# Mathematical Analysis of Eco-Bricks: Environmental and Economic Impacts of Plastic Waste Utilization for Sustainable Solid Waste Management

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**Abstract**
The increasing amount of plastic waste and the need for sustainable building materials have led to the search for alternative building solutions. This study investigates the feasibility of using shredded plastic waste as a partial substitute for sand in the production of eco-bricks. Eco-bricks were produced by replacing sand with shredded plastic in proportions ranging from 0 to 1 kg. Mechanical tests, including compressive strength and water absorption, were conducted to assess the material properties of the eco-bricks. Additionally, economic and sensitivity analyses were performed to evaluate the profitability of the eco-bricks. The findings indicated that all mixtures had water absorption rates of less than 20 percent, indicating that they were highly durable. The compressive strength increases as the plastic content rises, with a 1 kg mix recording a compressive strength of 20.96 N/mm², which is higher than that of the control group. Economic analysis revealed that all mixes were profitable, with returns on investment (ROI) ranging from 15.33 to 34.28. The sensitivity analysis also showed that mixes containing 0.25 to 1 kg of plastic generated profitability, even though profitability decreased with increasing cement prices. These findings suggest that eco-bricks made from plastic waste are technically and economically promising options for reducing waste and promoting eco-friendly construction methods. Future research should focus on the long-term performance and environmental impact of these eco-bricks on a larger scale to further confirm their practical application in the construction industry.

**Keywords**: Eco-bricks; plastic waste; recycling; waste management; sustainable development.

## Introduction

Plastic waste has become one of the most pressing environmental issues of our time. Municipal solid waste is projected to increase twofold by 2050, with the percentage of plastics rising in the overall solid waste. Plastic is also not biodegradable, hence making a serious menace to the environment, wildlife, and human health. Consequently, the world has been increasingly trying to limit the level of plastic pollution and increase the rates of recycling, particularly in the construction business, which faces high demand for resources that lead to resource depletion and environmental degradation. In this respect, incorporating plastic waste into construction materials, particularly eco-bricks, has become an appealing solution. The added advantage of using eco bricks is that they prevent the wastage of plastic materials, and it is also a cheap and sustainable source of construction in places where funds may be a limiting factor. (Kaza et al., 2018; Zheng & Suh, 2019).

Recent studies have shown that shredded plastics can be used as a substitute for fine aggregates in eco-bricks, with a beneficial effect on their strength while maintaining water absorption within reasonable limits (Kibria et al., 2023). A different study by Singh et al. (2022) proposes that plastic waste can also be used in concrete to provide similar advantages to eco-bricks, demonstrating that plastic waste is not only a solution for environmental concerns but also a viable alternative to conventional building materials. Nevertheless, as extensive studies have been done on the strength and durability of eco-bricks, very little is known about the economic viability of eco-bricks- particularly in third-world countries where the cost of construction materials plays a significant role in construction decisions (Siddique et al., 2008).

The implementation of eco-bricks in Tagudin, Ilocos Sur, by the Local Government Unit (LGU) is part of a program in the Philippines aimed at helping marginalized families by offering them free flooring made from eco-friendly materials. Additionally, other government agencies with limited budgets have also adopted the use of eco-bricks in constructing pavements and other facilities. Although there are prospects, the current eco-bricks produced by the Municipal Environment and Natural Resources Office (MENRO) are of low quality and do not meet the required structural performance for long-term usage. Gumallaoi's (2022) study reveals that the mechanical properties of these eco-bricks, such as adequate compressive strength and water resistance, are not met; therefore, these eco-bricks are less durable for use in construction projects. Consequently, further research is required to enhance the quality of these eco-bricks, particularly in terms of their mechanical working capability and economic feasibility for large-scale use.

According to Gumallaoi (2022), the results suggest that a more rigorous study is needed to optimize the creation of eco-bricks, thereby enhancing the structural performance and longevity of these products. The present study aims to bridge this gap by investigating the mechanical properties and economic viability of eco-bricks prepared using varying percentages of plastic waste. Some of the key aspects that will be evaluated include compressive strength, water absorption, and durability. Additionally, a cost-benefit analysis will be undertaken to calculate the return on investment (ROI) of producing eco-bricks at scale. This assessment will provide a holistic picture of the performance of eco-bricks in terms of technology as well as cost, and will be very insightful regarding the prospect of eco-bricks as a sustainable building material that people use in regions where they lack the resources to purchase costly construction materials.

