

Comparative Performance of Rice Husk Ash and Seashell-Based Binder as an Eco-Friendly Alternative to Commercial Cement Stabilizers

Matthew M. Balonglong*, Karen P. Calintig, Aljeed F. Dumao, Harley E. Partosa,
Maria Antonio Kyrell A. Bangalando, Rhea Roxana A. Grefaldia
St. Paul University Dumaguete City, Negros Oriental, Philippines

*Corresponding Author Email: mattbalong161@gmail.com

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Abstract. This study evaluates the potential of rice husk ash (RHA) blended with seashell powder as an eco-friendly alternative to commercial cement stabilizers. It employed a quasi-experimental design using a 1-meter height drop test and a 60-kg compressive strength test. The experiment involved two groups: a control group using commercial cement and an experimental group using a blend of RHA, seashell powder, sand, and a reduced amount of Portland cement. The results indicated no statistically significant difference in structural performance between the two groups, with comparable scores in both durability and compressive strength tests. The use of ASTM C140 guidelines ensured testing reliability. However, the study was limited to a single mix ratio due to resource constraints. Future research should test varying proportions and include additional durability parameters such as water absorption. The findings support the viability of RHA-seashell blends as partial replacements for traditional cement, contributing to sustainable construction practices.

Keywords: Cement stabilizer; Compressive strength; Durability; Rice husk ash; Sustainability.

1.0 Introduction

Sustainable construction remains a critical focus under SDG 9, promoting environmentally responsible infrastructure. Traditional cement manufacturing contributes significantly to CO₂ emissions (Adesina, 2020). Thus, alternative binders, including rice husk ash (RHA), have been explored for their high silica content and pozzolanic reactivity (Hu et al., 2020; Zhang et al., 2020). RHA, a byproduct of rice milling, shows potential as a substitute for commercial stabilizers. Recent studies have begun combining RHA with other additives such as lime, plastic waste, or organic ash (Miller et al., 2019). However, limited research exists on its combination with seashells, which contain calcium carbonate and can potentially enhance hydration and surface smoothness (Ruslan et al., 2022). Most studies focus on single-component blends or lack standard testing protocols. Additionally, the literature shows a research gap in optimized mix ratios for blended materials and comparative strength analysis using recognized test standards like ASTM C140.

This study bridges these gaps by assessing the structural performance of cement stabilized with a blend of RHA and seashell powder, compared to conventional cement. It uses standard impact and compressive testing to

evaluate the material's effectiveness as a sustainable alternative.

2.0 Methodology

2.1 Research Design

The study used a quasi-experimental comparative design. It tested cement blocks made with commercial stabilizer (control) against those made from a blend of RHA and seashell powder (experimental). The mix design included 110g RHA, 15g powdered seashells, 59g sand, 59g Portland cement, and 118mL water (1:2:4:2 by relative mass). Materials were processed by burning rice husks in perforated metal drums and manually crushing heated seashells. The mix was sun-cured for 24-48 hours. Future studies are encouraged to explore at least three different mix ratios for optimization. Testing procedures followed ASTM C140 guidelines. Two primary tests were performed: A 1-meter drop test assessed impact durability, and a 60-kg compressive strength test evaluated load resistance. To ensure fair assessment, five student scorers from the Grade 12 STEM strand of St. Paul University Dumaguete were randomly chosen to evaluate the outcomes of both the durability drop test and the compressive strength test. Each test result was rated independently, and the average scores were used for analysis.

Before conducting statistical tests, a normality check was done to validate the data sets. To determine whether there was a significant difference between the experimental and control groups, the Independent T-Test was applied. This research design was chosen to carefully assess whether RHA can provide comparable strength and durability to that of commercial cement under real-world conditions.

