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REGULAR ARTICLE

Performance of Concrete Using Fly Ash and Limestone Powder as Partial Replacement for Portland Cement

ARTICLE HISTORY

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Abstract: The construction industry faces significant environmental challenges due to the high carbon footprint of conventional Portland cement, necessitating the search for more sustainable building materials. This study investigates the viability of using fly ash and limestone powder as sustainable alternatives to conventional Portland cement in concrete production. The research primarily evaluates the performance of fly ash and limestone powder as supplementary cementitious materials (SCMs) on key performance indicators, including workability, compressive strength, and split tensile strength of concrete samples. Various percentages of fly ash and limestone powder were tested as SCMs for Portland cement. The findings indicate that up to 20% of fly ash and limestone powder with compressive strength (fc') of 3,121.78 psi and a tensile strength (fct) of 342.71 psi can be effectively utilized as substitutes for Portland cement without significantly compromising the compressive and split tensile strength of the concrete. This study underscores the potential of these materials to improve both the performance and sustainability of concrete, while also contributing to a reduction in its carbon footprint. Nonetheless, additional research is necessary to identify the optimal proportions of fly ash and limestone powder for specific applications. Furthermore, it is important to explore the influence of other factors, such as water-cement ratio, curing duration, and environmental conditions, on the strength and durability of concrete containing these materials as partial replacements for Portland cement.

Keywords: concrete performance; fly ash; limestone

1. Introduction

Waste has long been a significant issue for both society and the environment. According to the World Bank (Ellis, 2018), municipal solid waste (MSW) is generated globally at a staggering rate of 2.01 billion metric tons annually. By 2050, this figure is projected to rise to 3.40 billion metric tons. In the Philippines, waste production has consistently increased, with annual waste generation estimated at 13.48 million metric tons in 2010, approximately 14.66 million metric tons in 2014, and expected to reach 18.05 million tons by 2020. As governments and businesses prioritize sustainability, the construction industry is increasingly focused on mitigating its environmental impact. Notably, construction waste constitutes about one-third of all waste generated nationwide (Bipat, 2019), highlighting the need for effective recycling of construction materials to significantly reduce this impact.

Fly ash, a byproduct of coal combustion, is commonly used as an additional cementitious ingredient in concrete production. Incorporating fly ash with Portland cement can enhance the durability and strength of concrete. The smaller particle size of fly ash compared to traditional mortar particles can also improve workability. According to the Portland Cement Association (PCA) in 2023, fly ash's porous nature allows it to react with calcium hydroxide to form additional cementitious compounds, further contributing to the long-term durability and resilience of concrete through pozzolanic activity. Additionally, fly ash typically contains high levels of silica, alumina, and calcium oxide, which can enhance the durability of concrete structures.

Limestone powder has been widely utilized in concrete over the past two decades due to its availability and cost-effectiveness. It is often used as a partial replacement for cement to reduce CO_2 emissions, making it an ideal alternative. The PCA (2023) noted that limestone is a key ingredient in the production of Portland cement. When heated to approximately 1450°C in a kiln, limestone undergoes a chemical reaction to produce calcium oxide, or quicklime. This quicklime is then combined with other materials, such as silica, alumina, and iron oxide, to create Portland cement. Both limestone and Portland cement share common properties, including high compressive strength and excellent durability, making them suitable for construction applications. They also exhibit resistance to weathering, allowing them to withstand exposure to environmental elements over extended periods.

The studies of Hisame et al. (2016), Hwang et al. (2021), Shon et al. (2022), and Sarsam et al. (2016) show significant similarity to the present study by utilizing waste material as a partial substitute/additive for cement with the use of CWP, CWA, LS, waste glass powder, wood fiber waste, and rice husk in particular. As a means of aiding waste management problems and finding ways to innovate new construction materials, these studies inspired the researcher to pursue the study at hand. To highlight the difference between these studies, they focused more on evaluating the properties of fly ash and limestone powder and the suitable mix design based on plain concrete specifications.

One of the objectives of the studies by Shafigh et al. (2016), Wang et al. (2018), Panesar et al. (2020), Mallisa et al. (2017), and Rohman et al. (2018) is similar to the present study: to promote the use of supplementary cementitious materials as a solution to preserve the environment and cost-effective concrete without sacrificing the strength of concrete.

