Study on Compressive Strength of Eco-Friendly Concrete Utilizing Brick Powder from Oebelo as Pozzolanic Material

I Made Suparta[1]*

[1] Akademi Teknik Kupang, Kupang, Indonesia

* Corresponding author: suspartamade66@gmail.com

Article History

Received	Revised	Accepted	Published
July 06, 2026	*August 08, 2026*	*August 30, 2026*	*30 August 2026*

How to Cite

Suparta, I. M. (2026). Study on compressive strength of eco-friendly concrete utilizing brick powder from Oebelo as pozzolanic material. Cornerstone Civil Engineering Journal, 1(1), 65–70. https://ejournal.atkup.ac.id/index.php/ccej/article/view/7

ABSTRACT

Brick production waste in Oebelo Village, Kupang Regency, which reaches approximately 30% of total production, poses a potential environmental pollution threat. This study examines the utilization of brick powder (SBB) waste as a pozzolanic material for partial cement substitution in eco-friendly concrete mixtures. Laboratory test results indicate that Oebelo SBB has a cumulative active oxide content (SiO_2 + Al_2O_3 + Fe_2O_3) of 91.17%, exceeding the minimum pozzolanic-material requirement referenced in ASTM C618. Concrete cylinder compressive strength testing refers to structural requirements under SNI 2847:2019, with SBB substitution variations of 0%, 10%, 20%, and 30% and a constant water-cement ratio (w/c) of 0.5. Testing was conducted at curing ages of 28, 56, and 90 days to observe long-term pozzolanic reaction kinetics. The findings demonstrate that 10% SBB substitution achieves the best compressive strength among the substitution mixtures, reaching 34.5 MPa at 90 days, equivalent to 96.64% (approximately 97%) of the control concrete strength of 35.7 MPa. The utilization of SBB as a pozzolanic material therefore shows potential to support lower-cement concrete production while providing a practical pathway for local brick-waste utilization. Further durability and field-scale evaluation is recommended before broad structural application.

Keywords: *compressive strength; eco-friendly concrete; Oebelo brick powder; pozzolan*

ABSTRAK

Limbah produksi batu bata di Desa Oebelo, Kabupaten Kupang, yang diperkirakan mencapai sekitar 30% dari total produksi, berpotensi menimbulkan pencemaran lingkungan. Penelitian ini mengkaji pemanfaatan limbah serbuk batu bata (SBB) sebagai bahan pozzolan untuk substitusi parsial semen pada campuran beton ramah lingkungan. Hasil pengujian laboratorium menunjukkan bahwa SBB Oebelo memiliki kandungan kumulatif oksida aktif (SiO_2 + Al_2O_3 + Fe_2O_3) sebesar 91,17%, melampaui persyaratan minimum bahan pozzolan yang dirujuk dalam ASTM C618. Pengujian kuat tekan beton silinder mengacu pada persyaratan struktural SNI 2847:2019 dengan variasi substitusi SBB sebesar 0%, 10%, 20%, dan 30% serta faktor air-semen (w/c) konstan sebesar 0,5. Pengujian dilakukan pada umur perawatan 28, 56, dan 90 hari untuk mengamati perkembangan reaksi pozzolanik jangka panjang. Hasil menunjukkan bahwa substitusi SBB 10% memberikan kuat tekan terbaik di antara campuran substitusi, yaitu 34,5 MPa pada umur 90 hari atau 96,64% (sekitar 97%) dari kuat tekan beton kontrol sebesar 35,7 MPa. Pemanfaatan SBB sebagai bahan pozzolan dengan demikian berpotensi mendukung produksi beton dengan penggunaan semen yang lebih rendah sekaligus menjadi alternatif pemanfaatan limbah batu bata lokal. Pengujian durabilitas dan validasi skala lapangan tetap diperlukan sebelum penerapan struktural secara luas.

Kata Kunci: *kuat tekan; beton ramah lingkungan; serbuk batu bata Oebelo; pozzolan*

1. INTRODUCTION

Infrastructure development in Indonesia continues to experience massive growth, resulting in a high demand for concrete as a primary construction material. However, Portland cement production as the main binding material is an energy-intensive process that accounts for approximately 7-8% of global anthropogenic carbon dioxide (CO_2) emissions (Andrew, 2018). This condition drives a paradigm shift in concrete technology toward the concept of eco-friendly concrete (green concrete), which seeks to reduce cement consumption without compromising quality and durability. In the context of structural applications, this alternative material innovation must not ignore applicable technical regulations. Mechanical reliability, particularly the compressive strength of concrete, is an absolute parameter that must be met to guarantee the safety of building structures in accordance with the SNI 2847:2019 standard regarding Requirements for Structural Concrete for Buildings (Badan Standardisasi Nasional, 2019).