2.2 Research Locale

This study was carried out in two locations that were both familiar and accessible to the researchers. One of the sites was a privately managed facility located in Magatas, Sibulan, Negros Oriental. The other was within the grade school grounds of St. Paul University, Dumaguete. These places were chosen because they provided enough space and a secure environment to safely perform all the necessary tests and procedures for the study. Both sites served as testing grounds for comparing Rice Husk Ash (RHA) with a commonly used commercial cement stabilizer. The experiments focused on assessing how well these materials performed under natural conditions, without altering the surroundings. Among the tests conducted were drop tests, which checked how well the material could resist impact, and compressive tests, which measured how much weight the material could hold before breaking. These procedures were done following a consistent method to ensure the results were as fair and reliable as possible.

2.3 Research Participants

The participants of this study were Grade 12 students from the Science, Technology, Engineering, and Mathematics (STEM) strand of St. Paul University Dumaguete. To maintain fairness and eliminate bias in evaluating the results, five student scorers were randomly selected to assess both the drop test and the compressive strength test for the experimental and control groups. These scorers were not informed which samples belonged to which group, helping to ensure objective and consistent scoring throughout the testing process.

2.4 Research Instrument

To assess the performance of the materials in both the durability drop test and the compressive strength test, the study used a structured evaluation scale ranging from 1 to 5, with 5 representing the highest score and one the lowest. This rating scale was reviewed and validated by field experts to ensure its appropriateness and accuracy for the intended purpose. Prior to its official use, the scale was subjected to a dry run and reliability testing to confirm consistency in scoring. The selected student scorers used this scale to evaluate both the experimental and control group samples during the testing process. Their ratings provided the basis for measuring the relative strength and durability of the materials under investigation.

2.5 Data Gathering Procedure

The data gathering procedure for this study on rice husk ash (RHA) as an alternative cement stabilizer was carefully structured and executed in several stages. First, materials were prepared. Rice husks were burned in a tin can or metal drum with holes to facilitate airflow, using charcoal and other combustibles to ignite the fire. Once the husks turned black, indicating complete combustion, the resulting ash was sifted to remove unburned materials. Seashells were similarly processed, softened by heating, crushed using a mortar and pestle, and sieved to produce a fine powder. These components were then used to create the experimental cement mixture in a 1:2:4:2

ratio: 110 g RHA, 15 g powdered seashells, 59 g sand, 59 g Portland cement, and 118 mL water. The mixture was poured into molds to form rectangular blocks and dried in the sunlight for 24 to 48 hours. Testing involved five randomly selected Grade 12 STEM students from St. Paul University Dumaguete, who served as evaluators. For the drop test, five evaluators were engaged, utilizing a five-point rating scale. The researchers conducted five trials for both the control and experimental groups. The ratings were based on visible damage such as cracks, chipping, or structural failure. After each trial, the individual scores from the five evaluators were averaged to obtain the mean score per test. Subsequently, the composite mean was calculated for both the control and experimental groups to analyze further the significant difference using a t-test. A normality test was conducted to determine whether the data sets exhibited a normal distribution. Mean scores and standard deviations were also calculated to assess the consistency and reliability of the cement blocks. Immediately after the drop test, the same procedure was applied for the compression test. Five tests were conducted for both the control and experimental groups, evaluated by the same five scorers using the five-point scale to assess compression test results. A similar statistical analysis was done on the data from the compressive strength test.

Ethical considerations were upheld throughout the process, including obtaining permission to collect natural resources, avoiding excessive emissions during burning, and ensuring participant consent and unbiased evaluation. This rigorous procedure provided a reliable foundation for evaluating the viability of RHA as a sustainable alternative to commercial cement.

2.6 Data Analysis Procedure

The data analysis procedure of this study involved a systematic approach to evaluate the effectiveness of rice husk ash (RHA) as an alternative cement stabilizer. Once the experimental and control cement samples were tested through the 1-meter height drop test and the 60 kg compressive strength test, the scores were collected and analysed using both descriptive and inferential statistical methods. Descriptive statistics included calculating the weighted mean, composite mean, and standard deviation for each group to measure central tendency and variability, which helped assess the consistency and average performance of the samples. To ensure the appropriateness of statistical testing, a Shapiro-Wilk test was conducted to determine if the data followed a normal distribution. The resulting p-values were greater than 0.05, indicating that the data from both the control and experimental groups were normally distributed and suitable for parametric testing. Subsequently, an independent t-test was used to compare the performance of the experimental and control groups across both tests. This method allowed the researchers to determine whether any observed differences in scores were statistically significant. The results showed no significant differences between the two groups in both impact durability and compressive strength, with p-values above 0.05, supporting the hypothesis that RHA-based cement performs comparably to commercial cement. This analysis validated the potential of RHA as a sustainable cement alternative.