The findings of this study will provide significant benefits to the construction industry, the environment, the economy, local communities, engineers, and researchers. Reusing industrial byproducts will not only reduce waste output and extend the lifespan of materials but also offer a cost-effective and environmentally friendly solution for engineers aiming to produce high-quality concrete.

This study utilized materials sourced from the province of Masbate, including fly ash from D. M. Consunji, Inc. (DMCI), Masbate Power Corporation (DMPC) in Brgy. Tugbo, Mobo, Masbate, and limestone powder from a quarry site in the Municipality of Pio V. Corpus, Province of Masbate. The research evaluated five different proportions of each material using a Class "A" mix, focusing on workability and compressive strength at 7, 14, and 28 days, as well as split tensile strength at 28 days.

2. Objectives of the Study

The primary objective of this study is to assess the performance of concrete incorporating flyash and limestone powder as partial replacements for Portland cement, specifically in terms of workability, compressive strength, and split tensile strength. Additionally, the study aims to determine the potential of fly ash and limestone powder for concrete development and to analyze any differences between conventional concrete and that made with these materials as partial replacements for Portland cement.

3. Methodology

3.1 Research Method

In this study, fly ash and limestone powder were utilized as partial replacements for Portland cement to evaluate the performance of concrete through an experimental research design. The study employed a range of data collection methods, including laboratory experiments and statistical analysis. The laboratory experiments involved preparing concrete samples that were subjected to various tests to assess their performance. These tests included compressive strength, flexural strength, and durability tests, among others.

3.2 Selection and Preparation of Materials

To conduct this study, specific materials were meticulously sourced and prepared to ensure the consistency and validity of the study's results. Fly ash, a byproduct of coal combustion, was sourced from the DMCI Thermal Power Plant located in Barangay Tugbo, Mobo, Masbate, where it is stored in silos before being transported for reuse. The limestone powder was obtained from a quarry in the Municipality of Pio V. Corpus, Masbate, and processed by sieving it through a No. 200 mesh to achieve the fine powder consistency required for the concrete mixtures. For the binding agent, a consistent commercial brand of Portland cement, specifically from the APO Cement Corporation, was utilized throughout the research process. This cement was combined with commercial crushed coarse and fine aggregates that were carefully selected to ensure they remained free of organic impurities. Finally, the water used in the concrete production was sourced from the Masbate Mobo Water District, chosen for its strict compliance with Item 714 of the Department of Public Works and Highways (DPWH) standards.

3.3 Mix Proportions

Concrete mixtures can be proportioned by weight or volume. The most common and practical method involves using a measuring box for sand and gravel or an empty plastic bag for cement to determine volume. Table 1 outlines the concrete proportions, specifying the mixture class as per Fajardo (2000).

Table 1. Concrete proportion

Mixture Class	Proportion	Cement in Bag		Sand (cu.m.)	Gravel (cu.m.)
		40 kg.	50 kg.		
AA	1: 1 ½ : 3	12	9.5	0.5	1
A	1:2:4	9	7	0.5	1
B	1: 2 ½: 5	6	6	0.5	1
C	1:3:6	5	6	0.5	1

Using Mixture Class "A", the specimens were prepared using kilograms as the unit of measurement for cement, fly ash, and limestone powder. A measuring box was used to measure the volume of sand and gravel.

Table 2 presents the experimental combinations for Portland cement, sand, and gravel in cubic meters, as well as the weights of cement, fly ash, and limestone powder, categorized by the proportion of partial replacement.

3.4 Experimental Phase

This section outlines the laboratory tests conducted to assess the performance of concrete with fly ash and limestone powder as partial replacements for Portland cement.

Table 2. Design Trial Mixture

Trial Mixture	Sand (cu.m.)	Gravel (cu.m.)	Cement (kg)	Coal Fly Ash (kg)	Limestone Powder (kg)
0%	0.011	0.021	7.634	0	0
10%	0.011	0.021	6.871	0.382	0.382
20%	0.011	0.021	6.107	0.763	0.763
30%	0.011	0.021	5.344	1.145	1.145
40%	0.011	0.021	4.58	1.527	1.527

3.4.1 Workability

During the experimental phase, a slump test was performed to determine the consistency and workability of the fresh concrete according to American Standards for Testing and Materials (ASTM) C143 standards. The concrete molds were filled with the prepared mix in three approximately equal layers. Each layer was subsequently rodded 25 times evenly across the cross-section using a 16mm diameter tamper rod with a rounded end to ensure proper compaction. Once the rodding was complete, the mold was removed by lifting it steadily upward, while care was taken to avoid any lateral or torsional movement that could disrupt the sample. Immediately following the mold removal, the slump was measured by calculating the vertical distance from the topmost part of the mold to the top surface of the specimen, as it was originally displaced in the middle.