This paper is particularly critical in the Philippines, where eco-bricks are currently being applied to help low-income families and communities whose needs are met with affordable and low-cost building materials. To enhance the quality and cost-effectiveness of eco-bricks, we will work towards sustainable development and resource efficiency, aligning with the goals of the United Nations Sustainable Development Goals (SDGs), including responsible consumption, sustainable cities, and effective waste management (UN, 2020). Improved eco-bricks offer a valuable tool for sustainable urbanization, providing a low-cost alternative to traditional construction materials and thereby reducing plastic waste while meeting the building needs of marginalized groups.

The available research sources on plastic waste in construction materials reveal a significant advancement in the application of plastic aggregates to enhance the strength and longevity of materials, such as concrete (Siddique et al., 2008). Nevertheless, this does not eliminate a research gap in terms of finding the ideal balance between plastic waste and eco-bricks, as well as the financial aspects of manufacturing eco-bricks. Although people have historically focused on the technical characteristics of such materials, few have considered their cost-effectiveness, particularly in developing nations, where the cost of the materials is a significant consideration in decisions made when undertaking construction works. This study will provide a balanced perspective on the potential of eco-bricks as a sustainable construction material, addressing both their technical performance and economic viability.

This research aims to contribute to the growing body of knowledge on sustainable construction by providing evidence-based insights into both the mechanical performance and economic potential of eco-bricks. The study will specifically examine how different amounts of plastic waste incorporated into the mix affect the bricks' strength, durability, and overall cost. To better understand their feasibility, a sensitivity analysis will also be conducted, taking into account real-world factors such as changes in material prices, production efficiency, and local market demand. Through this approach, the study seeks to show that eco-bricks can be both structurally reliable and economically practical, an alternative building material particularly suited for communities with limited resources.

Ultimately, this study aims to promote the responsible reuse of plastic waste in construction by enhancing the quality and performance of eco-bricks while evaluating their potential for large-scale adoption. The findings are expected to inform policymakers, non-governmental organizations, and local government units in developing strategies that support green construction initiatives. By advancing the development of eco-bricks, this research contributes not only to effective waste management but also to the broader goal of sustainable urban growth, helping pave the way for a construction industry that builds responsibly and protects the environment for future generations.

**Objectives**

This study aims to determine the best formulation and computation for manufacturing eco-bricks, an alternative technology for solid waste management in Tagudin, Ilocos Sur. Specifically, it sought to answer the following objectives:

1. To determine the mechanical properties of the eco-brick containing shredded plastic waste: a) Water absorption rate, and b) Compressive Strength
2. To determine the significant difference between eco-bricks' water absorption and compressive strength.
3. To conduct a cost and return analysis on producing eco-bricks with the best mixture of plastic waste as a partial replacement for fine aggregates.

## Review of Literature

The use of plastic waste in construction materials, specifically in the making of eco-bricks, has been receiving interest due to its novelty in addressing waste management and environmental sustainability. Some studies have been conducted on the idea of using recycled plastics in the construction industry, focusing on the potential benefits of waste reduction, improved sustainability of building materials, and enhanced mechanical qualities of concrete and other materials. The review will examine the available literature on the mechanical properties, environmental advantages, and economic feasibility of plastic waste as eco-bricks, with a special focus on the development and performance of these materials.

**1. Use of Plastic Waste as Construction Material.**

Ali and Qureshi (2021) note that plastic waste can be utilized as a construction material, potentially offering more effective solutions for minimizing greenhouse gas emissions and environmental pollution. The use of plastic waste in construction leads to a decreased demand for traditional construction materials, such as cement and sand, thereby promoting a more sustainable construction industry. This aligns with the objectives of the current research, which aims to assess the feasibility of using plastic waste as eco-bricks. Nevertheless, although their study highlights the advantages of plastic waste in mitigating environmental damage, it lacks actual data on the mechanical properties of materials such as eco-bricks, which is one of the study's priority areas.

Kaza et al. (2018) provide an overview of waste management practices on a global scale, and more importantly, plastic waste management is becoming increasingly challenging. They estimate that the quantity of plastic waste will continue to increase worldwide, and it is essential to consider the use of innovative plastic solutions, such as eco-bricks, in recycling plastic to create building materials. This general outlook reflects the topicality of the given research, according to which the authors examine the possibility of using shredded plastic waste as a substitute for fine aggregates in eco-bricks, which will be used instead of traditional building materials and help reduce plastic waste levels. However, in the research of Kaza et al., the focus was not on the specific mechanical properties and cost analysis of eco-bricks, which remain the primary focus of this study.

