

Rubber Bricks Production Machine

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Abstract

This study aimed to design, fabricate, and evaluate a Rubber Bricks Production Machine intended for small-scale processing of discarded rubber tires into composite construction materials. Anchored in recycling theory, materials engineering, mechanical design principles, and an input–process–output framework, the study employed developmental and quantitative research designs. Thirty purposively selected respondents, comprising 15 faculty members from the University of Southern Mindanao–Kidapawan City Campus and 15 construction industry workers from Kidapawan City, evaluated the prototype using a validated 30-item questionnaire. Data were analyzed using frequency counts, percentages, and mode. Findings revealed that the machine's design was highly acceptable, particularly in structural assembly, durability, and maintenance accessibility. Usability was generally acceptable, with 23 respondents (76.67%) rating beginner-friendliness highly acceptable and 22 (73.33%) similarly rating ease of operation. However, overall functionality was moderately acceptable because of limitations in shredding efficiency, mixing consistency, and component synchronization. Initial testing identified excessive motor speed, rubber clogging, and shaft misalignment. Replacing the original 5-horsepower motor with a 2-horsepower motor, installing a gear reducer, and adjusting spacers improved operation but did not achieve sufficiently fine rubber particles. The study concluded that the prototype was suitable for initial small-scale applications but required improvements in blade configuration, material flow, mixing efficiency, and mechanical integration. The project aligns with Sustainable Development Goals 9 (Industry, Innovation and Infrastructure), 11 (Sustainable Cities and Communities), and 12 (Responsible Consumption and Production) through technological innovation, alternative construction materials, and waste utilization. Its potential sustainability contributions include resource conservation, applied engineering education, and community-oriented rubber recovery, although large-scale environmental and production outcomes were not evaluated.

Keywords: Circular Economy, Machine Design, Prototype Development, Recycling Technology, Rubber Bricks, Rubber Shredding, Sustainable Construction, Usability, Waste Rubber

1. Introduction

The increasing demand for construction materials and the accumulation of discarded rubber tires present significant environmental and technological challenges. Conventional brick production consumes natural resources and energy, while improper tire disposal contributes to pollution and waste accumulation. Recycling waste rubber into composite bricks offers an alternative approach that supports resource conservation, waste reduction, and sustainable construction. This study focuses on the design, fabrication, functionality, and acceptability of a Rubber Bricks Production Machine intended for small-scale production. By integrating rubber shredding, mixing, and brick-forming processes, the project explores a practical application of recycling technology and mechanical engineering. It also examines the machine's design and usability as essential considerations in developing an accessible and environmentally responsible production system.

Rapid urbanization and infrastructure development have increased the demand for construction materials, particularly bricks. However, conventional clay- and cement-based brick production requires substantial energy and raw materials, contributing to greenhouse gas emissions and natural resource depletion (Marinelli et al., 2023). Simultaneously, improper disposal of used tires remains a global environmental concern. More than one billion waste tires are generated annually, many of which accumulate in landfills and open dumpsites (Helmy et al., 2023). Because rubber is non-biodegradable, discarded tires can persist for extended periods, contributing to environmental pollution and potential health risks (Pei et al., 2024). The incorporation of recycled rubber into construction materials presents an opportunity to address these challenges. Alibrahim (2024) found that rubberized concrete demonstrates improved toughness and impact resistance, although its compressive strength may decrease. These properties suggest the potential application of recycled rubber in alternative construction products. In response, the present study developed a Rubber Bricks Production Machine designed to facilitate the processing of waste rubber into composite bricks. The project seeks to improve production consistency, reduce manual processing requirements, and support environmentally responsible material utilization. This approach aligns with circular economy principles emphasizing the transformation of waste into valuable resources (Marinelli et al., 2023). The study specifically aims to design and fabricate the machine, evaluate its functionality, and determine its acceptability in terms of design and usability. The prototype is intended for small-scale production of rubber composite bricks measuring $2.5 \times 4 \times 8$ inches. Recent evidence also indicates that crumb-rubber particle shape and dosage affect concrete strength and toughness (Hasan et al., 2025).