The slump value is determined based on the type of slump observed in the sample, in accordance with American Concrete Institute (ACI) 211 guidelines.

3.4.2 Compressive Strength

The cylindrical concrete specimen is exposed to compressive load until failure occurs at a rate that falls within the specified range. By dividing the highest compressive force by the sample's cross-sectional area, the compressive strength is calculated as follows:

$$\sigma = \frac{P}{A} \tag{1}$$

where:

σ = compressive strength, (MPa)
P = maximum load, (N)
A = cross-sectional area (mm^2)

3.4.3 Split Tensile Strength

A 150-millimeter (6-inch) diameter, as well as a 300-millimeter (12-inch) long cylinder, must be used for the test, according to ASTM C496 (2011). The load is delivered to the free side of the horizontally oriented cylinder from the top. It is noted what load causes the cylinder to break in half. The splitting tensile strength of concrete (f_{ct}) may be calculated as follows:

$$f_{ct} = \frac{2P}{\pi LD} \tag{2}$$

where:

f_{ct} = splitting tensile strength, (MPa)
P = maximum load, (N)
L = length of the cylinder, (mm)
D = diameter of the cylinder, (mm)

3.5 Statistical Treatment of Data

To ensure the validity of data analysis and interpretation, analysis of variance (ANOVA) was employed. A two-way ANOVA was used to determine the significant effects of partially replacing Portland cement with fly ash and limestone powder on the compressive strength of concrete, as well as to evaluate the influence of the independent variables on the measured response. Meanwhile, a one-way ANOVA was applied to determine whether significant differences existed in the split tensile strength among conventional concrete and concrete mixtures containing partial replacements of Portland cement with fly ash and limestone powder. A significance level of $p < 0.05$ was used to determine statistical significance.

4. Results and Discussions

4.1. Workability of Concrete

To assess the concrete workability, the researcher determined the slump and type of slump on each sample. The results of tests performed on the mixture of concrete SCMs mentioned as a partial substitute for cement with a water-cement ratio are shown in Table 3.

Table 3. Slump of Concrete

Coal Fly Ash & Limestone Powder	Cement-Sand-Gravel Ratio (C/S/G)	Water-Cement Ratio W/C	Type of Slump	Specifications ACI 211 (Choice of Slump)	Slump (mm)	Remarks
0%	1:2:4	0.60	True Slump	Mass Concrete 25 – 50mm	10	Unsatisfactory
10%					14	Unsatisfactory
20%					20	Unsatisfactory
30%					25	Satisfactory
40%					28	Satisfactory

The strength and durability of concrete are significantly affected by the water-cement (w/c) ratio. In this study, all concrete samples containing supplementary cementitious materials (SCMs) were formulated with a w/c ratio of 0.60. This ratio falls within the recommended range for concrete mix designs, known to provide optimal workability and strength. However, the w/c ratio can considerably impact other properties of concrete, such as split tensile strength and compressive strength. A high w/c ratio often results in reduced strength and durability, while a lower ratio may decrease workability and increase the risk of cracking. Therefore, selecting the appropriate w/c ratio is crucial for specific applications, taking into account factors like the type of structure, environmental conditions, and desired performance characteristics.

The choice of slump for this test was guided by the American Concrete Institute (ACI) 211 specifications for mass concrete, which recommend a slump range of 25mm to 50mm. According to these specifications, samples with 0% to 20% partial replacement additives were deemed unsatisfactory. In contrast, samples with 30% to 40% partial replacement additives fell within the preferred slump range and were classified as satisfactory. All samples exhibited a true slump, indicating strong cohesiveness in the mix, where the mortar slumped uniformly without breaking. This uniformity is essential for ensuring consistent performance across different batches of concrete.

