e-ISSN 2540-9840 p-ISSN 1412-3770 Jurnal Ilmiah Sains, October 2025, 25(2): 138-149
Accredited by Ministry of Education, Culture, Research and Technology No: 105/E/KPT/2022
DOI: https://doi.org/10.35799/jis.v25i2.59325
Available online at https://ejournal.unsrat.ac.id/v3/index.php/jis

Incorporation of Lokon Ash, Plastic and Fish Scales Waste in Concrete Composites and Their Compressive Strength

Maria D. Bobanto[1)], Dolfie P Pandara[1*)], Maureen Kumaunang[2)], Gerald H. Tamuntuan[1)], Ferdy Ferdy[1)], Rizkivany Marsaoly[1)]

[1)]Department of Physics Faculty of Mathematics and Natural Sciences, Sam Ratulangi University Manado, Indonesia, 95115
[2)]Department of Chemistry Faculty of Mathematics and Natural Sciences, Sam Ratulangi University Manado, Indonesia, 95115
*Corresponding author: dpandara_fisika@unsrat.ac.id

ABSTRACT

Sustainable construction efforts to reduce carbon dioxide emissions from cement production suggest incorporating pozzolanic and waste materials into concrete composites. This research focuses on evaluating the compressive strength of concrete composites that include Mount Lokon volcanic ash, plastic waste, and fish scale waste. The study was conducted through several stages: preparation of raw materials, production of concrete composites with varying mix ratios, curing for 14–28 days, and compressive strength testing using a Compression Testing Machine (CTM). The findings indicate that replacing 7% of cement with Lokon ash provides the best compressive strength, reaching 2.7 MPa after 14 days of curing. When plastic is used as an aggregate at 13% in a mix of 13% cement, 7% Lokon ash, and 67% sand, the compressive strength improves to 3.7 MPa after 28 days of curing. The inclusion of 7% fish scale waste in the composite increases compressive strength, though it still falls short of the minimum strength required by SNI standards. Lokon ash, plastic, and fish scale waste have potential for use in non-structural concrete blocks. Further research is required to better understand the role of fish scale waste as a filler in concrete blends with cement, Lokon ash, plastic, and sand. The integration of these materials supports the advancement of sustainable construction practices.
Keywords: Compressive strength; concrete; fish scale; Lokon ash; plastic

Inkorporasi Abu Lokon, Limbah Plastik Dan Sisik Ikan Dalam Komposit Beton Dan Nilai Kuat Tekan

ABSTRAK

Konstruksi berkelanjutan sebagai upaya mereduksi emisi gas karbondioksida sebagai efek samping produksi semen mengusulkan penggunaan material pozzolanic dan material limbah untuk diinkorporasi ke dalam komposit beton. Penelitian ini bertujuan mengkaji kuat tekan komposit beton yang diinkorporasi abu vulkanik Gunung Lokon, limbah plastik dan limbah sisik ikan. Metode penelitian meliputi tahap persiapan bahan baku, pembuatan komposit beton dengan variasi komposisi campuran, proses curing selama 14–28 hari, serta pengujian kuat tekan menggunakan Compression Testing Machine (CTM). Hasil riset menunjukkan bahwa subtitusi 7% abu Lokon sebagai komplemen semen telah memberikan kuat tekan optimum sebesar 2,7 MPa pada pengeringan selama 14 hari. Penggunaan plastik sebagai agregat dengan persentase 13 % dalam kombinasi semen 13%, abu Lokon 7% dan pasir 67% memberikan kuat tekan optimum sebesar 3,7 MPa pada lama pengeringan 28 hari. Penggunaan 7% limbah sisik ikan dalam komposit beton potensial meningkatkan kuat tekan komposit beton meskipun nilai kuat tekan masih di bawah nilai kuat tekan minimun SNI. Pemanfaatan abu Lokon, limbah plastik dan limbah sisik ikan dalam komposit beton berpotensi untuk diterapkan sebagai beton berupa batako untuk aplikasi non struktural. Dibutuhkan kajian lebih lanjut untuk mengetahui konstribusi limbah sisik ikan sebagai material pengisi dalam campuran beton berbahan semen, abu Lokon, plastik dan pasir. Pemanfaatan abu Lokon, limbah plastik dan limbah sisik ikan sebagai material suplemen dalam komposit beton mendukung konstruksi berkelanjutan.