One strategic and practical approach to reducing cement usage is through the utilization of pozzolanic materials, both natural and artificial. In Oebelo Village, Kupang Regency, traditional red brick manufacturing industries generate significant waste, estimated to reach 30% of total production due to firing defects or breakage during distribution. Chemically, the high-temperature clay firing process in brick production alters the mineralogical structure of the material into an amorphous and more reactive state (Bektas et al., 2006). Brick powder (SBB) from this waste possesses pozzolanic characteristics with a predominant content of silica (SiO_2) and alumina (Al_2O_3) compounds. These active compounds are capable of reacting secondary with calcium hydroxide ($Ca(OH)_2$) a byproduct of cement hydration to form additional calcium silicate hydrate (C-S-H) gel. The presence of this secondary C-S-H gel is crucial as it directly contributes to increasing pore density and strengthening the concrete paste matrix at advanced ages (Massazza, 1998).

Although the potential of red brick waste as a pozzolanic material has been widely studied, the specific utilization optimization of waste from local production centers in Oebelo as a substitution material in structural concrete mixes requires further exploration. Therefore, this study focuses on examining the compressive strength of concrete utilizing brick powder from Oebelo as a partial cement-substituting pozzolanic material. This research aims to determine the optimal SBB substitution proportion to create an eco-friendly concrete innovation that addresses local industrial waste problems while remaining mechanically robust and fully relevant for application in civil structural elements in accordance with the reliability prerequisites of SNI 2847:2019.

2. METHODS

2.1 Materials and Mix Design

This study uses Type I Portland cement as the primary binder meeting the SNI 2049:2015 specification. The pozzolanic material utilized is brick powder (SBB) sourced from waste remnants of traditional red brick manufacturing industries in Oebelo Village. To ensure an optimal level of pozzolanic reactivity, the brick waste was first crushed and sieved to pass the No. 200 sieve (75 µm particle size). This fineness is an essential mechanical parameter to increase the specific surface area of SBB, enabling it to react effectively as a pozzolanic material in accordance with ASTM C618 technical criteria (ASTM, 2019). Fine and coarse aggregates (crushed stone) utilize local materials whose physical characteristics have been tested to ensure compliance with concrete mixture specification standards.

The mix design refers to a standard weight proportion ratio of 1 cement : 2 fine aggregate : 3 coarse aggregate. The water-cement ratio (w/c) was kept constant at 0.5 to balance workability requirements during casting and achieve the target concrete quality. To evaluate the effectiveness of SBB performance in the concrete matrix, partial substitution variations of cement weight were set at 0% (as control concrete), 10%, 20%, and 30%.

2.2 Specimen Preparation and Testing Method

The test specimens were standard concrete cylinders with precision dimensions of 150 mm in diameter and 300 mm in height. Following casting and demolding at 24 hours, all specimens underwent wet curing (water curing). This curing is crucial to prevent premature moisture evaporation and ensure the availability of moisture required for the continuation of primary cement hydration reactions and to maximize the secondary pozzolanic reaction of SBB (Neville, 2011).

Compressive strength testing was conducted using a Universal Testing Machine with testing procedures referring to the SNI 1974:2011 standard. All testing stages and mechanical strength evaluations comply with the eligibility guidelines of SNI 2847:2019 on Requirements for Structural Concrete for Buildings (Badan Standardisasi Nasional, 2019). Compressive strength testing was scheduled at curing ages of 28, 56, and 90 days. The selection of long-term testing ages (56 and 90 days) focuses on observing the kinetics of concrete strength development. This is based on the characteristic reaction of pozzolanic materials which proceeds slower than normal cement; where the consumption of calcium hydroxide ($Ca(OH)_2$) by active silica from SBB requires more time to produce secondary calcium silicate hydrate (C-S-H) gel that densifies the concrete pore structure (Massazza, 1998).

3. RESULTS

3.1 Chemical Properties of Pozzolanic Brick Powder (SBB) from Oebelo

Chemical characteristic testing on brick powder (SBB) from Oebelo Village indicates that the material possesses primary oxide compound content highly potential as a pozzolanic material. Based on laboratory test results, the cumulative active compounds of silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) reach 91.17%.

Referring to the ASTM C618 pozzolan material standard specification (ASTM, 2019), the minimum cumulative requirement for these three oxide components for natural or calcined waste pozzolan categories is 70%. Consequently, the 91.17% value proves that Oebelo SBB waste meets and exceeds the chemical feasibility threshold standards, rendering it highly reactive for partial cement substitution in eco-friendly concrete mixtures.