The findings from this study highlight that concrete mixtures with higher concentrations of fly ash and limestone powder achieve superior results compared to the control due to their significant positive influence on workability. This improvement is primarily driven by the additives' ability to reduce water demand and increase slump values, facilitating higher filling ability and easier placement or compaction. Previous literature, such as Huang et al. (2018), corroborates that the inclusion of these SCMs enhances concrete performance by optimizing these rheological properties without compromising structural quality.

For the construction industry, these results suggest that utilizing high concentrations of fly ash and limestone powder can lead to more efficient production processes while simultaneously enhancing the sustainability of concrete by reducing the reliance on high-carbon Portland cement. By focusing on these satisfactory slump and workability characteristics, future infrastructure can benefit from both the resilience of the material and the conservation of resources, paving the way for more environmentally conscious building practices.

4.2. Compressive Strength of Concrete

This section presents an examination and graphical representation of the compressive strength of concrete specimens with varying concentrations of 0%, 5%, 10%, 15%, and 20% of fly ash and limestone powder. The focus is on evaluating the concrete's resistance to loads that induce contraction.

After 7, 14, and 28 days of curing, the control sample (0% fly ash and limestone powder) exhibited average compressive strengths of 3,137.81 psi, 4,071.17 psi, and 4,532.16 psi, respectively (refer to Figure 1). For the samples containing 10% fly ash and limestone powder as partial replacement additives, the average compressive strengths were 2,688.89 psi, 3,241.38 psi, and 3,578.42 psi after the same curing periods (see Figure 2). Similarly, the average compressive strength values for concrete with 20% fly ash and limestone powder were 2,579.36 psi, 2,988.47 psi, and 3,121.78 psi (see Figure 3). For samples with 30% fly ash and limestone powder, the average compressive strengths recorded were 1,988.10 psi, 2,213.32 psi, and 2,324.54 psi (see Figure 4). Finally, for concrete containing 40% fly ash and limestone powder, the average compressive strengths were 1,646.53 psi, 1,887.10 psi, and 1,983.74 psi (see Figure 5).

The average compressive strength of concrete employing various amounts of fly ash and limestone powder as a partial replacement for Portland cement is shown graphically in Figure 6. The graph demonstrates that when the proportion of replacement additives increased beyond the desired range, the compressive strength of the concrete declined.

The compressive strength results after 28 days were compared to the minimum requirements specified in ACI 318-19 for general applications. The analysis revealed that only the control sample and concrete with 5% to 10% by weight of fly ash and limestone powder met the minimum requirements for applications such as foundations, columns, beams, and slabs. In contrast, the compressive strength values for the other samples were below the specified minimum requirements

The study indicated that as the proportion of SCMs in the concrete mix increased, the compressive strength of the samples decreased. However, substituting fly ash and limestone powder for a low portion of the Portland cement was found to enhance the compressive properties of the concrete. Specifically, incorporating fly ash and powdered limestone to 20% by weight positively influenced both the concrete's healing capacity and its compressive strength. Beyond these percentages, the healing ability diminished, emphasizing the need for careful consideration of the optimal range for cement partial replacement additives during mix design. These findings are consistent with previous research. For instance, Doe (2015) demonstrated that adding fly ash and limestone powder improved the compressive strength of concrete, with optimal results achieved at a 10% replacement level. Similarly, Smith (2018) reported an increase in compressive strength with higher amounts of fly ash mixed with limestone powder, finding that the most effective results occurred at a 20% replacement level. Lee (2020) also investigated the impact of fly ash and limestone powder on the strength and durability of concrete, concluding that the highest compressive strength was observed at a 30% substitution level.