The literature identifies waste rubber characteristics, binder selection, material proportions, shredding mechanisms, mixing systems, molding processes, and machine construction as essential considerations in developing a rubber brick production machine. Globally, approximately 1.4 billion tires are manufactured annually, generating substantial quantities of end-of-life tires, which are projected to reach 1.2 billion annually by 2030 (Helmy et al., 2023). Improper disposal and stockpiling create environmental concerns, highlighting the importance of alternative recycling technologies. Recycling discarded tires can reduce landfill accumulation and conserve natural resources (Pei et al., 2024). Siddika et al. (2019) reviewed the properties and applications of waste tire rubber in concrete and highlighted its potential as a supplementary construction material. Their review emphasized that rubber particle characteristics and incorporation methods influence the mechanical performance, durability, and serviceability of rubberized cementitious composites. These findings provide additional support for investigating recycled rubber as a component of alternative construction materials. Waste rubber can be incorporated into composite bricks, paving blocks, and insulating materials. He et al. (2023) emphasized its potential for producing construction materials with improved flexibility and impact resistance, particularly for non-load-bearing applications. Similarly, Li et al. (2022) reported that treated rubber particles can improve durability and energy absorption in construction composites. The mechanical performance of rubber bricks depends considerably on binder selection and material proportions. Azunna et al. (2024) demonstrated that polyurethane binders provide effective adhesion between crumb rubber particles, producing durable and semi-flexible composites. Binder selection and interfacial bonding require material-specific testing; findings for cement-based rubber concrete should not be assumed to establish epoxy-bonded rubber-brick performance. Rubber content influences the strength and flexibility of composite materials. Higher rubber proportions generally improve energy absorption and flexibility but may reduce compressive strength (He et al., 2023). Similarly, Valente and Sibai (2019) reviewed the mechanical properties of concrete incorporating recycled tire rubber and reported that increasing rubber content generally reduces compressive strength and density while improving toughness. Their findings highlight the importance of controlling rubber proportions to achieve an appropriate balance between mechanical performance and material characteristics. These considerations are relevant to the development of rubber-based construction products, although the performance of rubber bricks requires separate experimental validation. Muhammad et al. (2023) reviewed the fresh and hardened properties of concrete incorporating waste tire rubber, highlighting the importance of evaluating how recycled rubber affects the performance of cement-based composites. These findings emphasize the need to consider material properties when developing alternative rubber-based construction products. Studies recommend rubber replacement levels of approximately 10%–25% to balance mechanical performance and sustainability benefits (He et al., 2023). Rubber incorporation can also reduce material density and improve thermal and acoustic insulation, supporting potential non-load-bearing applications (Helmy et al., 2023). Appropriate binder-to-rubber proportions, additives, and mixing techniques are necessary to improve material bonding and minimize strength reduction (He et al., 2023). Zhang et al. (2023) reviewed the workability and durability of concrete incorporating waste tire rubber and found that rubber addition can reduce workability while producing varying effects on durability properties, including water absorption, permeability, and resistance to environmental exposure. Their findings emphasize the importance of evaluating material proportions and processing conditions when developing rubber-containing construction composites. Although these findings concern cement-based concrete, they provide useful background for considering material consistency and the need for further testing of rubber brick products. Similarly, aggregate characteristics influence the durability, flexibility, and mechanical performance of rubber composites (Azunna et al., 2024; Helmy et al., 2023). Excessive rubber replacement may reduce stiffness and compressive strength (He et al., 2023; Helmy et al., 2023). Replacement levels of approximately 10%–30% have been identified as a