Kata kunci: Abu Lokon; beton; kuat tekan; plastik; sisik ikan

(Article History: Received 03-05-2025; Accepted 22-10-2025; Published 26-10-2025)

INTRODUCTION

The development of sustainable construction is a crucial issue because the construction sector has a significant impact on the environment, energy consumption, depletion of natural resources, and carbon dioxide (CO_2) emissions (Ahmad *et al*., 2021). Globally, construction relies heavily on cement as the primary material for concrete (Ibrahim, 2021; Khawaja *et al*., 2021). By 2050, global demand for Ordinary Portland Cement (OPC) is projected to increase by 200%, driving higher cement production (Miller *et al*., 2018). Large-scale cement production, however, conflicts with the growing scarcity of raw materials and rising CO_2 emissions, which amount to 0.94 tons of CO_2 per ton of cement produced (Robayo-Salazar & de Gutiérrez, 2018). Efforts to enhance sustainability in the construction sector include incorporating supplementary materials into concrete, such as waste materials and natural pozzolans (Ahmad *et al*., 2021; Robayo-Salazar & de Gutiérrez, 2018; Juenger, Snellings and Bernal, 2019; Luhar, Cheng & Luhar, 2019).

Among the waste materials requiring attention are plastic waste and fish scales. Plastic waste can harm marine life, and microplastics can accumulate in fish, posing health risks to humans. Meanwhile, fish scales can pollute the environment, emitting foul odors and harboring bacteria that threaten human health (Yadav *et al*., 2019). Addressing plastic and fish scale waste can be integrated into sustainable green construction efforts. Additionally, North Sulawesi has abundant natural pozzolans, such as volcanic ash from Mount Lokon, which remain underutilized. Mount Lokon volcanic ash, rich in silica and alumina, holds significant potential as a binding agent for use as a cement supplement (Bobanto et al., 2023).

This study employs Mount Lokon volcanic ash, plastic waste, and fish scale waste as supplementary materials in concrete composites due to their environmental and technical potential. Volcanic ash, abundant in North Sulawesi and rich in silica and alumina, serves as a pozzolanic material that can partially replace cement and reduce CO_2 emissions from cement production. Plastic waste, a persistent environmental pollutant, can function as a lightweight aggregate, reducing the reliance on natural sand while promoting circular use of resources. Fish scales, an underutilized by-product of the fisheries industry, are explored as a novel filler to mitigate waste disposal issues, although their effect on strength requires further optimization.

The integration of these materials supports sustainable construction practices while addressing waste management challenges. This approach requires an evaluation of the resulting compressive strength to ensure it meets Indonesian National Standards. Therefore, this research aims to incorporate Lokon volcanic ash, plastic waste, and fish scales into concrete composites and evaluate their impact on compressive strength. The findings are expected to provide valuable insights for advancing sustainable construction.

RESEARCH METHOD

This research was conducted in the Advanced Physics Laboratory at FMIPA Unsrat and the Material Testing Laboratory at Politeknik Negeri Manado. The study followed four main stages: raw material procurement and preparation, concrete composite production, curing, and compressive strength testing. The raw materials consisted of cement, Lokon volcanic ash, volcanic sand, shredded plastic waste, and fish scales (Red Snapper and Parrotfish). These materials were collected and prepared for use in the concrete composites. The preparation process involved drying and sifting the sand, followed by mixing the raw materials according to predetermined mix ratios. The mixtures were then molded into cylindrical samples. The molded concrete samples were subjected to curing (drying) for different durations (14, 21, and 28 days) to allow hydration and strength development. After curing, the samples were tested for compressive strength using a Compression Testing Machine (CTM). The test measured the ability of each composite to withstand applied loads and provided the data used for evaluating performance.

The materials used included cement, fine volcanic ash from Mount Lokon (44 µm), crushed Red Snapper and Parrotfish scales, shredded plastic (1–2 cm), fine sand as aggregate, and water. Three types of concrete composites were developed: Concrete Composite I comprised cement, Lokon ash, and sand, with four mix variations: Mix X (control) with a cement-to-sand ratio of 20%:80%, Mix A (13% cement, 7% ash, 80% sand), Mix B (7% cement, 13% ash, 80% sand), and Mix C (0% cement, 20% ash, 80% sand). Concrete Composite II incorporated shredded plastic into the mix while maintaining fixed proportions of cement and Lokon ash, with three variations: Mix PA (13% cement, 7% ash, 60% sand, 20% plastic), Mix PB (13% cement, 7% ash, 67% sand, 13% plastic), and Mix PC (13% cement, 7% ash, 73% sand, 7% plastic**).** Concrete Composite III incorporated powdered fish scales (Red Snapper or Parrotfish) while maintaining fixed cement and ash ratios, resulting in six variations: Mixes MA, MB, and MC for Red Snapper scales and Mixes TA, TB, and TC for Parrotfish scales, with proportions matching those in Concrete Composite II.