**2. Mechanical Characteristics of Materials with Plastic Incorporation.**

A thorough review of the use of recycled plastic in concrete, conducted by Siddique, Khatib, and Kaur (2008), has demonstrated that plastic waste can be utilized to enhance the durability and strength of concrete mixtures. Their results indicate that the mechanical properties of concrete, such as the compressive strength, are enhanced when plastic waste is added to it in the form of an aggregate. This serves the aim of the present research to determine the compressive strength and water absorption rate of eco-bricks, as these are important characteristics that determine their performance as a building material. Nevertheless, the review focuses more on concrete, whereas the current study focuses on eco-bricks, which differ in their composition and formulation.

Kibria, Islam, and Hossain (2023) investigated the mechanical properties and environmental impact of concrete using plastic waste as a substitute for aggregate. Their results show that plastic waste can enhance the mechanical characteristics of concrete, including compressive strength, while also minimizing the environmental footprint. These findings suggest that plastic waste materials can be converted into eco-bricks, which offer the same advantages. The study, however, does not explicitly focus on eco-bricks, but rather on concrete. Further research is required to make the findings applicable to eco-bricks, particularly in terms of water absorption and compressive strength.

Reviewing the use of plastic waste in the production of sustainable concrete, Singh, Nagar, and Agrawal (2022) found that plastic waste can be successfully incorporated into construction materials to enhance their mechanical properties and sustainability. Their article supports the objective of the current study, which is to determine the mechanical properties and sustainability of eco-bricks. Nevertheless, they lack precise information regarding the development of eco-bricks and the optimal combination of plastic waste, which this paper aims to establish. The present research will be based on these results and develop a formulation for eco-bricks to achieve optimal performance in terms of compressive strength and water retention.

**3. Sustainability and Environmental Impact.**

Zheng and Suh (2019) analyzed plans to reduce the global carbon footprint of plastics, emphasizing the need also to employ more sustainable alternatives to plastic waste. According to them, recycling plastic to construct new products is one of the best methods of reducing the environmental impact of plastic waste. This school of thought highlights why the current research focuses on investigating the potential of plastic waste in eco-bricks as a measure to minimize the carbon footprint of construction materials. Nevertheless, their study provides a general picture of the environment, but it fails to specify the environmental advantages of eco-bricks in particular, as well as their mechanical properties.

The environmental benefits of incorporating plastic waste into concrete are also highlighted by Kibria et al. (2023), who report that using plastic waste as an aggregate in concrete has a smaller carbon footprint than the total carbon footprint of construction materials. This aligns with the sustainability objectives of the present research, which aims to utilize plastic waste in eco-bricks as a more sustainable alternative to conventional construction materials. However, the research is based on concrete rather than eco-bricks. It needs to be pursued again to evaluate the particular green advantages of eco-bricks produced using plastic waste.

**4. Technology of Material Property Prognostication.**

Sharma and Vyas (2024) investigated the use of pond ash as a partial substitute for river sand in cement mortars, employing regression models to predict the mechanical properties of the material. The current study can be directly applied to this methodology of predicting material properties using a regression model, which also aims to predict the rate of water absorption and compressive strength of eco-bricks based on the formulation of eco-brick-forming plastic waste. Using the same regression models, the present research will identify the optimal combination of plastic waste to achieve the desired mechanical properties.

**5. Cost and Return Analysis**

Becerra and Goos (2021) proposed Bayesian I-optimal designs for using mixtures in choice experiments, which could be applied to the cost analysis of eco-bricks. Although this paper primarily focuses on the experimental design, rather than a cost analysis, the evaluation methodology for optimal mixtures may apply to the cost and return analysis of manufacturing eco-bricks using various formulations of plastic waste. However, a more direct mention of cost-benefit research on sustainable construction materials would enhance the correlation between the literature review and the cost analysis goals of the current research.