possible balance between sustainability and mechanical performance (He et al., 2023), while particle size, gradation, surface treatment, and mixing consistency further affect material homogeneity (He et al., 2023). Efficient processing equipment is equally important. Uniform blending of crumb rubber, binders, and additives is an important consideration in rubber composite production because mixing consistency influences material homogeneity and the quality of the resulting composite. Mixing-system durability requires separate evaluation; the cited mechanical tire-recycling review does not establish mixing-chamber durability. Molding precision is an important consideration in brick manufacturing because molding methods and compaction conditions influence the characteristics of the resulting products. Gupta et al. (2020) reviewed manufacturing processes for waste-incorporated unfired bricks and highlighted the importance of appropriate molding techniques, compaction parameters, and material proportions in achieving desirable mechanical performance. Standard brick dimensions of $2.5 \times 4 \times 8$ inches also facilitate handling and construction compatibility, as referenced in ASTM International (2017). The shredding mechanism is another critical component. Mechanical tire-recycling performance depends on the shredding configuration, operating parameters, and downstream particle-size reduction processes (Pei et al., 2024). Machine performance further depends on motor capacity and structural stability. Mechanical recycling performance depends on appropriate process design and operating parameters (Pei et al., 2024). The prototype's motor sizing and mild-steel selection are design choices that require direct engineering validation. Collectively, these studies establish the importance of integrating suitable recycled materials, effective binding systems, durable mechanical components, controlled processing, and reliable machine design in rubber brick production. Recent reviews emphasize the influence of particle size, replacement ratio, and rubber treatment on composite performance (Chaus & Marushchak, 2025; Wei, 2025).

The global accumulation of discarded tires and the environmental impacts of conventional construction materials have encouraged the development of alternative recycling and manufacturing technologies. International developments demonstrate the potential of integrating waste processing, mechanical automation, and construction material production. Existing technologies provide relevant foundations for the proposed machine. In the United States, Curtis (2015) developed a masonry siding system with embedded inserts (US20150218829A1), demonstrating the application of specialized molding techniques in construction materials. In China, Jiang et al. (2022) developed a waste tire recycling apparatus (CN215472420U) incorporating crushing rollers and vibrating screening mechanisms to improve rubber processing efficiency. Another United States invention by Yang (1985) introduced a high-speed automatic brick-making machine (US4515549A) that integrates material feeding, molding, pressing, and brick release to facilitate continuous production. These technologies demonstrate advancements in material processing and automated brick production. However, the present study concentrates on integrating rubber processing and brick production within a prototype intended for small-scale application. In the Philippine context, the project was developed at the University of Southern Mindanao–Kidapawan City Campus, Kidapawan City, Cotabato. The study involved faculty members from the College of Technology and selected construction industry workers in Kidapawan City who possessed relevant technical and practical experience. The local setting provided opportunities to examine the machine's functionality, design, and usability while considering the potential application of recycled rubber in small-scale construction material production. The study therefore connects international recycling and manufacturing concepts with local technological development and sustainability objectives.

The development of the Rubber Bricks Production Machine is grounded in recycling theory, materials engineering, mechanical design principles, and an input–process–output conceptual framework. Recycling theory emphasizes converting discarded materials into useful products to minimize environmental degradation and conserve resources (Marinelli et al., 2023). Through the principles of reducing, reusing, and recycling, waste tires can serve as alternative raw materials for producing rubber composite bricks. Materials engineering explains how combining different materials can improve the physical and mechanical properties of manufactured products (He et al., 2023). In rubber brick production, the interaction between rubber particles and binding materials influences strength, durability, and flexibility. Azunna et al. (2024) demonstrated that polyurethane binders effectively bond crumb rubber particles, supporting the production of durable and semi-flexible composites. Material proportions, curing conditions, and molding pressure consequently remain important considerations in rubber brick development. Shigley's Mechanical Design Theory (Budynas & Nisbett, 2020) provides the engineering foundation for developing reliable, efficient, and safe mechanical systems. The theory supports the design of shredding, mixing, compression, and molding components through appropriate load distribution, mechanical power transmission, and operational stability. Pei et al. (2024) further emphasized the importance of sufficient compaction force and controlled processing conditions in equipment designed for waste rubber applications. The study also follows an input–process–output conceptual framework. Inputs include the machine concept, design, materials, tools, equipment, time, and labor. The process involves planning, designing, constructing, testing, revising, and evaluating the prototype. The intended output is a fabricated Rubber Bricks Production Machine assessed according to its functionality, design, and usability. Together, these theoretical and conceptual foundations establish the relationship between recycled material utilization, mechanical system development, and the evaluation of machine performance.