The percentage composition of Mount Lokon ash, plastic waste, and fish scale waste in the concrete composites was determined based on three main considerations ((Yusra *et al*., 2024; Dhanalakshmi *et al*., 2025; Sulaiman *et al*., 2025). First, reference was made to previous studies, which indicate that moderate replacement levels (around 5–10%) of pozzolanic and waste materials usually provide the best balance between strength and sustainability, while higher levels (>20%) often cause strength reduction. Second, the chosen percentages were designed to ensure comparability across composite groups: Concrete Composite I varied ash content from 7% to 20%, while Composites II and III used 7%, 13%, and 20% of plastic or fish scales to evaluate both low and moderate inclusion levels. Third, practical and environmental considerations were taken into account: 7–13% substitution is realistic for non-structural concrete applications, while 20% was deliberately included to test the upper limit of substitution. In summary, the selected percentages reflect a balance between scientific relevance, comparability, and practical applicability, while also exploring the boundaries of material substitution in sustainable concrete composites. The composites were cured for 14, 21, or 28 days at room temperature, and their compressive strength was tested using a Compression Testing Machine (CTM) at the Material Testing Laboratory of Politeknik Negeri Manado.

Figure 1. Research Procedure

RESULTS AND DISCUSSION

Compressive Strength of Concrete Composite I

The results of the compressive strength tests for Concrete Composite I are shown in Figure 2. The composite made of cement and sand (Mix X) demonstrated the highest compressive strength across all curing durations: 3.4 MPa at 14 days, and 3.9 MPa at both 21 and 28 days. Mix A, which incorporated cement, Lokon ash, and sand in a 13%: 7%: 80% ratio, showed compressive strengths of 1.5 MPa, 2.7 MPa, and 2.2 MPa after 14, 21, and 28 days of curing, respectively. Mix B, with a 7%: 13%: 80% ratio of cement, Lokon ash, and sand, achieved compressive strengths of 0.6 MPa at 14 and 21 days and 0.4 MPa at 28 days. Mix C, which replaced all cement with Lokon ash, showed no measurable compressive strength at 14 and 21 days but achieved 0.1 MPa after 28 days of curing.

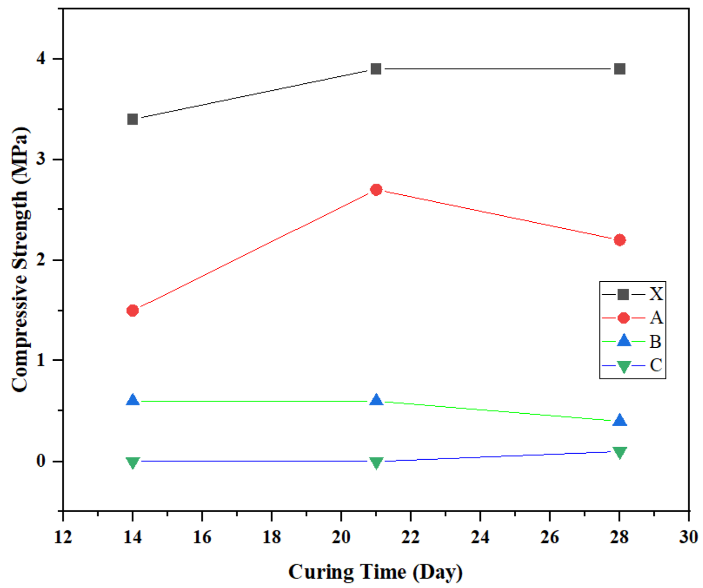

Figure 2. Compressive Strength vs Curing Time of Concrete Composite I

Curing duration significantly affected the compressive strength of Concrete Composite I. The incorporation of fine Lokon ash influenced the composite's strength, resulting in lower values compared to the cement-sand mixture. Notably, the use of 7% Lokon ash as a partial replacement for cement yielded a compressive strength of 2.7 MPa after 21 days of curing, exceeding the minimum standard of 2.5 MPa set by Indonesian National Standards (SNI 03-0349-1989) for lightweight non-structural wall bricks. These findings indicate that substituting 7% of the cement with fine volcanic ash from Mount Lokon produces a concrete composite that meets the quality standards for non-structural concrete blocks. Substituting 13% of the cement or replacing all of the cement material did not achieve compressive strength that meets the quality standards set by SNI. The complete replacement of cement with fine ash still failed to provide the required density and firmness in the composite after 14 and 21 days of curing. Even after 28 days of curing, no significant increase in compressive strength was observed.

