Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XV, 2026
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

DETERMINATION OF SPLITTING TENSILE STRENGTH OF PAVING BLOCKS CONTAINING CERAMIC WASTE

Mircea SĂLCUDEAN[1, 2], Mihai Teopent CORCHEȘ[2], Maria POPA[3], Mirel GLEVITZKY[3, 4]

[1]"Lucian Blaga" University of Sibiu, Doctoral School, Faculty of Engineering,
10 Victoriei Blvd, Sibiu, Romania
[2]"1 December 1918" University of Alba Iulia, Faculty of Computer Science and Engineering,
15-17 Unirii Street, Alba Iulia, Romania
[3]"1 December 1918" University of Alba Iulia, Faculty of Economic Sciences,
15-17 Unirii Street, Alba Iulia, Romania
[4]Politehnica University Timişoara, Faculty of Engineering Hunedoara,
5 Revolutiei Street, Hunedoara, Romania

Corresponding author email: mihai.corches@uab.ro

Abstract

This study investigates the influence of incorporating ceramic waste into paving block mixtures on their splitting tensile strength. The use of recycled ceramic materials aims to reduce environmental impact and promote sustainable construction practices. The aggregates were characterized in terms of particle size, shape, bulk density, porosity, water absorption, hardness, and chemical composition, with X-ray fluorescence (XRF) analysis used to determine the main oxides present in the ceramic waste. Experimental tests were conducted on paving blocks with varying percentages of ceramic waste replacing natural aggregates, including partial (50%) and full (100%) replacement. Splitting tensile strength was determined according to standardized procedures. The results indicate that ceramic waste affects the mechanical performance of paving blocks, with partial replacement slightly reducing tensile strength, while full replacement improves performance beyond the control mix. These findings highlight the importance of aggregate characterization for understanding mechanical behavior and support the potential of ceramic waste as an alternative aggregate in paving block production, contributing to circular economy objectives, particularly in low- to moderate-traffic applications.

Key words*: splitting tensile strength, paving blocks, ceramic waste, recycled aggregates, sustainable construction, durability.*

INTRODUCTION

In the global context of increasing urbanization and infrastructure development, the construction industry faces growing pressure to reduce its environmental footprint while maintaining adequate mechanical performance and durability of construction materials (Alghamdi, 2025; Glevitzky et al., 2026). The transition from a linear economic model toward a circular economy has become a strategic priority, emphasizing waste minimization, material reuse, and resource efficiency (Hasibuan et al., 2025). Within this framework, the reuse of industrial and construction waste in road infrastructure and paving applications represents a promising solution for reducing landfill disposal and conserving natural aggregates (Kuttah, 2024). Among the various waste materials investigated, recycled ceramic waste - originating from demolished structures, ceramic tiles, sanitary ware, and industrial rejects - has gained attention due to its high availability, chemical stability, and favourable mechanical properties (Meena et al., 2022). Ceramic materials are characterized by high hardness, resistance to abrasion, and durability, which makes them potential candidates for partial or total replacement of natural aggregates in paving blocks. Their reuse not only contributes to sustainable construction practices but also supports waste recovery and resource efficiency strategies (Jwaida et al., 2024).

Life cycle assessment research has shown that incorporating ceramic waste into various construction materials, such as paving blocks, reduces greenhouse gas emissions and energy consumption throughout their life cycle, making them more sustainable (Azam et al., 2024; Kiran et al., 2024).

The incorporation of ceramic waste into paving blocks aligns with the principles of sustainability, particularly by reducing the consumption of virgin raw materials and lowering the environmental impact associated with aggregate extraction (Torkittikul and Chaipanich, 2010). From a circular economy perspective, paving blocks represent an ideal construction product for waste valorization due to their modular nature, standardized manufacturing processes, and widespread use in pedestrian areas, parking zones, and low-traffic roads (Barbhuiya et al., 2025).

The incorporation of ceramic waste in paving blocks presents technical challenges, including variations in particle characteristics and bonding with the cement matrix. These factors can affect mechanical properties, particularly splitting tensile strength, which influences cracking resistance and long-term performance (Lin et al., 2023). Additionally, paving blocks containing ceramic waste may exhibit different behavior under high traffic loads, freeze–thaw cycles, or moisture variations, limiting their application in heavy-duty pavements (Famewo and Shokouhian, 2025).