Existing studies establish the potential of recycled rubber as a construction material and identify important factors affecting rubber composite performance, including material proportions, binder effectiveness, mixing uniformity, and compaction. Previous technological developments also demonstrate the application of shredding systems and automated brick-making mechanisms. However, the reviewed literature does not directly establish the functionality, design acceptability, and usability of an integrated Rubber Bricks Production Machine developed for the specific small-scale setting of this study. Although the individual processing technologies are documented, their application within the proposed prototype requires practical development and evaluation. This study addresses that need through the design and fabrication of a machine incorporating a hopper, shredding mechanism, mixing assembly, structural frame, and motor-driven system. The prototype is intended to produce rubber composite bricks measuring $2.5 \times 4 \times 8$ inches. The investigation focuses on three objectives: designing and fabricating the machine, evaluating its functionality, and determining its acceptability in terms of design and usability. Thirty purposively selected respondents, consisting of fifteen faculty members from the University of Southern Mindanao–Kidapawan City Campus and fifteen industry workers, participated in evaluating the project. The investigation is limited to prototype-scale production and does not extend to industrial manufacturing, alternative additives, or long-term durability evaluation. These boundaries establish the study's focus on machine development and initial performance assessment rather than comprehensive validation of rubber bricks for structural construction. The study is therefore justified by the need to examine the practical application of recycled rubber processing technology and determine the acceptability of a locally developed pretreatment and composite properties separately from machine usability and production performance (Wei, 2025; Chaus & Marushchak, 2025).

The development of the Rubber Bricks Production Machine aligns primarily with Sustainable Development Goals 9, 11, and 12 through its emphasis on technological innovation, sustainable construction materials, and waste resource utilization. SDG 9 – Industry, Innovation and Infrastructure. The study supports technological innovation through the design and fabrication of a machine that integrates rubber shredding, mixing, and brick production processes. Its focus on small-scale equipment development demonstrates the application of mechanical engineering and fabrication techniques to alternative construction material production. SDG 11 – Sustainable Cities and Communities. The project explores the potential use of recycled rubber bricks in non-structural applications such as pavements, walkways, and landscaping. By investigating an alternative construction material derived from discarded tires, the study supports efforts toward more resource-conscious infrastructure development and improved waste utilization. SDG 12 – Responsible Consumption and Production. The study directly supports responsible material consumption by exploring the conversion of waste rubber into useful composite bricks. Its emphasis on recycling and material recovery reflects circular economy principles, which encourage waste reduction and the productive reuse of discarded resources (Marinelli et al., 2023). These SDGs are directly connected to the project's intended environmental and technological contributions. However, the study evaluates a prototype rather than measuring large-scale waste reduction, lifecycle environmental impacts, or commercial production outcomes.

The study contributes to multidisciplinary sustainability by connecting environmental management, mechanical engineering, materials science, technological education, and community-oriented resource utilization. From an environmental sustainability perspective, the machine explores an alternative method of managing discarded rubber tires by converting them into potentially useful construction materials. This approach supports waste reduction, resource conservation, and the productive utilization of materials that would otherwise contribute to environmental pollution. In terms of technological and engineering sustainability, the study demonstrates the integration of mechanical components into a prototype designed for small-scale rubber brick production. Its evaluation of functionality, design, and usability provides a basis for identifying improvements in machine efficiency, reliability, and operational performance. The project also contributes to materials sustainability by exploring the use of recycled rubber in composite bricks. It recognizes the importance of appropriate binding materials, mixing consistency, and processing conditions in producing alternative construction products. Regarding educational and institutional sustainability, the study provides a practical application of technical knowledge in machine design, fabrication, recycling technology, and performance evaluation. Conducting the project within a technology education institution also supports applied learning and future research in sustainable equipment development. From a socio-economic and community sustainability perspective, the project investigates a small-scale production technology that may offer an alternative approach to utilizing locally available waste rubber. Its potential applications in non-structural construction materials may provide a foundation for further technological development and local resource recovery initiatives. Overall, the Rubber Bricks Production Machine demonstrates how mechanical engineering, waste management, materials development, and technological education can contribute to sustainability-oriented innovation. Although further improvements and performance validation are necessary, the study provides an initial foundation for developing practical recycling technologies that support responsible material utilization and sustainable construction practices.