**6. Literature and Research Direction gaps.**

Although the majority of available literature contains interesting facts regarding the environmental and mechanical advantages of using plastic waste as a construction material, research focused on the formulation and performance of eco-bricks is lacking. The majority of research papers are devoted to concrete, and the present research is expected to evaluate the specifics of the eco-bricks, including compressive strength and water absorption. Moreover, research on the cost and return analysis of eco-bricks is scarce, which is one of the primary objectives of the present study. This research gap in the literature has also justified the necessity of this research, which will not only compare the mechanical properties of eco-bricks but also provide an economic analysis of the production process.

# Research Methodology

## Research Design

A controlled experimental design was used in this study to explore the impacts of the addition of plastic waste on the physical and mechanical characteristics of eco-bricks of 8" x 8" x 2" in size or Grade A load-bearing units. To gain a deeper insight into these effects, predictive models were built using mixture formulation designs, in which the proportions of ingredients are systematically arranged to discover the most efficient mixes (Becerra & Goos, 2021).

The study consisted of five conditions: a control, which included no plastic waste, and four others that included plastic waste in the following amounts (0.25 kg, 0.5 kg, 0.75 kg, and 1.0 kg per batch). The treatments were also repeated 3 times to reinforce the reliability of the results. A randomized preparation order was used to minimize bias, and replication was employed to account for the variability inherent in manual mixing and casting.

Such a design enabled the tracing of the effect of various levels of plastic waste on the performance of eco-bricks. The findings provide a good foundation for making sustainable building materials through the practical application of recycled plastics.

## Materials and Procedures

Holcim, Bacnotan, La Union, Philippines, supplied the Ordinary Portland Cement (OPC) that complies with the ASTM C150 Type I requirements of this study. Thick sands were made from the Amburayan River, Tagudin, Ilocos Sur. The sand was also visually inspected to determine if it contained no impurities or foreign materials. Plastic waste, which includes clean residuals such as empty detergent sachets, plastic bags, food packaging, and tetra packs, was collected at the municipal waste segregation facility in Tagudin. The plastic waste was thoroughly washed with water and detergent to remove contaminants, then dried in the sun for 24-48 hours, and shredded mechanically into strips approximately 1-2 cm in length.

**Table 1**. Experimental Design

| **Treatment** | **Cement (bag)** | **Sand (kg)** | **Plastic waste (kg)** |
|---|---|---|---|
| T0 (Control) | 1 | 280 | 0 |
| T1 | 1 | 280 | 0.25 |
| T2 | 1 | 266 | 0.5 |
| T3 | 1 | 251 | 0.75 |
| T4 | 1 | 238 | 1.0 |

## Sample Preparation

A calibrated digital scale with an accuracy of +-0.01kg was used to weigh the materials. The cement sand mixture was mixed with shredded plastic and dried by hand on a clean, flat concrete surface. After this modified process, the mixture was mixed more than four times (Sharma & Vyas, 2024). The water was slowly added, and the mixture was mixed four more times to reach the desired consistency for molding.

**Figure 2.** Sample preparation

*Casting and Curing*. The ready mixture was poured into 8” x 8” x 2" metal molds. Manual compaction was performed using wooden and metal compacting tools, which removed entrained air and increased density. Demolded specimens were cured in a dark, well-ventilated area at a temperature between 25°C and 30°C and a relative humidity of 60-70%. On the first three days, the specimens were sprayed with water daily to maintain their moisture, and they were then cured for an additional seven days, following the best practices for curing concrete (Suriyaa, Gunasekaran, & Kumaran, 2021).

**Figure 3.** Casting and Curing of Eco-bricks

*Testing Procedures*. The compressive strength tests were conducted using a Universal Testing Machine (UTM) in accordance with ASTM C39 test requirements. All the specimens were loaded to failure, that is, in an axial direction, and the highest values of loads were noted. Philippine National Standard (PNS) 16-84 was used to conduct water absorption tests. The specimen was immersed overnight to determine its water absorption percentage, then dried on the surface, and weighed.

**Figure 4**. Comprehensive Strength Testing

***Quality Control and Data Reliability***

All the weighing instruments were calibrated. The raw materials were required to be contaminant-free, which was attained by visual examination. Standardization of mixing, casting, and curing was implemented individually to minimize variation. The following environmental parameters were measured daily: The preparation sequence was randomized in treatment to minimize systematic bias. However, operator blinding was impossible during mixing due to observable differences in plastic content; compressive strength testing was carried out by a blinded technician who was unaware of the treatment assignment.