Compressive Strength of Concrete Composite II

Concrete Composite II is made from cement, Lokon ash, sand, and plastic. The incorporation of plastic into the composite resulted in somewhat fluctuating compressive strength values (Figure 3). Mix PA achieved compressive strengths of 3.3 MPa, 2.7 MPa, and 3.2 MPa after 14, 21, and 28 days of curing, respectively. Mix PB, after curing for 14, 21, and 28 days, showed compressive strengths of 2.4 MPa, 1.8 MPa, and 3.7 MPa. Mix PC exhibited compressive strengths of 2.4 MPa, 1.5 MPa, and 1.9 MPa after curing for 14, 21, and 28 days. The 28-day curing period provided the most optimal compressive strength for Mix PB. In general, compressive strength decreased after 21 days of curing but increased again after 28 days. The extended curing time demonstrated a fluctuating trend in compressive strength values.

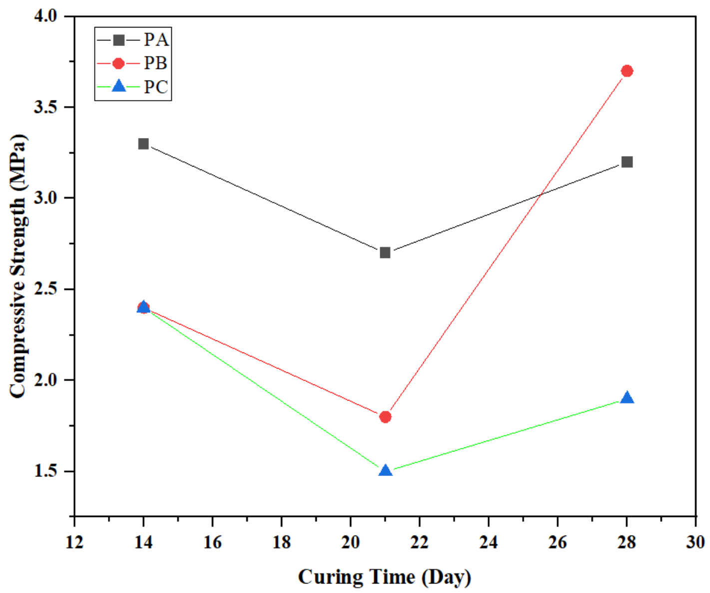

Figure 3. Compressive Strength vs Curing Time of Concrete Composite II

Figure 3 illustrates that increasing the volume percentage of plastic in concrete composites reduces the compressive strength. This decrease in strength may be due to several factors, including the irregular shape of the plastic particles (Babafemi *et al*., 2018), as well as the increase in water absorption and pore index (Resende *et al*., 2024). Although there is a reduction in compressive strength with a higher plastic content, this study's data shows that a 7% plastic inclusion in the concrete mixture still results in a compressive strength above the minimum standard required by SNI. Plastic, when used as a substitute for sand aggregate in the composite, provides a relatively lower unit weight, which can be beneficial for applications requiring lightweight structures.

Compressive Strength of Concrete Composite III

Concrete Composite III consists of two types: Concrete Composite III_M and Concrete Composite III_T. Concrete Composite III_M incorporates Red Snapper fish scales as a substitute for sand aggregates and as a filler material. Figure 5.9 shows the compressive strength values of the composite with three variations in the amount of Red Snapper fish scale powder. When 20% of the volume is replaced with Red Snapper fish scales, the compressive strength is 0.8 MPa, 0.8 MPa, and 1.0 MPa after 14, 21, and 28 days of drying, respectively. With only a 13% incorporation of fish scales, the compressive strength increases to 1.0 MPa, 1.0 MPa, and 1.4 MPa at the same drying intervals. When the percentage is further reduced to 7%, the compressive strength increases to 1.4 MPa, 1.1 MPa, and 1.7 MPa at 14, 21, and 28 days of drying. In general, incorporating Red Snapper fish scales into the concrete composite reduces the compressive strength. The compressive strength of the concrete with fish scales remains below the minimum standard required by SNI for non-structural lightweight blocks (SNI 03-0349-1989).