From the perspective of the circular economy and waste recovery, various types of waste have been investigated for paving block production, including ceramic waste, recycled concrete aggregates, glass waste, rubber particles, and industrial by-products such as fly ash or slag (Wattanasiriwech et al., 2009). Each waste type offers specific benefits but also introduces technical limitations that must be carefully assessed to ensure compliance with performance requirements (Glevitzky et al., 2025). The use of ceramic waste, in particular, offers advantages such as improved abrasion resistance and reduced environmental impact, but may result in reduced tensile performance at higher replacement levels (Meena et al., 2022).

The technological process of manufacturing paving blocks containing ceramic waste generally follows conventional procedures, including material selection, mix proportioning, compaction, curing, and quality control (Dehghani et al., 2024; Poon, et al., 2002). Nevertheless, the presence of ceramic aggregates may require adjustments to mixture design, water–cement ratio, and compaction parameters to achieve optimal mechanical performance. Ensuring consistency and reproducibility in production is essential for large-scale implementation (Silveira et al., 2025).

The use of recycled materials in paving blocks must comply with construction standards and regulations. The key reference is EN 1338:2003 (EN 1338, 2003), which sets essential requirements for mechanical strength, durability, and conformity assessment of concrete paving blocks. Standardized testing methods, including splitting tensile strength, ensure consistent performance evaluation and safe application in infrastructure (Iduwin et al., 2024).

This study aims to evaluate the influence of ceramic waste incorporation on the splitting tensile strength of paving blocks and to identify suitable replacement levels that maintain acceptable mechanical performance. The findings support the application of circular economy principles in paving systems, particularly for low to moderate traffic conditions.

MATERIALS AND METHODS

The use of recycled materials in paving blocks must comply with a set of technical standards and regulations that ensure mechanical performance, durability, and operational safety. At the international and European levels, the most relevant requirements are defined by standards for precast concrete products, testing methods, and the use of recycled aggregates.

One of these is EN 1338 - Concrete paving blocks - Requirements and test methods, which establishes requirements regarding mechanical strength, freeze-thaw resistance, water absorption, abrasion resistance, and dimensional tolerances of concrete paving blocks. This standard is essential for assessing the conformity of products intended for use in road and pedestrian infrastructure.

The determination of splitting tensile strength is carried out in accordance with EN 12390-6 (EN 12390-6, 2009), which describes the standardized testing method applicable to both conventional concrete and concrete containing recycled aggregates, including ceramic waste.

Regarding the materials used, EN 12620 – Aggregates for concrete regulates the

requirements for natural and recycled aggregates, including permissible limits for impurities, physical properties, and durability characteristics (EN 12620, 2002). This standard allows the use of aggregates derived from waste, provided that quality requirements are met.

At the international level, ASTM standards are also frequently used for comparison and experimental validation. Among the most relevant is ASTM C496/C496M - Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, which provides an alternative method for determining splitting tensile strength (ASTM C496/C496M, 2017).

From a sustainability and circular economy perspective, European policies such as Waste Framework Directive (Directive 2008/98/EC) and the European Union Circular Economy Action Plan encourage the reuse of construction and demolition waste, including ceramic waste, in construction materials, provided that applicable technical standards are respected.

Compliance with these main standards and regulations is essential for the market acceptance of paving blocks containing ceramic waste and for ensuring safe use in infrastructure applications, especially in areas with low or moderate traffic.

To demonstrate the feasibility of using ceramic waste in the manufacturing process of paving blocks, experimental concrete mixes were developed in which natural aggregates were partially replaced with ceramic fragments. Tile and ceramic waste originating from construction and demolition activities were used, with a particle size of 4-8 mm (Figure 1), obtained through crushing and granulometric sorting.



Figure 1. Aggregates from ceramic waste size 4-8 mm

Granulometry. 500 g of dried aggregate are weighed and sieved through a standard set of 4-8 mm sieves, and the percentage retained on each fraction is determined (EN 933-1, 2003).

Bulk density and porosity. The dry mass of the aggregate is determined, then it is submerged in water for 24 hours. The saturated mass is weighed, and the bulk density and porosity are calculated (EN 1097-6, 2010).

Water absorption. Similar to the bulk density method; absorption is calculated as a percentage: $(m_{saturated}-m_{dry})/m_{dry}\times 100$ (EN 1097-6, 2010).