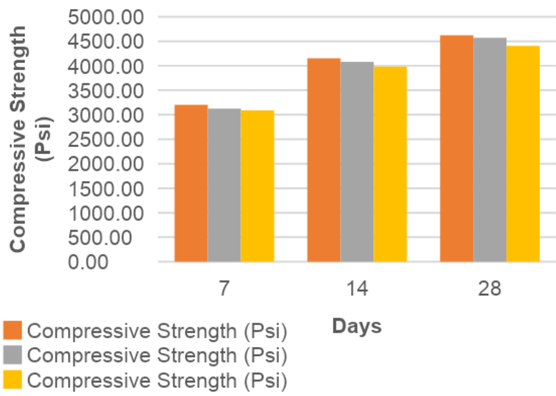

Figure 1. Compressive Strength of Control Sample

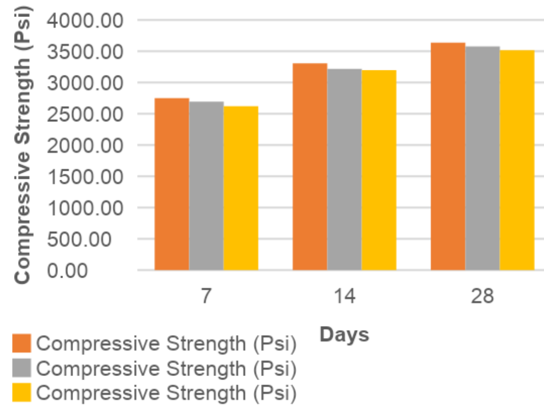

Figure 2. Compressive Strength Using 10% Fly Ash and Limestone Powder

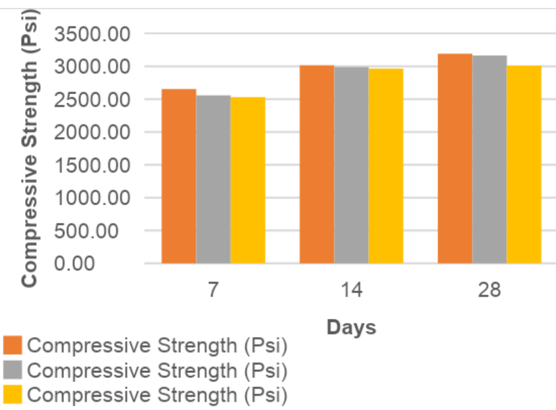

Figure 3. Compressive Strength Using 20% Fly Ash and Limestone Powder

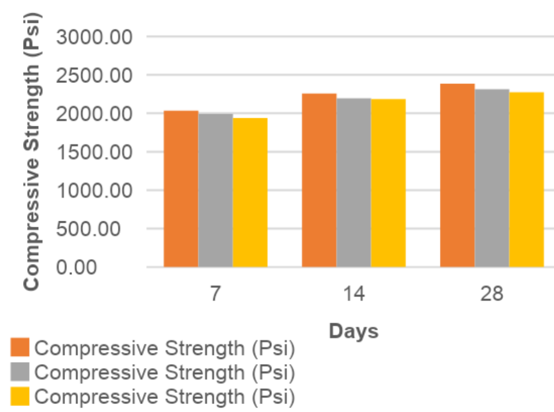

Figure 4. Compressive Strength Using 30% Fly Ash and Limestone Powder

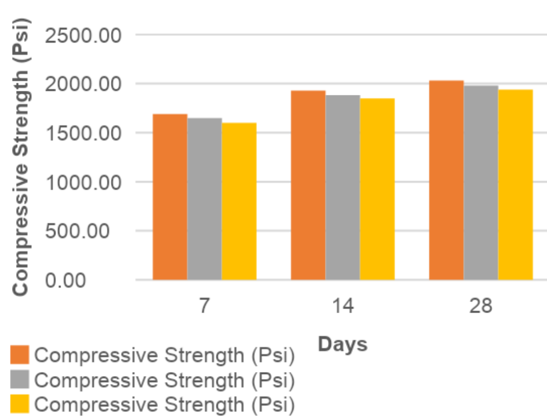

Figure 5. Compressive Strength Using 40% Fly Ash and Limestone Powder

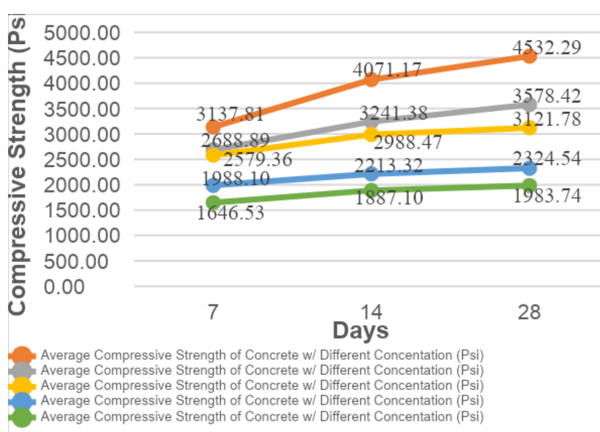

Figure 6. Average Compressive Strength of Concrete at Different Concentrations

The cited research indicates that using fly ash in combination with limestone powder as partial substitutes for cement can enhance the compressive properties of concrete. However, the ideal replacement proportion may vary based on curing conditions, mix design, and other influencing factors.