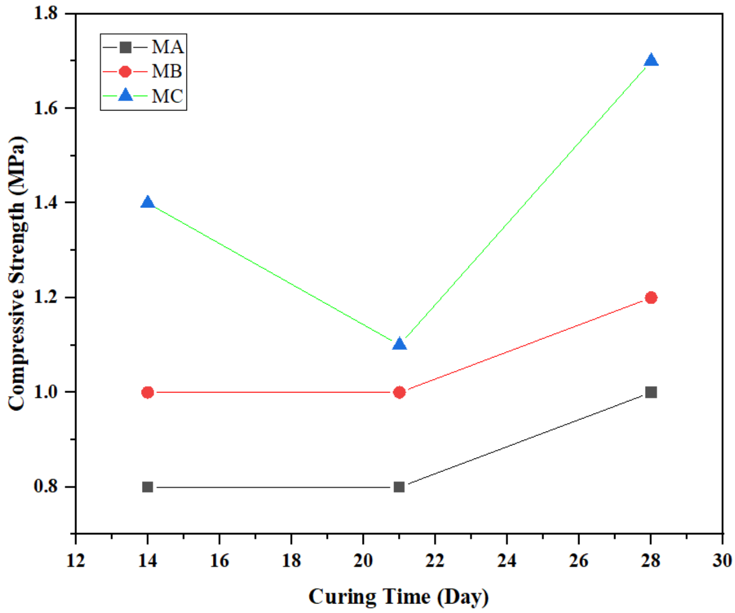

Figure 4. Compressive Strength vs Curing Time of Concrete Composite III_M

In addition to Red Snapper fish scales, Parrot fish scales were also incorporated into the concrete mixture. The compressive strength results are shown in Figure 5. Concrete composites with Parrot fish scale powder incorporated at volume percentages of 20%, 13%, and 7% exhibited a trend of increasing compressive strength. Substituting fish scale powder into the composite reduces its strength and density, thus decreasing its ability to withstand pressure. Figure 5 presents the compressive strength data of Concrete Composite III_T. A 7% inclusion of Parrot fish scales resulted in compressive strengths of 1.0 MPa, 1.4 MPa, and 2.3 MPa after 14, 21, and 28 days of drying, respectively. A 13% inclusion resulted in strengths of 0.8 MPa, 1.3 MPa, and 1.5 MPa, while a 20% inclusion yielded strengths of 1.0 MPa, 1.1 MPa, and 1.1 MPa, for the same drying periods.

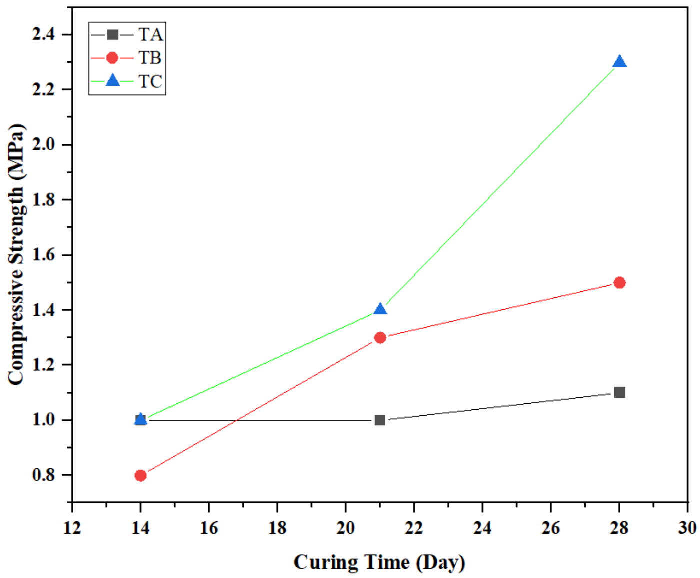

Figure 5. Compressive Strength vs Curing Time of Concrete Composite III_T

This research indicates that incorporating fish scales into concrete mixtures has a significant effect, notably causing a reduction in the compressive strength of the concrete.

The resulting compressive strength values fall below the minimum standard for non-structural brick applications (SNI 03-0349-1989). This decline is attributed to the fish scales increasing the water content in the mixture and reducing the material's density, which impacts the concrete's ability to withstand compressive loads (Resende *et al*., 2024). Furthermore, the study shows that at a 7% inclusion rate of fish scales, compressive strength exhibited an increasing trend after 28 days of curing. This suggests potential for using fish scales as an aggregate material in concrete composites for non-structural applications, although special treatment is required before incorporating them into the mixture.

In comparing the three composites, Concrete Composite II exhibited the best performance. Composite I, which combined cement, Mount Lokon ash, and sand, achieved acceptable compressive strength when 7% of cement was substituted with volcanic ash, reaching 2.7 MPa after 21 days. However, higher proportions of ash significantly reduced strength. Composite II, which incorporated shredded plastic as part of the aggregate, showed the highest improvement; the optimal mix (13% cement, 7% ash, 67% sand, and 13% plastic) achieved 3.7 MPa after 28 days, surpassing the results of both Composites I and III. By contrast, Composite III, which included fish scales, generally produced lower compressive strength values, with a maximum of 2.3 MPa at 7% fish scale content, below the SNI standard for non-structural applications. These findings indicate that the integration of plastic waste, in controlled proportions, offers the most effective approach to enhancing compressive strength while supporting sustainable construction practices.