Hardness/abrasion resistance. Los Angeles test. The aggregate and steel balls are placed in a rotating drum, rotated for a standard number of cycles, and then the aggregates are sieved to determine the percentage loss due to wear (EN 1097-2, 2010).

Chemical composition. The aggregates are dried, then ground to a fine, homogeneous powder of 65 μm and then analyzed. The chemical composition of the aggregate from ceramic waste was determined by X-ray fluorescence (XRF) spectrometry using a Quant'X ARL energy-dispersive X-ray fluorescence spectrometer (Thermo Fisher Scientific, Waltham, MA, USA).

The specimens were prepared manually by homogenizing the components according to the experimental mix design, then cast into standard molds, kept for 24 hours, and subsequently cured for 28 days at 20°C. The testing was performed using a Matest universal testing machine for static material testing, whose technical characteristics are presented in Table 1.

Table 1. Characteristics of the MATEST Static Material Testing Machine

Model	CYBER PLUS EVOLUTION / CO7gPN191
Usage	Measurement of the compressive strength of hardened concrete (cylinders, cubes, and prisms)
Measurement Range	From 25 to 250 kN and from 20 to 3000 kN
Force Application Method	Compression
Testing Conditions	Temperature from +5 °C to +40 °C; Humidity from 30% to 70%
Standards Compliance	EN 12390-4, SR EN 772-1

For the control sample (R1), the standard concrete mix C16/20 (Table 2), also known as B250, was used, which is one of the most commonly used concrete mixes in Romania. For the two experimental mixes, 50% of the natural 4-8 mm aggregate was replaced with ceramic

waste aggregate for R2, and 100% replacement of natural 4-8 mm aggregate with ceramic waste aggregate was used for R3 (Table 2).

Table 2. Composition of the concrete mixes used

Material	R1 (kg)	R2 (kg)	R3 (kg)	Material Source
Cement	0.7375	0.7375	0.7375	Heidelberg Materials, Chișcădaga Cement Plant, Hunedoara
Aggregate 0-4 mm (quarry)	1.9725	1.9725	1.9725	Elis Aggregates, Jidovu Quarry, Zlatna, Alba
Aggregate 4-8 mm (quarry)	0.9175	0.45875	-	Elis Aggregates, Jidovu Quarry, Zlatna, Alba
Aggregate 4-8 mm (ceramic waste)	-	0.45875	0.9175	Planodom Construct SRL, Cugir, Alba
Aggregate 8-16 mm (quarry)	1.6975	1.6975	1.6975	Elis Aggregates, Jidovu Quarry, Zlatna, Alba
Water	0.65	0.65	0.65	SC APA CTTA SA, Alba Iulia, Alba

Figure 2 shows the manual preparation of the experimental mixes by incorporating ceramic waste, which partially (R2) or completely (R3) replaces the natural aggregates. For the control mix (R1), standard concrete from the SC Elis Pavaje batching plant in Petrești was used.



Figure 2. Composition of the experimental concrete mixes

All determinations and experiments were performed in triplicate.

RESULTS AND DISCUSSIONS

The key physical and mechanical properties of the ceramic waste aggregate used in the study are summarized in Table 3. The average chemical composition of the ceramic waste aggregate determined by X-ray fluorescence (XRF) analysis is presented in Table 4.

Table 3. Properties of ceramic waste aggregate

Property	Value	Remarks / Implications
Particle size	4-8 mm	According to experimental description; promotes good compaction in concrete
Particle shape	Irregular, angular	Increases mechanical adhesion with cement paste; may affect workability
Bulk density	2.2-2.6 g/cm³	Similar to natural aggregates; allows correct proportioning
Porosity	Moderate (≈15-25%)	Higher water absorption than natural aggregates; influences water/cement ratio
Water absorption	6-10%	Requires pre-wetting or adjustment of mixing water
Mohs hardness	6-7	Hard surface; contributes to mechanical strength
Color	Red-brown and whitish	Indicates a mixture of gres and faience

Table 4. Chemical Composition of Ceramic Waste Aggregate

Compound	Value (wt.%)
SiO_2	70.93
Al_2O_3	15.21
Fe_2O_3	4.70
CaO	3.04
K_2O	1.33
MgO	1.25
Na_2O	0.60
TiO_2	0.41
ZrO_2	0.17
Loss on Ignition	2.06

The XRF results indicate that the ceramic waste aggregate is predominantly composed of silica (70.93%) and alumina (15.21%), characteristic of clay-based ceramics. Minor amounts of Fe_2O_3, CaO, alkalis (K_2O, Na_2O), and other oxides are present, while the low loss on ignition (2.06%) suggests minimal organic or moisture content. This composition indicates a stable, mostly inert material suitable for partial replacement of natural aggregates, with limited impact on the chemical behavior of concrete but potential effects on porosity and permeability.