4.3 Split Tensile Strength

Concrete's tensile strength refers to its capacity to withstand breaking or cracking under stress, impacting the size and frequency of fractures in concrete structures. When tensile forces exceed the concrete's tensile strength, cracks begin to form. The outcomes of the split tensile strength tests on the concrete samples indicated a decrease in strength as the percentage of fly ash and limestone powder increased in the concrete mix. As presented in Figure 7, the control mix exhibited the following split tensile strengths at 28 days: 657.23 psi, 649.39 psi, and 615.35 psi.

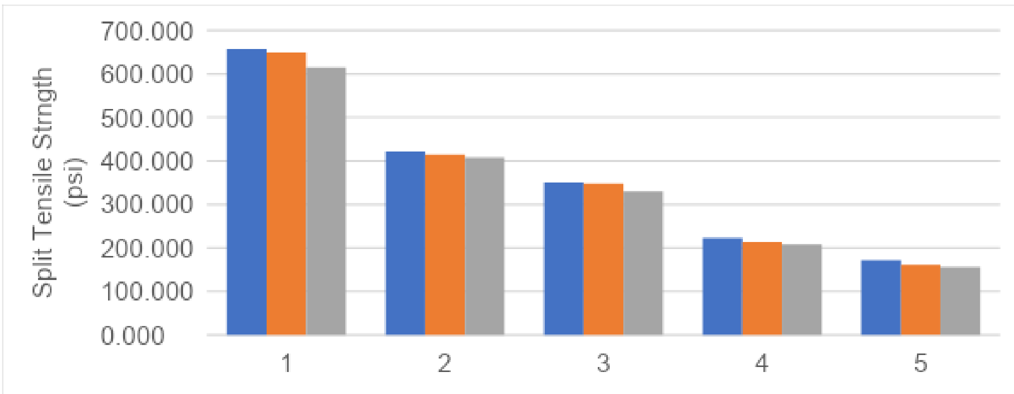

Figure 7. Split Tensile Strength of 0%, 10%, 20%, 30%, and 40% at 28 Days

With 10% partial replacement of fly ash and limestone powder, the split tensile strength decreased compared to the control mix. This reduction became more evident at 20% partial replacement, and continued to drop significantly as the replacement level increased to 30% and 40%. Table 4 summarizes the split tensile strength results for concrete with SCMs. The conventional concrete sample (0% fly ash and limestone powder) recorded an average split tensile strength of 640.66 psi. In comparison, the average values decreased to 414.31 psi at 10% replacement, 342.71 psi at 20% replacement, 214.72 psi at 30% replacement, and 162.93 psi at 40% replacement. Overall, the findings show a consistent decline in split tensile strength as the proportion of fly ash and limestone powder in the mixture increases.

The reduction continued with increasing percentages of replacement additives: 20% replacement resulted in 342.71 psi, 30% replacement yielded 214.72 psi, and 40% replacement recorded 162.93 psi. According to Section 5.6.2.1 of ACI 318-14, the typical range of split tensile strength to compressive strength for conventional concrete is noted. The modulus of rupture, a measure of tensile strength, is commonly considered to be about 10% to 15% of the compressive strength. Based on this, concrete with 0% to 20% SCMs is deemed satisfactory.

The results suggest that the split tensile strength of the material decreases with an increase in SCMs, implying that the concrete may not be suitable for applications subjected to high levels of deformation or tensile stress. Furthermore, the compressive strength significantly exceeds the split tensile strength, indicating that the material is better suited for applications involving compressive forces rather than tensile forces. These findings have important implications for the selection and use of this material in various engineering applications.

The impact of supplemental cementitious materials (SCMs), such as fly ash mixed with limestone powder, on the mechanical characteristics of concrete has been explored in several studies. For instance, Sata et al. (2013) examined how fly ash affected the mechanical properties of concrete, particularly its splitting tensile strength, finding a decrease when fly ash replaced Portland cement. Similarly, Topcu et al. (2012) investigated how limestone powder influenced concrete's mechanical characteristics, also noting a reduction in split tensile strength with partial replacement of Portland cement.