The compressive strength results of the three concrete composites can be explained by the role and interaction of each supplementary material in the cementitious matrix. At low substitution rates (around 7%), Lokon volcanic ash contributed positively to compressive strength. Its fine particles, rich in silica and alumina, reacted pozzolanically with calcium hydroxide released during cement hydration to form additional calcium silicate hydrate (C–S–H) gel, thereby densifying the matrix. This explains the optimum strength of 2.7 MPa observed at 7% substitution. When the ash replacement increased to 13–20% or was used as a full replacement, insufficient cementitious material remained to initiate and sustain hydration, leading to reduced binding capacity and lower strength. This threshold effect aligns with other international studies, which also reported optimum performance at 5–10% volcanic ash substitution and strength reduction at higher levels (Agboola Shamsudeen Abdulazeez *et al*., 2020; Ahmad *et al*., 2024).

Shredded plastic acted as a lightweight aggregate replacement. Plastic is hydrophobic and has weak interfacial bonding with cement paste; therefore, higher plastic content typically reduces compressive strength due to increased voids and weak interfaces. However, at a balanced content (13% plastic with 7% ash), the composite achieved the highest overall compressive strength of 3.7 MPa after 28 days. This can be attributed to a favorable balance between reduced density and adequate cementitious bonding, with Lokon ash helping to densify the paste around plastic particles. These results are consistent with international findings showing that small to moderate levels of plastic aggregate can be tolerated in non-structural concretes, while higher contents cause significant reductions in strength (Babafemi *et al*., 2018; Resende *et al*., 2024; Zulkernain *et al*., 2021).

Unlike ash and plastic, the inclusion of fish scale waste generally reduced compressive strength. Fish scales, containing organic matter and hydroxyapatite, increased water demand and reduced the density of the mixture. Even at the lowest content (7%), compressive strength peaked at only 2.3 MPa, below the SNI minimum for non-structural lightweight blocks. This result differs from some international studies, where fish scale powders processed by calcination or used at nanoscale exhibited positive effects on compressive strength (Arain *et al*., 2022; Sulaiman *et al*., 2025). The difference highlights the importance of pre-treatment; raw fish scales in this study acted as weak fillers, while treated or nano-sized fishery wastes reported elsewhere enhanced matrix densification and strength.

Overall, the findings confirm a general trend widely observed in international research: supplementary waste materials can improve or maintain compressive strength only within a narrow optimum window, typically around 5–13%. Beyond this level, matrix dilution, weak bonding, or increased porosity dominate, resulting in lower strength. The similarity of results for Lokon ash and plastic with global studies indicates that the threshold concept is broadly valid. The difference in fish scale outcomes underscores the need for processing strategies to unlock their potential. This comparison strengthens the international relevance of the present research by showing that local materials (Lokon ash, Indonesian fish scales, and plastic waste) follow global sustainability patterns while offering unique challenges and opportunities in tropical contexts.

This research reveals the potential of Mount Lokon volcanic ash, plastic waste pieces, and fibers from Red Snapper and Parrotfish scales as supplementary components in concrete mixtures. Using volcanic ash as a substitute in concrete improves its compressive strength. The pozzolanic reaction between volcanic ash and cement generates calcium silicate hydrate, creating a dense gel that strengthens the concrete (Bashir & Elahi, 2023). Replacing 7% of cement with Lokon volcanic ash produced an optimal compressive strength of 2.7 MPa, suitable for non-structural applications. For structural concrete, substituting 10% of cement with volcanic ash significantly enhanced matrix strength, achieving a compressive strength of about 25 MPa (Bashir & Elahi, 2023). However, exceeding the optimal volcanic ash proportion leads to a decrease in compressive strength. Alternative approaches, such as calcining the volcanic ash, can further enhance the strength of cement-volcanic ash composites (Karolina *et al*., 2023). Calcination increases the pozzolanic activity of Lokon ash by elevating its amorphous phase (Bobanto *et al*., 2023).