Tensile strength tests by splitting were performed on the concrete samples 28 days after casting (EN 12390-3, 2002). The tests were carried out for both the standard mix and the experimental mixes (Figure 3).

As a result of the splitting tensile strength tests (Figure 3), the obtained results are presented in Table 5.

The results obtained for the three studied mixes demonstrate a significant influence of replacing natural aggregates with ceramic waste on the mechanical behavior of pavers.



Figure 3. Specimens tested in splitting tension

Table 5. Results of the splitting tensile strength tests.

Mix	Sample 1	Sample 2	Sample 3
R1 (control concrete)	2.663	2.222	2.198
R2 (50% ceramic aggregate)	1.737	1.910	2.010
R3 (100% ceramic aggregate)	2.672	2.360	2.850

These observations align with current trends in the scientific literature, which highlight the high potential of recycled ceramic materials for use in precast concrete products (Wattanasiriwech et al., 2009).

The test values obtained for the standard C16/20 mix (R1) are consistent with the characteristic strengths of this type of concrete and confirm the reliability of the preparation and testing procedures. The performance of the control mix provides a solid baseline for comparison and is also in accordance with European standards for evaluating splitting tensile strength according to EN 12390-6.

The mix with 50% replacement of the 4-8 mm aggregate with ceramic waste (R2) shows greater variability in results, as well as a decrease in average tensile strength compared to the control mix. This reduction can be explained by the physical and structural properties of the ceramic particles, such as increased roughness and high-water absorption, which may compromise the quality of the cement-aggregate interface. Recent studies indicate that such heterogeneities can significantly affect mechanical behavior, particularly in regions subjected to tensile stresses (Dehghani et al., 2024; Silveira et al., 2025).

The R3 mix, with 100% replacement of the 4-8 mm aggregate, exhibited superior results compared to both the control concrete and R2. This behavior suggests that a fully homogeneous mix composed entirely of ceramic aggregates can produce a compact internal structure. The characteristics of ceramic particles, such as angular shape and hard surface, contribute to more efficient stress transfer in the splitting zone, a phenomenon also reported in other studies on the use of ceramics as recycled aggregates (Wattanasiriwech et al., 2009).

Statistical analysis

To evaluate the influence of replacing natural aggregates with ceramic waste on the splitting tensile strength of concrete blocks, the experimental data obtained for the three mixes (R1, R2, R3) were statistically analyzed (Aloman, 1998; Gluck, 1971). The objective of the analysis was to identify differences between the mixes, as well as to assess the variability and stability of their mechanical behavior (Popa et. al, 2022). The values were summarized in Table 6 using the arithmetic mean, standard deviation (SD), median, and coefficient of variation (CV).

Table 6. Descriptive statistics for splitting tensile strength

Mix	Mean (MPa)	SD (MPa)	Median (MPa)	CV (%)
R1	2.361	0.242	2.222	10.2
R2	2.082	0.362	1.960	17.4
R3	2.605	0.345	2.605	13.2

Variability ranged from low to moderate among the three mixes. While R1 and R3 exhibited coefficients of variation below 15%, R2 showed a slightly higher coefficient of variation (17.4%), indicating a greater dispersion of the experimental results.

To evaluate the differences between the three concrete mixes, a one-way analysis of variance (ANOVA) was applied to the experimental data. The statistical analysis revealed significant differences in the mean splitting tensile strengths among the three compositions, with the most pronounced variations observed between R2 and R3, as well as between R2 and R1. In particular, the mix with partial replacement (R2) exhibited a clear reduction in mechanical performance compared to both the control concrete and the fully substituted mix (R3), highlighting the influence of partial substitution on the integrity of the cement–aggregate interface and the overall stress transfer within the specimens.