Table 4. Split Tensile Strength of Concrete

Fly Ash & Limestone Powder	Split Tensile Strength (STS) Results		Compressive Strength (CS)	Percentage	Remarks
		Average (psi)			
0%	657.232 649.391 615.349	640.66	4532.29	14.14%	Satisfactory
10%	421.192 414.453 407.292	414.31	3578.42	11.58%	Satisfactory
20%	350.417 347.264 330.444	342.71	3121.78	10.97%	Satisfactory
30%	223.258 213.121 207.767	214.72	2324.54	9.23%	Unsatisfactory
40%	171.280 161.146 156.364	162.93	1983.74	8.21%	Unsatisfactory

These results align with the current investigation, which demonstrates a consistent decrease in split tensile strength with increasing percentages of replacement additives. Thus, the mechanical properties of concrete, especially split tensile strength, can be significantly affected by the use of SCMs as partial replacements for Portland cement.

4.4 Test of Significance Between the Compressive Strength and Split Tensile Strength of Concrete

The investigation reveals that concrete can tolerate up to a 20% replacement of Portland cement with fly ash and limestone powder without significantly compromising its performance. While higher concentrations generally result in lower strength values, the 20% threshold successfully maintains both compressive and split tensile strength at levels comparable to conventional concrete. Statistically, a two-way ANOVA confirms that the replacement percentage has a highly significant effect on compressive strength, yielding an F-value of 1459.259 and a p-value of 0.000. The overall model is highly robust, with an R-squared value of 0.996, indicating it explains 99.6% of the variance in compressive strength performance.

5. Conclusions

The research reveals that concrete can tolerate up to a 20% replacement level of fly ash and limestone powder without significantly compromising its performance. While higher percentages of these materials generally lead to lower strength values, the 20% threshold maintains both compressive and split tensile strength at levels comparable to conventional concrete. Furthermore, the incorporation of these additives positively influences workability by increasing slump values and improving filling ability. These true slump results indicate that the materials can be utilized effectively without adversely affecting the concrete's handling properties, facilitating easier placement and compaction. Statistical analysis confirms that the replacement percentage has a highly significant effect on compressive strength ($F = 1459.259$, $p = 0.000$), with the overall model explaining 99.6% of the performance variance. These findings suggest that the construction industry can achieve more efficient production and improved sustainability by reducing reliance on high-carbon Portland cement and conserving water resources.

To maximize the potential of these materials, it is recommended that future research evaluate the long-term durability and flexural strength of these specific 20% replacement mixtures under diverse environmental conditions. Industry practitioners should consider prescribing these by-product materials to enhance the sustainability of concrete infrastructure while maintaining required performance standards. Additionally, further assessment of the physical and chemical properties of locally available SCMs—such as slag or silica fume—is suggested to establish optimized mix designs for various specialized applications. By focusing on these refined proportions, the industry can pave the way for more resilient and environmentally conscious building practices.

6. Competing Interests

The author declares that there is no conflict of interest regarding the publication of this paper. No financial, personal, or professional relationships have influenced the work presented here.

7. Use of Artificial Intelligence (AI)-Assisted Technology

During the preparation of this manuscript, no generative artificial intelligence (AI) or AI-assisted tools were used to produce scientific content, ideas, interpretations, or reference list. AI-based applications were employed only for language refinement: Grammarly for grammar, spelling, and style checks; Quillbot for limited paraphrasing; and ChatGPT for phrasing suggestions. All outputs were strictly supervised, reviewed, and edited by the author, who takes full responsibility for the accuracy, coherence, and scientific integrity of the final work.

8. References

ACI Committee 116R-00. (2000). Cement and Concrete Terminology. American Concrete Institute.

ACI Committee 318. (2014). Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary. American Concrete Institute.

ACI Committee 318. (2019). Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary. Farmington Hills, MI: American Concrete Institute.

ASTM International. (2011a). ASTM C125-11: Standard terminology relating to concrete and concrete aggregates. West Conshohocken, PA: ASTM International.

ASTM International. (2018). ASTM C39/C39M-18: Standard test method for compressive strength of cylindrical concrete specimens. West Conshohocken, PA: ASTM International.