**Data Analysis**

A Universal Testing Machine (ASTM C39) was used to determine the compressive strength, while water absorption was measured according to the Philippine National Standard (PNS 16-84). SPSS was used to perform statistical analysis, and ANOVA and post hoc tests were employed to identify differences among treatments. Economic viability was evaluated using the return on investment (ROI), and the sensitivity analysis evaluated the impact of changes in cement prices on profitability.

## Results

**Water Absorption Test**

The highest absorption rate is determined to be 20 percent. The following is the formula:

$$\textbf{Water absorption} = \left\{\frac{(\boldsymbol{w2} - \boldsymbol{w1})}{\boldsymbol{w1}}\right\} * \mathbf{100} \qquad \text{Equation 1}$$

where W1 = weight of dry bricks (kg)
W2 = weight of wet bricks (kg)

**Table 2:** Water absorption of the different treatments

| Treatment | Amount of Plastic (kg) | Average Water absorption (%) |
|---|---|---|
| 0 | 0 | 4.62 |
| 1 | ¼ | 6.45 |
| 2 | ½ | 6.48 |
| 3 | ¾ | 6.45 |
| 4 | 1 | 7.69 |

The findings in Table 2 indicate that as the amount of plastic waste increased in the eco-bricks, the water absorption also gradually increased. The control group (Treatment 0) with no plastic had the lowest water absorption at 4.62%. As plastic content was introduced, the water absorption rates for the eco-bricks with ¼ kg (Treatment 1), ½ kg (Treatment 2), and ¾ kg (Treatment 3) remained relatively similar, ranging from 6.45% to 6.48%. However, the eco-bricks with 1 kg of plastic (Treatment 4) had the highest water absorption rate at 7.69%. Despite the increase in plastic content, the water absorption remained within acceptable levels, suggesting that even with higher plastic proportions, the eco-bricks retained satisfactory durability. The findings highlight that while the presence of more plastic waste in the eco-bricks led to slightly higher water absorption, it did not result in a drastic decline in performance.

**Compressive Strength**

The compressive strength of the bricks was tested using a universal testing machine. The bricks were placed under compression, and the strength was recorded until they broke.

**Table 3:** Compressive Strength of the different eco-brick treatments

| Treatment | Amount of Plastic (kg) | Ave. Compressive Strength ($N/mm^2$) |
|---|---|---|
| TO | 0 | 17.54 |
| T1 | ¼ | 9.67 |
| T2 | ½ | 10.19 |
| T3 | ¾ | 19.40 |
| T4 | 1 | 20.96 |

The findings in Table 3 reveal the compressive strength of the different eco-brick treatments with varying amounts of plastic waste. The control group (Treatment 0), which contains no plastic, had a compressive strength of 17.54 $N/mm^2$. As plastic content increased, the compressive strength initially decreased, with Treatment 1 (¼ kg of plastic) showing a significant drop to 9.67 $N/mm^2$. However, as the amount of plastic increased, the compressive strength improved. Treatment 2 (½ kg of plastic) slightly increased to 10.19 $N/mm^2$, and Treatment 3 (¾ kg) substantially increased to 19.40 $N/mm^2$. The highest compressive strength was observed in Treatment 4 (1 kg of plastic), which reached 20.96 $N/mm^2$, surpassing the compressive strength of the control group. These results indicate that while small amounts of plastic reduce the compressive strength of the eco-bricks, higher plastic content beyond a certain threshold actually enhances the compressive strength, suggesting that plastic can contribute positively to the mechanical properties of eco-bricks when used in appropriate quantities.

**Table 4:** Significant Difference in the water absorption of the eco-bricks

| Water Absorption | | | | | |
|---|---|---|---|---|---|
| | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | .233 | 4 | .058 | .269 | .891 |
| Within Groups | 2.167 | 10 | .217 | | |
| Total | 2.400 | 14 | | | |

Table 4 reveals no significant difference in the water absorption of eco-bricks (p = 0.891). This means that the amount of plastic added in the four treatments does not affect the water absorption level of eco-bricks. It implies that adding 1/4, ½, ¾, and 1 kg of plastic has the same capacity to absorb water as not adding any plastic.