2. Material and methods

2.1 Research Design

The study utilized developmental and quantitative research designs. The developmental approach guided the design, fabrication, testing, and improvement of the Rubber Bricks Production Machine, while the quantitative approach assessed its functionality, design, and usability based on respondents' evaluations. A descriptive approach was also applied to the testing of rubber bricks, including compressive strength testing intended to determine their load-bearing capacity and mechanical performance. The development process involved planning, designing, constructing, testing, revising, and evaluating the prototype. The machine incorporated a hopper, shredding mechanism, mixing chamber, molding assembly, structural frame, and motor-driven components. Mild steel was used for the main structure because of its strength, weldability, and suitability for fabrication. The system included a 2-horsepower electric motor, gear reducer, shafts, bearings, pulleys, carbide blades, and other mechanical components necessary for processing waste rubber. Fabrication involved preparing materials, constructing the frame and processing components, assembling the mechanical and electrical systems, and conducting trial operations. Initial testing identified rubber clogging, excessive motor speed, and shaft misalignment. The original 5-horsepower motor was replaced with a 2-horsepower motor, a gear reducer was installed to regulate speed and increase torque, and the washer and spacer arrangements were adjusted to improve shaft alignment. Despite these modifications, the shredded rubber remained relatively large rather than forming granules suitable for brick production. The prototype was designed for small-scale production of rubber composite bricks measuring $2.5 \times 4 \times 8$ inches. Its evaluation focused on machine performance and acceptability rather than large-scale industrial production.

2.2 Locale of the Study

The study was conducted at the University of Southern Mindanao–Kidapawan City Campus (USM-KCC), located in Kidapawan City, Cotabato, Philippines. The institution served as the primary setting for the fabrication, assembly, testing, and evaluation of the Rubber Bricks Production Machine. Its technical facilities, equipment, and faculty expertise supported the development and assessment of the prototype. Selected construction industry workers from Kidapawan City also participated in the study. Their experience in material handling and construction-related processes provided practical perspectives on the machine's operation and potential application in recycling waste rubber.

2.3 Respondents of the Study

The respondents consisted of thirty individuals, comprising fifteen faculty members from the College of Technology of the University of Southern Mindanao–Kidapawan City Campus and fifteen construction industry workers from Kidapawan City. The faculty members contributed technical evaluations of the machine's design and usability, while the industry workers provided assessments based on their practical knowledge and experience in construction and material processing. Their evaluations were used to determine the acceptability of the developed prototype in terms of functionality, design, and usability.

2.4 Sample and Sampling Procedure

The study employed purposive sampling to select thirty respondents with relevant technical knowledge and practical experience. Participants were chosen based on their ability to provide meaningful evaluations of the Rubber Bricks Production Machine. The sample included fifteen faculty members from the College of Technology of USM-KCC and fifteen industry workers from Kidapawan City. This sampling approach enabled the researcher to obtain assessments from individuals familiar with mechanical systems, equipment operation, and construction-related applications.