Table 1. Chemical Composition of Brick Powder from Oebelo Village, Kupang Regency

Compound	Chemical Composition (%)
SiO_2	69.80
Al_2O_3	12.27
Fe_2O_3	9.10
CaO	5.20
SO_3	4.40

3.2 Concrete Compressive Strength Test Results

Compressive strength testing of concrete cylinders with dimensions of 150 mm diameter and 300 mm height was performed at curing ages of 28, 56, and 90 days. The average compressive strength test results across various SBB substitution variations against cement weight are summarized in Table 1 below.

Table 1. Summary of Concrete Compressive Strength Test Results with SBB Substitution Variations

SBB Substitution Variation	Compressive Strength at 28 Days (MPa)	Compressive Strength at 56 Days (MPa)	Compressive Strength at 90 Days (MPa)	Percentage vs. Control (90 Days)
0% (Control)	28.40	33.10	35.70	100.00%
10%	26.10	31.40	34.50	96.64%
20%	23.50	28.90	31.80	89.08%
30%	20.20	25.10	27.60	77.31%

Source: Laboratory test results provided in the source manuscript.

3.3 Analysis of Compressive Strength Development

Based on statistical data processing and strength development curves from 28 to 90 days, the mechanical strength growth pattern exhibits characteristic features of materials containing pozzolanic admixtures:

Early-Age Performance (28 Days): At 28 days, concrete with SBB substitution variations exhibited lower compressive strength values compared to normal concrete (control). This is attributed to the reduced primary cement clinker content and the slower kinetics of the pozzolanic reaction during the initial mixing phase (Neville, 2011).

Long-Term Performance (56 and 90 Days): As curing time progressed, a very significant increase in compressive strength occurred across all SBB variations. This enhancement is driven by secondary reactions between active silica (SiO_2) from SBB and calcium hydroxide ($Ca(OH)_2$)—a byproduct of primary cement hydration—to form additional calcium silicate hydrate (C-S-H) gel (Massazza, 1998). This secondary C-S-H gel fills vacant pore spaces, thereby densifying the micro-pore structure of the concrete paste.

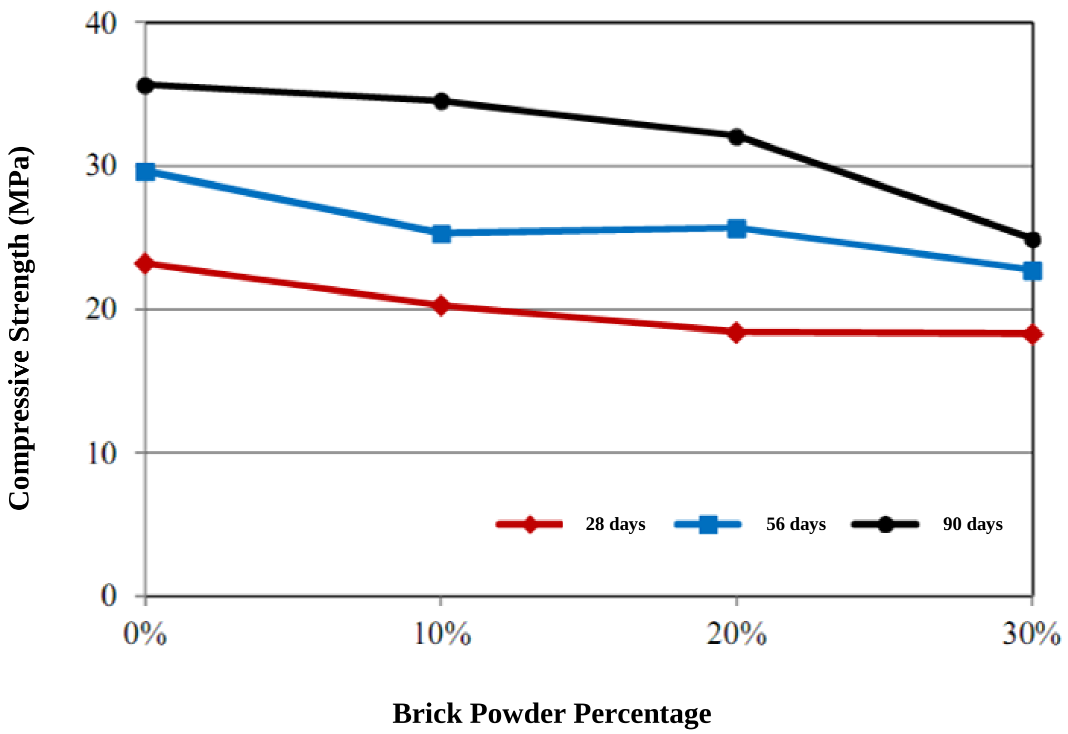

Figure 1. Scatter plot of brick powder percentage versus compressive strength.

4. DISCUSSION

4.1 Comparative Discussion and Structural Implications

Based on the analysis results, the 10% SBB substitution variation provides the most optimal mechanical performance, achieving a compressive strength of 34.5 MPa at 90 days. This value is highly competitive as it equals 97% of normal concrete compressive strength without substitution (35.7 MPa).