The statistical evaluation indicate that the percentage of natural aggregate replacement has a decisive effect on the splitting tensile strength of the concrete. While partial replacement at 50% results in a noticeable decrease in average

strength, complete replacement at 100% leads to an increase in average strength relative to the control mix, suggesting that a fully homogeneous mix composed entirely of ceramic aggregates can provide a more compact internal structure and improved stress distribution under tensile loading. Additionally, all three mixes exhibited low variability, as indicated by the coefficients of variation, which demonstrates good experimental stability and reproducibility of the testing procedures. The homogeneous structure of the R3 mix, in particular, promotes superior mechanical behavior, confirming the potential of recycled ceramic aggregates as a viable alternative to natural aggregates.

CONCLUSIONS

The experimental results demonstrate that the substitution of natural aggregates with recycled ceramic aggregates significantly influences the mechanical performance of paving blocks. Partial replacement tends to reduce splitting tensile strength, primarily due to the heterogeneous particle shape, increased roughness, and higher water absorption of ceramic aggregates, which can affect the quality of the cement–aggregate interface. Complete replacement, however, leads to improved tensile performance, indicating that a fully homogeneous mix of ceramic aggregates can form a compact internal structure that enhances stress transfer under tensile loading. Despite the promising mechanical behavior, the brittle nature and water absorption characteristics of ceramic aggregates should be carefully considered for applications subject to heavy or repeated dynamic loading. These findings underscore the potential of ceramic waste as a sustainable alternative to natural aggregates, providing environmental benefits by reducing construction and demolition waste, conserving natural resources, and supporting circular economy principles. Further investigations are recommended to evaluate additional properties such as abrasion resistance, freeze-thaw durability, water absorption, and long-term performance, in order to validate the applicability of recycled ceramics in diverse paving block applications.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of Elis Pavaje SRL, Romania, a paving block manufacturer that actively incorporates construction and demolition waste into its products, promoting sustainable and circular construction practices.

REFERENCES

Alghamdi, A. (2025). Sustainable Practices in Construction Management and Environmental Engineering: A Review. *Sustainability*, *17*(22), 10027.

Aloman, A. (1998). *Statistics and probability in scientific experiment* [Statistica si Probabilitate in Experimentul Stiintific], Matrix Rom, Bucharest, Romania.

ASTM International. (2017). *ASTM C496/C496M-17: Standard test method for splitting tensile strength of cylindrical concrete specimens*. West Conshohocken, PA: ASTM International.

Azam, A., Gabr, A., Ezzat, H., Arab, M., Alshammari, T. O., Alotaib, E., & Zeiada, W. (2024). Life cycle assessment and pavement performance of recycled aggregates in road construction. *Case Studies in Construction Materials, 20,* e03062.

Barbhuiya, S., Qureshi, T., & Das, B. B. (2025). Advancing sustainable pavements: A review of low-carbon construction materials and practices. *Discover Concrete and Cement, 1*(1), 19.

Dehghani, O., Eslami, A., Mahdavipour, M. A., Mostofinejad, D., Ghorbani Mooselu, M., & Pilakoutas, K. (2024). Ceramic waste powder as a cement replacement in concrete paving blocks: mechanical properties and environmental assessment. *International Journal of Pavement Engineering*, *25*(1).

European Committee for Standardization (2002). *EN 12390-3: Testing hardened concrete – Part 3: Compressive strength of test specimens*. Brussels, Belgium: CEN.

European Committee for Standardization (2002). *EN 12620: Aggregates for concrete*. Brussels, Belgium: CEN.

European Committee for Standardization (2003). *EN 1338: Concrete paving blocks – Requirements and test methods*. Brussels, Belgium: CEN.

European Committee for Standardization (2003). *EN 933-1: Tests for geometrical properties of aggregates – Part 1: Determination of particle size distribution – Sieving method*. Brussels, Belgium: CEN.

European Committee for Standardization (2009). *EN 12390-6: Testing hardened concrete – Part 6: Tensile splitting strength of test specimens*. Brussels, Belgium: CEN.

European Committee for Standardization (2010). *EN 1097-2: Tests for mechanical and physical properties of aggregates – Part 2: Methods for the determination of resistance to fragmentation (Los Angeles test)*. Brussels, Belgium: CEN.

