrative, illustrating the close relationship between practice, process, and the knowledge generated.

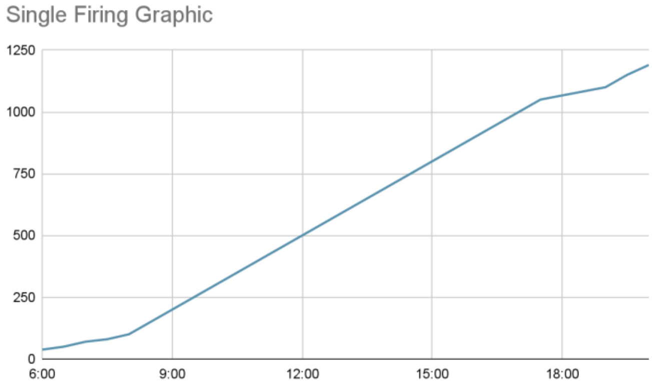


Fig. 3a Graphic
(Source: Fitriani, et al., 2025)

This model allows for direct involvement in material experiments alongside theoretical reflection, positioning the manufacturing process as a source of data and analytical method in environmentally orientated craft research. Of the 16 works created using reformulated materials with glass fibre residue, some remained intact, while one work exploded at the top due to internal air pockets caused by imperfect mixing. The glaze was applied using a spray gun and compressor. Still, the inability of the clay to adhere properly caused the glaze not to adhere perfectly, a phenomenon commonly referred to as "crawling" in ceramics. This was also influenced by the single firing method and firing the piece while it was still wet. However, structurally, glass wool can aid in good construction when combined with waste clay. Pure waste clay can indeed be used, but under certain conditions, it is more prone to melting due to a lack of fibres and excessive waterglass content, which also causes pure waste clay to take longer to dry. Figure 4 shows that even in a wet state and exposed to rapid and fluctuating temperature changes, clay mixed with glass fibres exhibits greater durability and strength compared to pure clay.

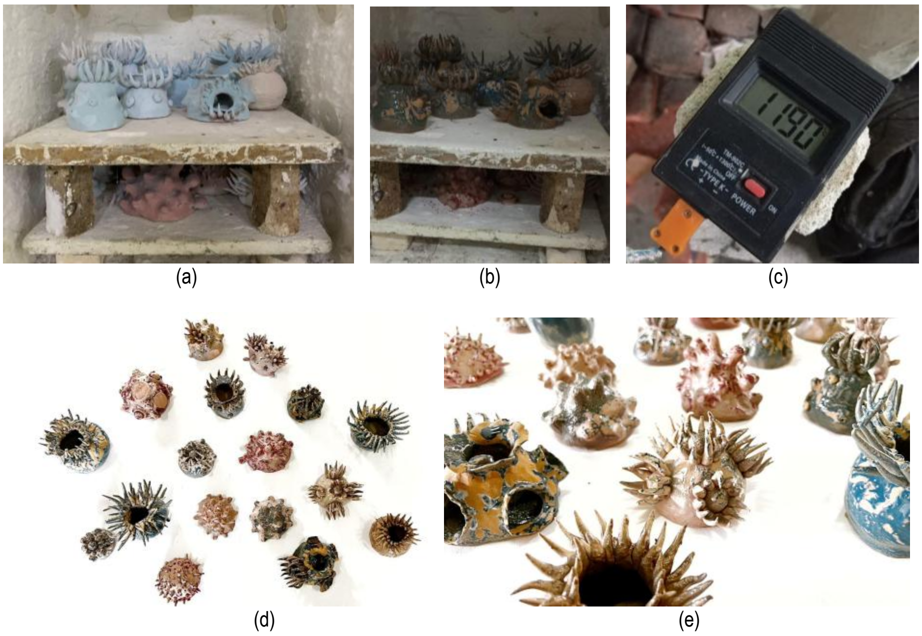


Fig. 4 (a) Before Firing, (b) Firing, (c) Thermocouple, (d) result 1, (e) result 2
(Source: Fitriani, et al., 2025)

4.0 Discussion

The reutilization of glass wool residue in ceramic production presents a compelling intersection between sustainability, material innovation, and critical artistic inquiry. This study not only reveals the technical potential of glass wool as an aggregate material but also challenges the established hierarchies in ceramic material practices. Typically discarded due to its fragility and concerns about toxicity, glass wool is reimagined here not as waste, but as a contributor to a new material vocabulary within contemporary ceramics. The integration of glass wool residue offers a multifaceted approach to reducing the ecological footprint of ceramic studios, particularly in regions such as Indonesia, where formal waste processing systems are underdeveloped. By reclaiming this industrial byproduct, the study embodies the principle of material circularity, emphasising a localised response to global sustainability imperatives. It signals a paradigm shift from the conventional logic of extraction and disposal toward one of recovery, adaptation, and regeneration.