The addition of plastic to concrete composites presents a challenge as increasing plastic content negatively impacts mechanical properties (Zulkernain *et al*., 2021). A higher amount of cement reduces the interaction between plastic particles and the matrix, such as cement or volcanic ash. The weak bond between plastic waste and cement paste, caused by plastic's hydrophobic properties that hinder cement hydration on its surface, contributes to a decline in compressive strength (Zulkernain *et al*., 2021). This issue can be mitigated by enhancing adhesion at the plastic-matrix interface using fillers (Lazorenko *et al*., 2022). Plastic-mixed concrete offers benefits such as improved impact resistance, reduced shrinkage and micro-cracking, increased impermeability, and better resistance to salt scaling (Kamal *et al*., 2021). It also enhances thermal and electrical insulation, lowers water absorption, and reduces alkali content in the concrete (Kadam *et al*., 2021). However, plastic-reinforced concrete is less suitable for applications involving heat exposure (Kadam *et al*., 2021; Wiswamitra *et al*., 2021). This study corroborates prior findings that fish scale incorporation lowers concrete's compressive strength. Therefore, fish scales and similar fishery waste are recommended for use in concrete composites at low concentrations (Yusra et al., 2022; Arain *et al*., 2022). To overcome the limitations of plastic in concrete, several studies propose using fishery waste in nanoscale form as a filler material (Luhar *et al.*, 2019; Osman *et al*., 2020).

CONCLUSION

The addition of Lokon volcanic ash, plastic waste, and fish scale waste influences the compressive strength of concrete composites. Optimal compressive strength can be achieved by substituting these materials in appropriate proportions. Replacing 7% of cement volume with Lokon volcanic ash results in a compressive strength of 2.7 MPa, while incorporating 13% plastic waste in a mixture with 13% cement, 7% Lokon ash, and 63% sand delivers the highest strength of 3.7 MPa among the tested combinations. Fish scale waste demonstrates potential as a limited-use aggregate. Further studies are required to evaluate its role as a filler in concrete composites enhanced with Lokon ash and plastic waste. Integrating Lokon ash, plastic waste, and fish scale waste as supplementary materials in concrete composites contributes to sustainable construction practices.

ACKNOWLEDGMENT

We extend our gratitude to the Rector of Sam Ratulangi University, represented by LPPM Unsrat, for awarding the RDUU K2 research grant with contract number 653/UN12.13/LT/2024.

REFERENCES

Agboola, S.A., Mamman, A.I., Tapgun, J. & Bappah, H. (2020). Strength Performance of Concrete Produced with Volcanic Ash as Partial Replacement of Cement. *International Journal of Engineering Research and Technology*, *9*(3), 372–378. https://doi.org/10.17577/ijertv9is030396

Ahmad, J., Alattyih, W., Jebur, Y.M. & Rahmawati, C. (2024). Mechanical properties of sustainable concrete made with partially substitution of volcanic ash: a review (part I). *Innovative Infrastructure Solutions*, *9*(10), 370. DOI:10.1007/s41062-024-01678-0

Ahmad, W., Ahmad, A., Ostrowski, K. A., Aslam, F., & Joyklad, P. (2021). A scientometric review of waste material utilization in concrete for sustainable construction. *Case Studies in Construction Materials*, *15*, e00683.

Arain, F.A., Jatoi, M.A., Raza, M.S., Shaikh, F.A., Khowaja, F., & Rai, K. (2022). Preliminary Investigation on Properties of Novel Sustainable Composite: Fish Scales Reinforced Cement Concrete. *Jurnal Kejuruteraan*, *34*(2), 309-315. DOI:10.17576/jkukm-2022-34(2)-14

Babafemi, A.J., Šavija, B., Paul, S.C., & Anggraini, V. (2018). Engineering properties of concrete with waste recycled plastic: A review. *Sustainability*, *10*(11), 3875. DOI:10.3390/su10113875

Bashir, M.I., & Elahi, A. (2023). Micro Structural Study of Concrete with Indigenous Volcanic Ash. *Engineering Proceedings*, *44*(1), 19.

Bobanto, M.D., Pandara, D.P., Ferdy, F., Tiwow, V.A., Aritonang, H., Tanauma, A., & Todingan, R. (2023). Effect of Calcination on the Ash from Lokon Volcano and Its Potentially Sustainable Binder Material. *International Journal on Advanced Science, Engineering & Information Technology*, *13*(6), 2067-2072. https://doi.org/10.18517/ijaseit.13.6.18900

Dhanalakshmi, K., Alex, A.G., Jose, P.A., & Kumar, R.D. (2025). Effect of Using Recycled E-Waste Plastic as Coarse Aggregate with Supplementary Nano-fills in Concrete. *International Journal of Concrete Structures and Materials*, *19*(1), 1-20. https://doi.org/10.1186/s40069-025-00779-z

Ibrahim, K. I. M. (2021). Recycled waste glass powder as a partial replacement of cement in concrete containing silica fume and fly ash. *Case Studies in Construction Materials*, *15*, e00630.

Juenger, M. C. G., Snellings, R., & Bernal, S. A. (2019). Supplementary cementitious materials: New sources, characterization, and performance insights. *Cement and Concrete Research*, *122*, 257–273.