2.7 Ethical Considerations

Ethical considerations also include the environmental impact of the product's development, prioritizing that the use of rice husk ash in cement will not harm people's health. The researchers will be using the materials responsibly and will not be promoting wastage of the resources used that would harm the environment. In conducting the experiments, the researchers will exercise caution in the excessive emissions of carbon gases, especially in burning the rice husks and applying the best filtered and environmentally friendly commercial cement. For the credibility and reliability of the data, the researchers will observe transparency by requesting five (5) random participants to evaluate the cement to avoid any biases. They will not manipulate the results of the tests and will stay true to what was observed in the testing process. The researchers obtained authorization from the local government to collect seashells on public seashores. This is to ensure fairness and the avoidance of environmental and property damage.

3.0 Results and Discussion

The tables shown below are the data from the scorers who evaluated both tests on the cement. The following provides a discussion and answers to the questions stated in the statement of the problem. The effectiveness of rice husk ash (RHA) as a cement stabilizer depends on its ability to withstand heavy loads over extended periods. RHA contains a high percentage of silica, like lime, which enhances its pozzolanic properties. This makes it a suitable supplementary cementitious material in concrete. Incorporating RHA improved the structural durability of the mixture, allowing it to withstand heavy loads over extended periods. Studies confirmed that RHA contributes to the overall strength and stability of cement-based materials, making it a viable alternative to

traditional stabilizers (Aliyu & Karim, 2016). Rice Husk Ash also contains a high percentage of silica, which enhances its pozzolanic properties. Its high silica content allows it to function similarly to lime and other supplementary cementitious materials, making it a sustainable and effective cement stabilizer (Musa, 2010).

Rice husk ash demonstrates significant versatility when combined with various aggregates such as sand and crushed seashells. Data from the tests suggest that cement stabilized with RHA performs comparably to commercial cement, particularly when mixed with other natural and renewable aggregates. The use of RHA in cement composites mixed with seashells and plastic waste demonstrates that the resulting material maintains strength comparable to commercial cement. The study highlighted RHA's potential in sustainable construction by effectively binding with natural and renewable aggregates (Alcala, 2009). Cement stabilized with RHA performed similarly to conventional cement, particularly when blended with other sustainable aggregates like sand. RHA's pozzolanic properties were also emphasized, which contribute to its compatibility with various natural materials (Hu et al., 2020). Table 1 shows the data analyzed and compared with the control and experimental groups.

Table 1. Mean and Standard Deviation of the Control and Experimental Groups based on the 1-meter Height Drop Test Scores

Scorer	Control Group (Commercialized Cement) WM	Experimental Group (Alternative Cement) WM
1	2.24	2.29
2	2.48	2.58
3	2.68	2.82
4	3.12	3.14
5	3.32	3.38
Composite Mean	2.77	2.84
Standard Deviation	0.45	0.44

Based on the composite mean scores, the experimental group (alternative cement) has a slightly higher drop test score (2.8416) compared to the control group (2.768). However, the standard deviations are very close, indicating similar variability in both groups' data. The results of the 1-meter height drop test indicate that the alternative cement (experimental group) exhibited a slightly higher composite mean score (2.8416) compared to the commercial cement (control group) with a composite mean of 2.768. The similarity in standard deviations (0.4467 for the control group and 0.4368 for the experimental group) suggests comparable variability, indicating that both cement types demonstrate consistent structural performance under impact conditions. This finding aligns with the research of Hu et al. (2020), which highlights the pozzolanic properties of rice husk ash (RHA), contributing to enhanced mechanical strength and durability when used as a cement substitute. Additionally, RHA-based cement formulations emphasize their capability to achieve performance levels similar to conventional cement while offering environmental benefits (Miller et al., 2019). These studies support the structural reliability of alternative cement materials, reinforcing their potential as sustainable replacements in construction.