This strength achievement proves that utilizing Oebelo SBB waste up to the 10% level is highly competent and meets mechanical suitability prerequisites for reinforced concrete structural elements. This evaluation aligns fully with safety boundaries and structural criteria established in SNI 2847:2019 on Requirements for Structural Concrete for Buildings (Badan Standardisasi Nasional, 2019). Although strength reductions occurred at 20% and 30% variations due to decreased active cement proportions, optimal SBB utilization successfully supports sustainable construction principles without compromising building structural integrity.

5. CONCLUSION

Based on laboratory test results, statistical data analysis, and comparative discussions regarding the utilization of brick powder (SBB) waste from Oebelo Village as a partial cement-substituting pozzolanic material, several main conclusions can be drawn:

Pozzolanic Chemical Characteristics: Brick powder (SBB) waste from Oebelo Village possesses active cumulative compounds of silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) of 91.17%. This value exceeds the minimum pozzolan material specification threshold (70%) under the ASTM C618 standard, proving that Oebelo SBB exhibits excellent chemical reactivity for use as a supplementary cementitious material in concrete mixtures (ASTM, 2019).

Optimal Compressive Strength Performance: SBB substitution of 10% by cement weight delivers the most optimal mechanical performance. At long-term curing age (90 days), concrete with 10% substitution achieves a compressive strength of 34.5 MPa, equivalent to 97% of normal concrete strength (35.7 MPa). This strength enhancement is driven by secondary pozzolanic reactions producing additional calcium silicate hydrate (C-S-H) gel to densify the concrete paste pore structure (Massazza, 1998; Neville, 2011).

Compliance with Structural Standards: The application of Oebelo SBB at the optimal proportion limit proves competent in meeting mechanical strength prerequisites for reinforced concrete structural elements. Therefore, this eco-friendly concrete application is deemed safe and fully aligned with the technical guidelines of SNI 2847:2019 for Structural Concrete Requirements for Buildings (Badan Standardisasi Nasional, 2019).

Environmental and Social Implications: Utilizing this SBB waste provides a strategic solution to address traditional brick manufacturing waste accumulation in Oebelo Village (reaching approximately 30% of total production), while supporting sustainable and eco-friendly construction industry practices (eco-friendly concrete).

ACKNOWLEDGEMENTS

The author gratefully acknowledges Akademi Teknik Kupang for the academic and institutional support provided during the preparation of this study. Appreciation is also extended to the laboratory personnel and technical staff who assisted with material preparation, specimen testing, and laboratory activities related to the evaluation of Oebelo brick powder as a pozzolanic material.

AUTHOR CONTRIBUTIONS

I Made Suparta was solely responsible for conceptualization, methodology, material preparation, laboratory investigation, data collection, data analysis and interpretation, validation of the results, manuscript preparation, critical review, editing, and approval of the final version for publication.

FUNDING STATEMENT

This research received no external funding.

CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest regarding the publication of this article.

DATA AVAILABILITY STATEMENT

The laboratory data supporting the findings of this study are available from the corresponding author upon reasonable request.

ETHICAL STATEMENT

This study was based on laboratory testing of construction materials and did not involve human participants, personal data, or experimental animals. All cited data sources and technical references have been appropriately acknowledged.

REFERENCES

Andrew, R. M. (2018). Global CO2 emissions from cement production. Earth System Science Data, 10(1), 195-217.

ASTM International. (2019). ASTM C618-19 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. West Conshohocken, PA: ASTM International.

Badan Standardisasi Nasional. (2011). SNI 1974:2011 Cara Uji Kuat Tekan Beton dengan Benda Uji Silinder. Jakarta: BSN.

Badan Standardisasi Nasional. (2015). SNI 2049:2015 Semen Portland. Jakarta: BSN.

Badan Standardisasi Nasional. (2019). SNI 2847:2019 Persyaratan Beton Struktural untuk Bangunan Gedung. Jakarta: BSN.

Bektas, F., Wang, K., & Ceylan, H. (2006). Effects of crushed clay brick aggregate on mortar durability. Construction and Building Materials, 20(3), 190-197.

Massazza, F. (1998). Pozzolana and pozolanic cements. Dalam Hewlett, P. C. (Ed.), Lea's Chemistry of Cement and Concrete (4th ed., pp. 471-635). Elsevier Science.

Neville, A. M. (2011). Properties of Concrete (5th ed.). Harlow: Pearson Education Limited.

Suparta, I. M. (2016). Sifat Mekanis Beton Dengan Substitusi Parsial Serbuk Batu Bata Pada Semen. Tesis Program Magister Teknik Sipil Universitas Udayana, Denpasar.