**Table 5:** The significant difference in the compressive strengths of eco-bricks

| Compressive Strength | | | | | |
|---|---|---|---|---|---|
| | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | 334.066 | 4 | 83.517 | 11.251 | .001 |
| Within Groups | 74.227 | 10 | 7.423 | | |
| Total | 408.293 | 14 | | | |

Table 5 shows a significant difference in the compressive strength of the eco-bricks (df = 4, p-value = .001). This means that the Compressive Strength of the co-bricks varies significantly in each treatment. This implies that the amount of plastic added to each treatment substantially affects the Compressive Strength of eco-bricks.

**Table 6:** Post Hoc Analysis

| Group Comparison | P-value | Interpretation |
|---|---|---|
| TO vs. T1 | .03 | Significant |
| TO vs. T2 | .05 | Not Significant |
| TO vs. T3 | .91 | Not Significant |
| TO vs. T4 | .56 | Not Significant |
| T1 vs. T2 | 1.0 | Not Significant |
| T1 vs. T3 | .001 | Significant |
| T1 vs. T4 | .003 | Significant |
| T2 vs. T3 | .01 | Significant |
| T2 vs. T4 | .005 | Significant |
| T3 vs. T4 | .951 | Not Significant |

The post hoc analysis of Table 6 indicates that treatments one and two differ significantly from the other treatments. The results indicate that the influence of adding 1/4kg of plastic and 1/2kg of plastic to the treatment differs from the Compressive Strength of adding 3/4kg of plastic (Treatment 3) and 1 kg of plastic (Treatment 4) to the Compressive Strength of the traditional method of brick production. Consequently, adding 1/4 kg and 1/2 kg is not as powerful as the Compressive Strength of the other treatments.

**Return on investment**

The return on investment (ROI) is used to measure the profit increase of a particular investment. Companies use this computation to identify various investment opportunities to generate the most outstanding profitability and a company advantage.

**Table 7**: Return on Investment

| Treatment | Cost Price in Pesos | | | | Net Return on Investment | | | ROI {(TS-TCP)/TCP} *100 |
|---|---|---|---|---|---|---|---|---|
| | Cement | Sand | Labor | Total Cost Price (TCP(Php) | No. of Pcs Produced | Total Sales (TS)(Php | Net Return (TS-TCP) | |
| TO | 250.00 | 46.704 | 175.00 | 471.704 | 68 | 544.00 | 72.296 | 15.33 |
| T1 | 250.00 | 46.704 | 175.00 | 471.704 | 75 | 600.00 | 128.296 | 27.20 |
| T2 | 250.00 | 44.369 | 175.00 | 469.369 | 76 | 608.00 | 138.631 | 29.54 |
| T3 | 250.00 | 41.867 | 175.00 | 466.867 | 76 | 608.00 | 141.133 | 30.23 |
| T4 | 250.00 | 39.698 | 175.00 | 464.698 | 78 | 624.00 | 159.302 | 34.28 |

Legend: ROI – Return on Investment TCP – Total Cost Price
TS – Total Sales

Economic analysis shows that none of them were profitable treatments. TCP values decreased by 464.698 to 471.70, and Sales decreased by 544.00 to 624.00. The net return value was 15.33-34.8 (ROI between ₱72.296 in T0 and ₱159.302 in T4). These findings suggest that eco-bricks production is economically viable, and T4 gives the most viable result.

**Table 8**. Sensitivity Analysis of ROI at Different Cement Prices

| Cement Price (₱) | T0 ROI (%) | T1 ROI (%) | T2 ROI (%) | T3 ROI (%) | T4 ROI (%) |
|---|---|---|---|---|---|
| 280 | 8.43 | 19.59 | 21.75 | 22.37 | 26.14 |
| 290 | 6.47 | 17.67 | 19.80 | 20.41 | 24.13 |
| 300 | 4.57 | 15.84 | 17.92 | 18.52 | 22.18 |
| 310 | 2.73 | 14.10 | 16.11 | 16.69 | 20.30 |
| 320 | 0.95 | 12.44 | 14.37 | 14.92 | 18.47 |
| 330 | -0.78 | 10.86 | 12.70 | 13.21 | 16.70 |
| 340 | -2.46 | 9.35 | 11.09 | 11.55 | 14.99 |
| 350 | -4.10 | 7.91 | 9.54 | 9.94 | 13.32 |

Increased cement prices between PHP280 and PHP350 decreased ROI in all treatments, and cost sensitivity was confirmed. T0 was unprofitable above 330; however, T1-T4 returned positive returns, with T4 always recording the highest ROI (13.32% at 350). These results highlight the importance of effective material management and suggest that increased plastic inclusion enhances resistance to price fluctuations.