Kadam, A.M., Porwal, P.P., Gondil, Y.D., Khot, R.R., Chavan, P.P., & Patil, P.T. (2021). Partial Replacement of Course Aggregate in Manufacturing of Waste Plastic Concrete Blocks. *International Journal of Research in Engineering, Science and Management*, *4*(7), 66–70.

Kamal, M.A., Moussa, R. R., & Guirguis, M. N. (2021). Recycled Plastic as an Aggregate in Concrete. *Civil Engineering and Architecture*, *9*(5), 1289–1294.

Karolina, R., Tarigan, J., Johari, M.A.M., Hardjasaputra, H., & Mijarsh, M.J.A. (2023). Compressive strength of geopolymer concrete from volcanic ash calcination. *AIP Conference Proceedings*, *2741*(1).

Khawaja, S. A., Javed, U., Zafar, T., Riaz, M., Zafar, M. S., & Khan, M. K. (2021). Eco-friendly incorporation of sugarcane bagasse ash as partial replacement of sand in foam concrete. *Cleaner Engineering and Technology*, *4*, 100164.

Lazorenko, G., Kasprzhitskii, A., & Fini, E. H. (2022). Sustainable construction via novel geopolymer composites incorporating waste plastic of different sizes and shapes. *Construction and Building Materials*, *324*, 126697.

Luhar, S., Cheng, T.W., & Luhar, I. (2019). Incorporation of natural waste from agricultural and aquacultural farming as supplementary materials with green concrete: A review. *Composites Part B: Engineering*, *175*, 107076.

Luhar, S., Rajamane, N. P., Corbu, O., & Luhar, I. (2019). Impact of incorporation of volcanic ash on geopolymerization of eco-friendly geopolymer composites: A review. *IOP Conference Series: Materials Science and Engineering*, *572*(1), 12001.

Miller, S. A., John, V. M., Pacca, S. A., & Horvath, A. (2018). Carbon dioxide reduction potential in the global cement industry by 2050. *Cement and Concrete Research*, *114*, 115–124.

Osman, M. H., Mohamad, M. Y. R. N., Sunar, N. M., Ali, R., Hamidon, N., Hamid, N. H. A., & Harun, H. (2020). Response Surface Methodology Optimization of Concrete Strength Using Hydroxyapatite Nanopowder As Admixture. *Progress in Engineering Application and Technology*, *1*(1), 134–141.

Resende, D. M., de Carvalho, J. M. F., Paiva, B. O., Gonçalves, G. dos R., Costa, L. C. B., & Peixoto, R. A. F. (2024). Sustainable Structural Lightweight Concrete with Recycled Polyethylene Terephthalate Waste Aggregate. *Buildings*, *14*(3), 609.

Robayo-Salazar, R. A., & de Gutiérrez, R. M. (2018). Natural volcanic pozzolans as an available raw material for alkali-activated materials in the foreseeable future: A review. *Construction and Building Materials*, *189*, 109–118.

Sulaiman, E. A., Alwash, J. J. H., Jasim, T. A., Al-Khafaji, Z., & Falah, M. (2025). Investigating the Effect of Applying Fish Scale Powder in Concrete as Sustainable Blending Materials. *Revue Des Composites et Des Materiaux Avances*, *35*(3), 403.

Wiswamitra, K.A., Dewi, S.M., Choiron, M. A., & Wibowo, A. (2021). Heat resistance of lightweight concrete with plastic aggregate from PET (polyethylene terephthalate)-mineral filler. *AIMS Materials Science*, *8*(1), 99–118.

Yadav, M., Goswami, P., Paritosh, K., Kumar, M., Pareek, N., & Vivekanand, V. (2019). Seafood waste: a source for preparation of commercially employable chitin/chitosan materials. *Bioresources and Bioprocessing*, *6*(1), 8.

Yusra, A., Jasmi, J., Simatupang, H. M. P., Irwansyah, I., Opirina, L., Yusra, A., Ji, J., Simatupang, H. M. P., & Irwansyah, I. (2024). *Optimizing concrete strength through pozzolan variation, heat treatment, and alkaline solution modulation: A comprehensive study*.

Yusra, A., Samsunan, S., Ikhwali, M. F., & Satria, A. (2022). *The Environmentally Substitution of Shellfish Shells on the Strength of Concrete*. EasyChair.

Zulkernain, N. H., Gani, P., Chuan, N. C., & Uvarajan, T. (2021). Utilisation of plastic waste as aggregate in construction materials: A review. *Construction and Building Materials*, *296*, 123669.