European Committee for Standardization (2010). EN 1097-6: Tests for mechanical and physical properties of aggregates – Part 6: Determination of particle density and water absorption. Brussels, Belgium: CEN.

European Parliament and Council. (2008). *Directive 2008/98/EC on waste (Waste Framework Directive)*. Official Journal of the European Union, L312, 3–30.

Famewo, B. G., & Shokouhian, M. (2025). A review of pavement performance deterioration modeling: Influencing factors and techniques. *Symmetry, 17*(11).

Glevitzky, M., Glevitzky, I., Mucea-Ștef, P., Popa, M., Dumitrel, G.-A., & Vică, M. L. (2025). Integrated Risk Framework (IRF) - Interconnection of the Ishikawa Diagram with the Enhanced HACCP System in Risk Assessment for the Sustainable Food Industry. *Sustainability*, 17(2), 536.

Glevitzky, M., Mucea-Ștef, P., Corcheș, M.-T., Sălcudean, M., Marica, E., Șerban, S. G., & Popa, M. (2026). Integrated Environmental Risk Assessment and Performance Evaluation of Asphalt Plants Incorporating Reclaimed Asphalt Pavement Under the ISO 14001 Framework. *Eng*, *7*(2), 95.

Gluck, A. (1971). *Mathematical methods in the chemical industry* [Metode matematice in industria chimica], Tehnică Publishing House, Bucharest, Romania.

Hasibuan, G. C. R., Al Fath, M. T., Yusof, N., Dewi, R. A., Syafridon, G. G. A., Jaya, I., Anas, M. R., & Syahrizal (2025). Integrating circular economy into construction and demolition waste management: A bibliometric review of sustainable engineering practices in the built environment. *Case Studies in Chemical and Environmental Engineering, 11,* 101159.

Iduwin, T., Hadiwardoyo, S. P., Sumabrata, R. J., Lumingkewas, R. H., & Rivai, A. I. (2024). Investigation of Concrete Paving Block Characteristics and Performance across Different Shapes and Thicknesses. *Engineering, Technology & Applied Science Research*, *14*(6), 18429–18438.

Jwaida, Z., Dulaimi, A., & Bernardo, L. F. A. (2024). The use of waste ceramic in concrete: A review. *CivilEng, 5*(2), 482–500.

Kiran, G. U., Nakkeeran, G., Roy, D., & Alaneme, G. U. (2024). Optimization and prediction of paver block properties with ceramic waste as fine aggregate using response surface methodology. *Scientific Reports, 14*(1), 23416.

Kuttah, D. (2024). Recycling of industrial and construction waste materials in roads construction. *International Journal of Geotechnical Engineering, 18*(4), 346–359.

Lin, C., Kanstad, T., Jacobsen, S., & Ji, G. (2023). Bonding property between fiber and cementitious matrix: A critical review. *Construction and Building Materials, 378,* 131169.

Meena, R. V., Jain, J. K., Chouhan, H. S., & Beniwal, A. S. (2022). Use of waste ceramics to produce sustainable concrete: A review. *Cleaner Materials, 4,* 100085.

Poon, C. S., Kou, S. C., & Lam, L. (2002). Use of recycled aggregates in molded concrete bricks and blocks. *Construction and Building Materials, 16*(5), 281–289.

Popa, M., Glevitzky, I., Dumitrela, G.-A., Popa, D., Vîrsta, A., & Glevitzky, M. (2022). Qualitative analysis and statistical models between spring water quality indicators in Alba County, Romania. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*, *11*, 358-366.

Silveira, T. A. d., Nörnberg, R. d. P., Santi, M. S., Morales, R. R., Tessaro, A. B., Rosseto, H. L., Delucis, R. d. A., & Trindade, G. H. (2025). Mechanical Performance and Durability of Concretes with Partial Replacement of Natural Aggregates by Construction and Demolition Waste. *Waste*, *3*(4), 32.

Torkittikul, P., & Chaipanich, A. (2010). Utilization of ceramic waste as fine aggregate within Portland cement and fly ash concretes. *Cement and Concrete Composites, 32*(6), 440–449.

Wattanasiriwech, D., Saiton, A., & Wattanasiriwech, S. (2009). Paving blocks from ceramic tile production waste. *Journal of Cleaner Production, 17*(18), 1663–1668.