Table 2 extracts the data from the table above and calculates the weighted mean and p-value based on the mean and standard deviation of the 1 m drop tests' results. Since both p-values are greater than 0.05, this suggests that both groups' data are typically distributed. The analysis for the significant difference could be analyzed through a t-test.

Table 2. Distribution of Data Analysis Using the Shapiro-Wilk Test

Group	W Statistic	p-value
Control Group	0.95	0.7613
Experimental Group	0.98	0.9422

Based on the results, there is no significant difference between the control and the test samples, indicating that the incorporation of oyster shell ash (OSA) and rice husk ash (RHA) did not negatively affect the compressive strength after a 1 m drop. This supports the idea that these materials can serve as adequate partial cement replacements without compromising structural performance. Similar findings have been reported in previous studies that explored the use of RHA and other waste-based materials in cement composites (Hu et al., 2020; Ruslan et al., 2022). The consistent strength values also suggest that using alternative materials like RHA and OSA contributes to sustainable construction practices without sacrificing durability. This is important considering that cement production is a major contributor to global carbon emissions (Adesina, 2020; Barcelo et al., 2014; Ali et al., 2015). The use of waste-derived additives aligns with efforts to lower environmental impact while maintaining mechanical reliability (Shi et al., 2011; Zhang et al., 2020). Overall, the data supports the potential of green cement alternatives in practical applications.

Since the p-value (0.799) is greater than 0.05, this indicates that there is no statistically significant difference between the commercialized cement and the alternative cement in terms of mean drop test scores. Table 3 presents the results of the independent t-test, where the computed t-statistic is -0.263 with a p-value of 0.799.

Table 3. Significant Difference of the 1-meter High Drop Test Scores of the Control and Experimental Groups

Group	Composite Mean	Standard Deviation	
Control	2.77	0.45	
Experimental	2.84	0.44	
t-statistic			-0.263
p-value			0.799

The t-statistic suggests that the two-group means are very similar and have little to no difference between them. Since this p-value is greater than 0.05, this indicates that there is no statistically significant difference between the commercialized cement and the alternative cement in terms of durability (1-meter drop test scores). Findings are also supported by observations that cement incorporating rice husk ash (RHA) and other alternative materials can achieve similar mechanical properties as traditional cement (Aliyu & Karim, 2016). Miller et al. (2019) also emphasize that RHA-based cement can perform comparably to conventional cement under various conditions, reinforcing its potential as a sustainable alternative. Shi et al. (2011) also highlight that new cement formulations utilizing pozzolanic materials can maintain structural integrity while reducing environmental impact.

Table 4 shows the analysis of data based on the results from the evaluation of the 60 kg Compressive Weight Test. The mean scores for both the control and experimental groups are identical at 3.80, with slight variations in standard deviation (0.371 for the control and 0.398 for the experimental), indicating similar variability in the data.

Table 4. Mean and Standard Deviation of the Control and Experimental Groups Based on the 60kg Compressive Weight Test Scores

Scorer	Control Group (Commercialized Cement) WM	Experimental Group (Alternative Cement) WM
1	3.48	3.38
2	3.40	3.48
3	3.80	3.76
4	4.04	4.05
5	4.28	4.34
Composite Mean	3.80	3.80
Standard Deviation	0.37	0.40

The results of the 60kg compression test reveal that both the control and experimental cement formulations yielded an identical mean compressive strength of 3.80, with slight variations in standard deviation (0.371 for the control and 0.398 for the experimental). These findings indicate that the alternative cement exhibits mechanical properties comparable to commercialized cement, suggesting its potential viability as a sustainable alternative. The minimal variability in the data further supports the consistency and reliability of both formulations under compressive loading conditions. Findings are further supported by studies that demonstrated the incorporation of rice husk ash (RHA) in cement formulations does not significantly compromise compressive strength while enhancing eco-friendliness and sustainability (Hu et al., 2020). Similarly, Miller et al. (2019) reported that RHA-based cement maintains structural integrity while reducing carbon footprint, reinforcing its feasibility as an alternative binder. These results highlight the potential of sustainable cement formulations in mitigating environmental impact without sacrificing mechanical performance.