Technically, the study shows that glasswool, when used in optimal quantities (not exceeding 5%), can enhance structural strength while simultaneously producing unique surface textures through glaze crawling and surface cracking. These qualities, while traditionally considered defects in functional ceramics, acquire aesthetic and conceptual value in the realm of sculptural and experimental works. This subversion of expected outcomes aligns with the ethos of material agency, where the unpredictable behaviour of matter is embraced as an active participant in the creative process, rather than a passive medium to be controlled. However, the inclusion of glass wool is not without its limitations. Its presence interferes with plasticity and glaze bonding, and its chemical instability raises concerns for food-safe or functional applications. These drawbacks underscore the importance of critical material literacy—understanding not only how materials perform but also the ethical implications of their origin, transformation, and eventual afterlife. In this regard, the study indirectly addresses the material ethics of making, urging artists to reckon with the consequences of their material choices. Moreover, the adoption of a Practice-Based Research (PBR) methodology enables the research to contribute beyond utilitarian concerns, positioning the ceramic objects as epistemological artefacts, embodied forms of knowledge that result from iterative engagement and reflexive making.

The ceramic pieces function as sites of negotiation between control and chance, aesthetic intentions, and material resistance. This reflective approach aligns with broader movements in post-disciplinary craft and new materialism, which call for a reinvention of making as a form of critical inquiry rather than mere production. Importantly, this research reaffirms the capacity of studio ceramics to act as a microcosm for larger systemic change. In contexts where sustainability is often viewed through a technological or policy lens, the studio becomes a site of grassroots innovation. Glasswool residue, a material typically associated with insulation and construction, is transformed into an agent of poetic and political expression. This radical recontextualisation emphasises how artistic practice can illuminate alternative ecological futures—ones that are situated, relational, and materially attentive. From an educational and institutional standpoint, this project also raises questions about how sustainable material innovation can be embedded within the curriculum of art and craft institutions.

The lack of structured waste management systems in art schools, particularly in Southeast Asia, highlights the need to rethink pedagogies that prepare students not only to be skilled makers but also environmentally conscious practitioners. This study exemplifies how academic research can catalyse such shifts, encouraging hands-on experimentation, ecological thinking, and community collaboration. It advocates for a future where sustainability is not an optional add-on but a foundational ethos woven into every stage of the making process, from sourcing and design to disposal and reuse.

5.0 Conclusion and Recommendation

This research has demonstrated that glass wool residue, commonly regarded as a hazardous and unrecyclable byproduct in ceramic practices, holds overlooked potential as an aggregate material in contemporary ceramic works, particularly within sculptural and experimental contexts. Utilising a practice-based research approach, this study assessed both the technical viability and the aesthetic and conceptual possibilities of the material. While the residue presents limitations, including reduced plasticity and weak glaze adhesion, it also generates distinctive surface characteristics such as glaze crawling, cracking, and unpredictable textures. Within the context of artistic practice, these outcomes were interpreted not merely as technical deficiencies but as material provocations that expand the expressive language of ceramic art. More significantly, this research challenges the conventional binary between material and waste, questioning how value is constructed within artistic production. By recontextualising glass wool residue as a creative resource, the study contributes to broader discussions on material ethics, environmental accountability, and the role of artists as agents of sustainable transformation. In contexts such as Indonesia, where formal waste-management infrastructures remain limited within small-scale ceramic studios, such approaches emerge not simply as alternatives but as necessary interventions. Nevertheless, several limitations must be acknowledged. Due to its unstable chemical composition and potential health risks, the application of glass wool residue should be restricted to non-functional ceramic works. The absence of material stabilisation processes and long-term performance evaluation represents a key limitation of this study. Therefore, future research is recommended to focus on chemical or mechanical stabilisation methods to improve workability, reduce toxicity, and enhance compatibility with different clay bodies. Long-term durability testing—particularly under environmental stressors such as humidity, temperature fluctuation, and mechanical pressure—is also essential to evaluate material resilience over time. In addition, the findings indicate the need for institutional-level engagement. Art schools and ceramic studios are encouraged to develop standardised protocols for waste handling, experimentation, and safety, including clear guidelines for ventilation, protective equipment, and material processing. Embedding material literacy and ecological awareness within educational curricula may strengthen the continuity of sustainable ceramic practices. Finally, this study identifies several directions for further research. Interdisciplinary collaboration between ceramic practitioners, material scientists, and environmental researchers could expand both analytical depth and practical application. Community-based initiatives such as open studios, artist residencies, and participatory workshops may further support knowledge exchange and public engagement. The methodological framework applied in this research may also be extended to the exploration of other underexamined ceramic waste streams, including kiln bricks, glaze slurry, and bisque shards. Through such expansions, ceramic practice may continue to function as a site of creative experimentation and ecological reflection, offering alternative material pathways that are both artistically generative and socially responsive.

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Paper Contribution to Related Field of Study
This paper contributes to the field of craft and ceramic studies by exploring sustainable material innovation through the reuse of residual waste. Applying a Practice-Based Research (PBR) methodology, this study bridges artistic experimentation and ecological responsibility. It opens new perspectives on non-traditional materials in ceramics and promotes reflective, process-orientated approaches within environmentally conscious creative practices.

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