2.5 Research Instrument

The study utilized a researcher-developed questionnaire to assess the acceptability of the Rubber Bricks Production Machine in terms of functionality, design, and usability. The instrument consisted of thirty items, with ten items allocated to each evaluation criterion. The questionnaire underwent validation by three mechanical faculty members from the University of Southern Mindanao–Kidapawan City Campus and received an overall validation rating of “Very Highly Valid.” A five-point rating scale was used to interpret respondents' evaluations. Weighted mean scores of 4.21–5.00 were classified as Highly Acceptable, 3.41–4.20 as Acceptable, 2.61–3.40 as Moderately Acceptable, 1.81–2.60 as Less Acceptable, and 1.00–1.80 as Not Acceptable. The instrument provided the quantitative data used to assess the prototype's functionality, design, and usability.

2.6 Data Gathering Procedure

The data gathering process began with the preparation and submission of the required documents to the Research Ethics Committee Office (RESO) for approval. The researcher subsequently requested permission from the Dean of the College of Technology of the University of Southern Mindanao–Kidapawan City Campus to conduct the evaluation involving faculty members. Following approval, the researcher administered the validated

questionnaire to the selected faculty members and industry workers. Respondents evaluated the Rubber Bricks Production Machine based on its functionality, design, and usability. The completed questionnaires were collected, consolidated, and organized for statistical analysis. The responses served as the basis for determining the machine's acceptability and identifying aspects requiring further improvement.

2.7 Data Analysis Techniques

The study employed descriptive statistical techniques, particularly frequency count, percentage distribution, and mode, to analyze respondents' evaluations of the Rubber Bricks Production Machine.

Frequency count was used to determine the number of responses for each evaluation item, while percentage distribution described the proportion of respondents selecting each rating. The mode identified the most frequently selected rating for assessing the machine's functionality, design, and usability. The responses were interpreted using the established five-point acceptability scale, ranging from Not Acceptable to Highly Acceptable. These techniques provided a descriptive assessment of the prototype's acceptability based on the evaluations of faculty members and industry workers.

2.8 Ethical Considerations

The researcher complied with the institutional requirements for conducting the study by submitting the necessary documents to the Research Ethics Committee Office (RESO). Permission was also requested from the Dean of the College of Technology before administering the questionnaire to faculty respondents.

The evaluation was conducted following the required institutional approval procedures, and the collected responses were consolidated and analyzed for the purposes of the study.

3. Results and Discussion

3.1 Development and Acceptability of the Rubber Bricks Production Machine

3.1.1 Design and Construction of the Rubber Bricks Production Machine

The developed Rubber Bricks Production Machine incorporated a hopper, shredding mechanism, mixing chamber, motor-driven transmission system, and structural frame. The shredding mechanism utilized 4-inch carbide blades supported by shafts, bearings, and pillow blocks. A 2-horsepower electric motor connected to a 60:1 gear reducer provided mechanical power, while a belt-and-pulley system transmitted motion to the processing components. The mixing chamber was fabricated from sheet metal, and the structural frame was constructed using steel angle bars. Electrical switches, wiring, epoxy, and welded connections were incorporated into the assembly. Fabrication involved cutting, welding, drilling, component alignment, and mechanical assembly. The developed prototype demonstrated the integration of material-processing and mechanical components into a compact system intended for small-scale rubber brick production. Its structural design provided support for the processing mechanisms, while the motor and gear reduction system were intended to regulate operating speed and increase torque. The integration of shredding and mixing components established a basis for converting discarded rubber into composite construction materials, although operational testing identified areas requiring further mechanical improvement.