## Discussions

The findings of this study reveal several interesting trends in the use of plastic waste in eco-bricks, particularly in terms of water absorption and compressive strength. The water absorption increased slightly as plastic content rose, with the eco-bricks containing 1 kg of plastic showing the highest absorption rate at 7.69%. This result is consistent with studies by Siddique et al. (2008), who found that incorporating recycled plastic into concrete and building materials generally leads to increased water absorption. While the higher water absorption is concerning in some applications, the values observed in this study are still within acceptable limits for construction materials. Eco-bricks are typically deemed durable as long as the water absorption remains below 10% (Siddique et al., 2008).

Furthermore, the study by Sharma and Vyas (2024) also noted that using alternative aggregates, such as pond ash or waste materials, does not lead to significant durability degradation, which supports the findings of this study regarding plastic-based eco-bricks.

The results showed an intriguing pattern, where the compressive strength initially decreased with the inclusion of small amounts of plastic waste (¼ kg), but increased significantly as the plastic content exceeded ½ kg. The eco-bricks made from 1 kg of plastic waste demonstrated the highest compressive strength (20.96 N/mm²), surpassing that of the control group (17.54 N/mm²). This aligns with recent studies, such as those by Kibria et al. (2023), which reported that incorporating plastic waste into concrete can enhance compressive strength beyond a certain threshold of plastic content. This phenomenon can be explained by the improvement in the internal bonding structure of the eco-bricks as the plastic waste reaches a critical proportion, which contributes positively to the material's strength (Singh, Nagar, & Agrawal, 2022). The increased compressive strength observed in this study is also consistent with findings by Ali and Qureshi (2021), who highlighted that plastic waste, when used appropriately, can enhance the mechanical properties of construction materials while contributing to environmental sustainability by reducing plastic waste.

However, the decrease in compressive strength at the ¼ kg and ½ kg plastic levels observed in the study suggests that low plastic content may disrupt the bonding between the other aggregates and the cement matrix, a phenomenon similarly noted by Becerra and Goos (2021). It is essential to note that the optimal level of plastic content for enhancing mechanical properties may vary depending on the type and processing of the plastic waste, which could be a topic for future research.

The findings also highlight the economic potential of using plastic waste in eco-bricks. In light of the growing concerns about plastic pollution and the economic benefits of recycling, incorporating plastic waste into construction materials presents a promising solution to address both environmental and economic challenges. According to Kaza et al. (2018), the global volume of plastic waste is expected to increase significantly. Finding sustainable ways to recycle this material into usable products, such as eco-bricks, could help mitigate waste accumulation. The potential economic viability of these eco-bricks, particularly in developing countries, lies in their ability to provide a low-cost alternative to traditional building materials. As the construction industry continues to explore more sustainable options, the findings of this study align with the need for cost-effective, environmentally friendly materials in the global building sector.

## Conclusions

This study demonstrates that the use of plastic waste in manufacturing eco-bricks enhances their technical and economic performance. All treatments retained water absorption values in the lower bracket of 20 percent, which is a sign of durability. In contrast, compressive strength increased as the amount of plastic added in the treatment reached a maximum of 20.96 $N/mm^2$. Financial analysis yielded positive returns in all treatments, with sensitivity analysis indicating that eco-bricks will be profitable under various cement price conditions, particularly in the 0.25-1 kg plastic range. The originality of the work lies in the joint evaluation of mechanical and financial aspects. The results indicate that eco-bricks are both technically feasible and economically viable, making them a viable alternative to traditional bricks. One of the implications is that local governments and small-scale producers can adopt eco-bricks as community-based waste management and low-cost housing programs.

### Recommendations

Since the study only considered two mechanical properties of eco-bricks when adding plastic in the range of 1/4kg to 1kg, other researchers may consider testing additional mechanical properties and exploring solid waste materials other than plastic as aggregates in brick making. Future studies should also focus on examining the long-term performance of these materials in real-world conditions and investigating additional benefits, such as reduced carbon footprint, to assess the full potential of plastic-based eco-bricks in sustainable construction.

### Acknowledgements

A particular word of gratitude goes to the Local Government Unit of the Municipality of Tagudin, Ilocos, for allowing the study to be conducted using their facilities and staff. The researcher also acknowledges the Ilocos Sur Polytechnic State College for the research fund allotted for this study.

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