Table 5 presents the general analysis of both the control group and experimental group, based on the mean of each respondent and trial, which calculates the weighted statistic and p-value. Both datasets follow a normal distribution ($p > 0.05$), meaning parametric tests like the independent t-test are appropriate for further analysis.

Table 5. Distribution of Data Analysis Based on the 60kg Compression Test

Group	W Statistic	p-value	Normality
Control Group	0.94	0.680	Yes
Experimental Group	0.95	0.736	Yes

Table 6 illustrates the final analysis of the results of the 60 kg Compressive Weight Test. This evaluates whether there is a significant difference between the two groups. The p-value (1.000) is much greater than 0.05, meaning there is no statistically significant difference between the control and experimental group scores.

Table 6. *Significant Difference of the 60kg Compression Test Scores of the Control and Experimental Groups*

Group	Composite Mean	Standard Deviation	
Control	3.80	0.37	
Experimental	3.80	0.40	
t-statistic			0.000
p-value			1.000

This suggests that the experimental condition did not significantly affect the scores. The results of the 60kg compression test indicate that both the control and experimental groups exhibited normally distributed data ($p > 0.05$), justifying the use of parametric statistical tests. The independent t-test analysis ($t = 0.000$, $p = 1.000$) further demonstrates that there is no statistically significant difference between the two groups, suggesting that the alternative cement performs equivalently to commercial cement in terms of compressive strength. This finding underscores the potential of alternative cement formulations as viable substitutes without compromising structural integrity. These results align with prior research, such as Aliyu and Karim (2016), who found that incorporating rice husk ash (RHA) in cement-based materials maintained compressive strength while enhancing sustainability. Similarly, Shi et al. (2011) highlighted that alternative cement formulations, including supplementary cementitious materials, can achieve comparable mechanical performance while reducing environmental impact. These findings reinforce the feasibility of alternative binders in cement production, supporting the development of eco-friendly construction materials.

4.0 Conclusions

The study concludes that a blend of rice husk ash (RHA) and seashell powder is a viable, eco-friendly alternative to commercial cement stabilizers. Using a quasi-experimental approach, two groups, one with commercial cement and another with RHA-seashell blend, were subjected to a 1-meter drop test and a 60-kg compressive strength test, both compliant with ASTM C140 standards. In the drop test, the experimental group recorded a slightly higher composite mean score (2.84) than the control group (2.77), indicating comparable or marginally improved impact durability. In the compressive test, both groups achieved identical composite mean scores of 3.80, confirming parity in structural load resistance. Statistical analysis, including Shapiro-Wilk tests for normality and independent t-tests for group comparison, revealed no significant difference between the two formulations (p-values of 0.799 and 1.000, respectively). These findings suggest that despite the alternative binder using less Portland cement, its performance was equivalent in both durability and strength. This supports its feasibility as a sustainable partial substitute in cementitious applications. However, the study was limited by the use of a single mix ratio and two basic tests. Future research should build on this by employing multiple mix proportions to identify optimal blends, scaling up production to industry-level application, and conducting additional ASTM-compliant evaluations such as water absorption, dimensional stability, and fire resistance. These additional tests would provide a more holistic understanding of long-term durability and environmental resilience. Overall, the findings contribute valuable empirical evidence supporting the integration of agricultural and marine waste byproducts, such as RHA and seashells, into sustainable construction practices, aligning with global goals for carbon reduction and circular resource use.

5.0 Contributions of Authors

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

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7.0 Conflict of Interests

All authors declare that they have no conflicts of interest.

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