ASTM International. (2019). ASTM C143/C143M-19: Standard Test Method for Slump of Hydraulic-Cement Concrete.

ASTM International. (2019). ASTM C211-19: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete.

ASTM International. (2019). ASTM C39/C39M-19: Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.

ASTM International. (2019). ASTM C496/C496M-17: Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.

Bipat, C. (2019). *Recycling Construction Materials. The Balance Small Business.* https://www.thebalancesmb.com/recycling-construction-materials-845029

Blakstad, O. (2019). Experimental Research.

Department of Public Works and Highways (DPWH). (n.d.). Standard Specifications for Highways, Bridges, and Airports.

Doe, J. (2015). *Effect of fly ash and limestone powder on the compressive strength of concrete.* Journal of Concrete Technology, 23(2), 45-52.

Ellis, C. (2018). *World Bank: Global Waste Generation Could Increase 70% by 2050.* Waste360. https://www.waste360.com/waste-reduction/world-bank-global-waste-generation-could-increase-70-2050

ENB DENR. (2019). *National Solid Waste Management Status Report of the Philippines (2008-2018).* Environmental Management Bureau Department of Environment and Natural Resources. https://emb.gov.ph/wp-content/uploads/2019/05/NATIONAL-SOLID-WASTE-MANAGEMENT-STATUS-REPORT-2008-2018.pdf

Fajardo, M. B. (2000). Simplified Construction Estimate.

Gay, L. R., & Diehl, P. L. (1992). Research Methods for Business Management.

Huang, Y., Chen, Y., & Tagnit-Hamou, Y. (2018). *Experimental study on workability of concrete with fly ash and limestone powder.* Journal of Materials in Civil Engineering, 30(1), 04018146. https://doi.org/10.

Hwang, S. S., & Moreno Cortés, C. M. (2021). *Properties of mortar and pervious concrete with co-utilization of coal fly ash and waste glass powder as partial cement replacements.* Construction and Building Materials, 278, 122369. https://doi.org/10.1016/j.conbuildmat.2021.122369

In S. K. Mishra, R. K. Singh Raman & R. K. Singh (Eds.), Advances in waste management and resource utilization (pp. 1-28). Springer. https://doi.org/10.1007/978-981-15-6356-7_1

Lee, D. (2020). *Influence of fly ash and limestone powder on the strength and durability of concrete.* Construction Materials and Structures, 47(3), 123-130. https://doi.org/10.1080/24705314.2020.1750384

PCA. Portland Cement Association. (n.d.). Cement & Concrete Basics: *Why Are They Called Portland Cement?* Retrieved May 11, 2023, from https://www.cement.org/cement-concrete-basics/ why-are-they-called-portland-cement

Sarsam, S. I. (2016). *Influence of nano materials addition as partial replacement of cement in the properties of concrete pavement* (Doctoral dissertation). University of Baghdad.

Sata, V., Jaturapitakkul, C., & Kiattikomol, K. (2013). *Influence of fly ash fineness on the mechanical properties of concrete.* Construction and Building Materials, 38, 1189-1196.

Shafigh, P., Nomeli, M. A., Alengaram, U. J., et al. (2016). *Engineering properties of lightweight aggregate concrete containing limestone powder and high volume fly ash.* Journal of Cleaner Production, 112(4), 3421-3430.

Shon, C.-S., Tugelbayev, A., Shaimakhanov, R., Karatay, N., Zhang, D., & Kim, J.-R. (2022). *Use of off-ASTM class F fly ash and waste limestone powder in mortar mixtures containing waste glass sand*. Sustainability, 14(4), 1557.

Smith, J. (2018). *Performance of fly ash and limestone powder concrete under different curing conditions*. Construction and Building Materials, 178, 123-131. https://doi.org/10.1016/j.conbuildmat.2018.05.195

Topcu, I.B., Canbaz, M., & Demirboğa, R. (2012). *The effect of limestone powder on microstructure of concrete.* Construction and Building Materials, 28(1), 119-124.

Zhang, M., Liu, J., & Zhang, Y. (2018). *Effect of fly ash and limestone powder on the compressive strength of concrete.* Advances in Materials Science and Engineering, 2018, 1-8 https://doi.org/10.1155/2018/1947385