3.1.2 Functionality of the Rubber Bricks Production Machine

The functionality evaluation revealed varying levels of acceptability across the machine's operating components. Shredding unit performance was rated moderately acceptable by 12 respondents (40%), while the shredding method was also classified as moderately acceptable. Overall machine operation was rated moderately acceptable by 13 respondents (43.33%), component integration by 14 respondents (46.67%), and the ability to perform intended functions by 18 respondents (60%). In contrast, operational consistency was rated acceptable by 16 respondents (53.33%), while mixing chamber performance was rated acceptable by 12 respondents (40%). The controls and buttons received the highest functional assessment, with 20 respondents (66.67%) rating them highly acceptable. Overall, the machine's functionality was considered moderately acceptable. These findings indicate that the machine demonstrated satisfactory control responsiveness and operational stability but required improvements in shredding efficiency, component coordination, and overall system integration. Effective cutting mechanisms depend on blade sharpness, alignment, and appropriate power transmission (Budynas & Nisbett, 2020; Pei et al., 2024). Improved synchronization between shredding and mixing operations may enhance system performance (Pei et al., 2024). The acceptable ratings for mixing and operational consistency reflect the importance of material and process stability in mechanical systems (He et al., 2023). Furthermore, the favorable assessment of the control system supports ergonomic principles emphasizing responsive controls and reduced operator error (International Organization for Standardization, 2024). The importance of uniform rubber particle production is also supported by recent experimental research on rubberized concrete (Hasan et al., 2025).

3.1.3 Design Acceptability of the Rubber Bricks Production Machine

The design evaluation showed generally high acceptability among the thirty respondents. Secure component assembly was rated highly acceptable by 20 respondents (66.67%), while 18 respondents (60%) gave the same rating to the machine frame. Material durability was rated highly acceptable by 19 respondents (63.33%).

Accessibility and maintenance-related features also received favorable evaluations, with 16 respondents (53.33%) rating these aspects highly acceptable. Meanwhile, practicality in the intended working environment was rated acceptable by 15 respondents (50%), and component arrangement was rated acceptable by 13 respondents (43.33%). Overall, the machine's design was evaluated as highly acceptable, particularly in terms of structural construction, material durability, and maintainability. The results suggest that the machine's structural stability, secure assembly, and material selection were among its strongest design characteristics. Proper component fastening and structural rigidity contribute to reliable mechanical operation and reduced vibration (Budynas & Nisbett, 2020; Pei et al., 2024). The favorable assessment of material durability is consistent with the importance of strength, toughness, and wear resistance in mechanical equipment (He et al., 2023). Similarly, accessible components and simplified maintenance support equipment serviceability and reduced maintenance requirements (International Organization for Standardization, 2024). However, the acceptable ratings for practicality and component arrangement indicate opportunities to improve spatial organization and operational convenience, consistent with ergonomic design principles (International Organization for Standardization, 2024).

3.1.4 Usability Acceptability of the Rubber Bricks Production Machine

The usability evaluation revealed favorable assessments of basic machine operation and user accessibility. Ease of operation was rated highly acceptable by 22 respondents (73.33%), clarity of operating instructions by 18 respondents (60%), and beginner-friendliness by 23 respondents (76.67%). Material handling and feeding were rated acceptable by 12 respondents (40%), workflow smoothness by 13 respondents (43.33%), operational safety by 11 respondents (36.67%), control responsiveness by 19 respondents (63.33%), and ease of maintenance by 13 respondents (43.33%). However, operational process efficiency and task completion speed were each rated moderately acceptable by 12 respondents (40%). Additionally, five respondents (16.67%) gave a low acceptability rating to task completion efficiency. Overall, the machine demonstrated acceptable usability, with stronger performance in ease of operation and user-friendliness than in operational efficiency. The findings indicate that the machine was relatively easy to understand and operate, including for users with limited experience. This supports usability principles emphasizing intuitive controls, clear instructions, and reduced cognitive demands (International Organization for Standardization, 2023). The favorable beginner-friendliness rating also aligns with Norman (2013), who emphasized that effective design enables users to understand system functions without extensive training. Nevertheless, the moderate assessments of operational efficiency and task completion suggest that improvements in material handling, workflow coordination, and mechanical integration are necessary. Ergonomic and system design enhancements may reduce operational effort and improve workflow efficiency (International Organization for Standardization, 2024).

3.2 Operational Challenges and Prototype Improvements

The initial testing of the Rubber Bricks Production Machine identified several mechanical limitations affecting its performance. Rubber materials accumulated within the shredding mechanism because of excessive rotational speed, resulting in inefficient cutting and material clogging. To address this problem, the original 5-horsepower motor was replaced with a 2-horsepower motor, and a gear reducer was installed to regulate speed and increase torque. Misalignment of the washer and spacer also affected material feeding and cutting. Although these components were repositioned, the shredded rubber remained in relatively large pieces rather than the smaller granules required for brick production. These findings demonstrate that motor speed, torque, cutting alignment, and material flow were critical factors affecting the prototype's performance. The modifications improved machine operation but did not completely resolve the limitations of the shredding mechanism. The results indicate that further refinement of the cutting assembly and coordination between processing components is necessary to improve shredding consistency and overall production efficiency. Literature on crumb rubber processing and use suggests that particle size should be recorded quantitatively during future prototype trials (Roychand et al., 2020; Chaus & Marushchak, 2025).

3.3 Overall Performance of the Rubber Bricks Production Machine

The combined evaluation findings showed that the Rubber Bricks Production Machine achieved varying levels of acceptability across its three assessment dimensions. Design received the strongest overall evaluation, with highly acceptable ratings for structural assembly, frame construction, material durability, and maintenance accessibility. Usability was generally acceptable, particularly in ease of operation, clarity of instructions, and beginner-friendliness. Functionality received a moderately acceptable overall assessment, with limitations concentrated in shredding performance, system integration, and operational efficiency. Control responsiveness and operational consistency were identified as relatively strong functional characteristics. These findings indicate that the machine's favorable structural design and user accessibility did not fully translate into efficient mechanical performance. Although the prototype demonstrated potential for small-scale waste rubber processing, its production capability remained constrained by shredding limitations and incomplete coordination among its components. Improvements in cutting efficiency, material flow, and system integration are therefore necessary to enhance functionality while maintaining the machine's favorable design and usability characteristics. The study provides an initial basis for further refinement of the prototype toward more consistent rubber brick production.

4. Conclusion & Recommendations

The study concluded that the Rubber Bricks Production Machine demonstrated satisfactory design and usability but moderate overall functionality. The prototype successfully performed basic processing operations, with its control system receiving highly acceptable evaluations for responsiveness and ease of operation. However, limitations in shredding efficiency, mixing consistency, and component synchronization affected its overall performance. Although the machine was functional and suitable for prototype-level and small-scale applications, further improvements are necessary to enhance its efficiency, reliability, and production capability before it can be considered suitable for continuous or large-scale operations.

It is recommended that the Rubber Bricks Production Machine be improved by refining the shredding mechanism, blade configuration, alignment, spacing, and clearance to produce finer and more uniform rubber particles while minimizing clogging. The use of high-speed steel blades, larger spacers, protective guards, improved feeding guides, and adjustable speed controls is recommended to enhance cutting efficiency, durability, and operational safety. The mixing system should also be improved by optimizing blade angles, chamber capacity, motor speed, torque, and sealing to achieve uniform material distribution and prevent leakage. Furthermore, proper synchronization between the shredding and mixing mechanisms is recommended to ensure continuous material flow, consistent operation, and improved overall production efficiency.

The study was limited to the development and evaluation of a prototype Rubber Bricks Production Machine intended for small-scale applications. Its performance was constrained by inconsistent shredding, rubber clogging, inadequate particle-size reduction, uneven mixing, and limited coordination between mechanical components. Although the machine demonstrated acceptable design and usability, these operational limitations prevented it from achieving fully optimized and continuous production. The study did not cover large-scale industrial manufacturing, alternative material additives, or long-term durability testing of the rubber bricks.

5. Compliance with ethical standards

The authors adhered to the institutional research procedures of the University of Southern Mindanao–Kidapawan City Campus. The required documents were submitted to the Research Ethics Committee Office (RESO), and permission was sought from the Dean of the College of Technology before conducting the evaluation. Following the institutional approval procedures, the validated questionnaire was administered to selected faculty members and construction industry workers. The collected responses were consolidated and analyzed for the purpose of evaluating the functionality, design, and usability of the Rubber Bricks Production Machine.

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