eVitroKhem. 2026; 5:381
doi: 10.56294/evk2026381

ORIGINAL

Clam Shells (Megapitaria Squalida) For the Manufacture of Mineral Additives in Concrete Mixes

Conchas De Almeja (Megapitaria Squalida) Para la Fabricación de Adiciones Minerales en Mezclas de Concreto

Alicia Zulema Rodríguez Lizárraga[1], Karla Karina Romero Valdez[1], Jesús Manuel Bernal Camacho[1], Víctor Manuel Martínez García[2]

[1]Universidad Autónoma de Sinaloa, Facultad de Ingeniería y Tecnología Mazatlán. Mazatlán, México.
[2]Universidad Autónoma de Sinaloa, Facultad de Arquitectura y Diseño Mazatlán. Mazatlán, México.

Cite as: Rodríguez Lizárraga AZ, Romero Valdez KK, Bernal Camacho JM, Martínez García VM. Clam Shells (Megapitaria Squalida) For the Manufacture of Mineral Additives in Concrete Mixes. eVitroKhem. 2026; 5:381. https://doi.org/10.56294/evk2026381

Submitted: 11-07-2025 **Revised:** 15-09-2025 **Accepted:** 08-11-2025 **Published:** 01-01-2026

Editor: Prof. Dr. Javier Gonzalez-Argote

Corresponding author: Víctor Manuel Martínez García

ABSTRACT

This research analyzes the feasibility of using chocolate clam shells (Megapitaria squalida) as a mineral additive in concrete mixtures to reduce the environmental impact of marine waste and the high consumption of Portland cement. A quantitative methodological approach was applied, including the collection, cleaning, crushing, calcination, and grinding of the biomaterial, followed by compressive strength and durability tests on concrete specimens with 10 % partial cement replacement. The results showed that shells calcined at 800˚C and 1000˚C exhibit suitable pozzolanic properties and improve the mechanical strength of concrete, exceeding the values obtained in reference mixtures. Likewise, electrical resistivity tests indicated a very low chloride penetration, demonstrating high durability and good protection against steel reinforcement corrosion. The findings confirm that Megapitaria squalida shells, due to their high calcium carbonate ($CaCO_3$) content, represent a sustainable and economically viable alternative for producing eco-friendly concrete. Their incorporation contributes to reducing CO_2 emissions associated with cement manufacturing, promoting practices aligned with the Sustainable Development Goals (SDGs).

Keywords: Sustainable Concrete; Megapitaria Squalida; Marine Waste; Mineral Additives; Durability.

RESUMEN

La investigación analiza la viabilidad del uso de conchas de almeja chocolata (Megapitaria squalida) como adición mineral en mezclas de concreto, con el fin de disminuir el impacto ambiental derivado de los residuos marinos y del alto consumo de cemento Portland. Se empleó un enfoque metodológico cuantitativo que incluyó la recolección, limpieza, trituración, calcinación y molienda del biomaterial, seguido de ensayos de resistencia a la compresión y durabilidad en concretos con reemplazos parciales del 10 %. Los resultados demostraron que las conchas calcinadas a 800˚C y 1000˚C presentan propiedades puzolánicas adecuadas y favorecen la resistencia mecánica del concreto, superando los valores obtenidos en las mezclas de referencia. Asimismo, las pruebas de resistividad eléctrica indicaron una muy baja penetración de cloruros, reflejando una alta durabilidad y buena protección frente a la corrosión del acero de refuerzo. El análisis final confirma que las conchas de Megapitaria squalida, por su alto contenido de carbonato de calcio ($CaCO_3$), son una alternativa sostenible y económicamente viable para la producción de concretos ecológicos. Su incorporación contribuye a reducir las emisiones de CO_2 asociadas a la fabricación del cemento, promoviendo prácticas alineadas con los Objetivos de Desarrollo Sostenible.

Palabras clave: Concreto Sostenible; Megapitaria Squalida; Residuos Marinos; Adiciones Minerales; Durabilidad.

INTRODUCTION

The environmental impact of the construction industry, particularly in the manufacturing process of cement, the main constituent of concrete, has led to the proposal of viable alternatives to reduce gas emissions into the atmosphere and, therefore, reduce the carbon footprint.

The use of marine waste as a by-product represents an innovative and sustainable option for research. The chocolate clam shell (Megapitaria squalida) is a bivalve species prevalent in the waters of the Mexican Pacific whose outer skeleton has a chemical structure rich in calcium carbonate, a characteristic that makes it suitable for use as a mineral additive in concrete mixtures.

Inadequate collection, improper disposal and dumping, as well as the lack of effective waste treatment, cause environmental pollution problems and affect terrestrial and marine ecosystems. These effects, which influence climate change, represent elements that impact global socioeconomic development.

In Mexico, the production (live weight) of clams in 2023 was 18 062 tons, of which 17 536 tons correspond to capture and 526 tons to aquaculture, with Baja California Sur being the main producer, followed by Sinaloa. The average annual growth rate of production over the last 10 years is -4,78 %.[1]

Currently, the disposal of chocolate clam shells (Megapitaria squalida) represents a serious pollution problem, mainly in coastal areas. After the clam body or meat has been consumed, the shell is discarded in different places, such as areas near where it is sold, streets and other public places, and even in landfills where large volumes are dumped indiscriminately.

The reuse of chocolate clam shells for the manufacture of mineral additives in concrete mixtures undoubtedly represents an efficient and cost-effective solution for this waste.

Theoretical framework

Concrete is the most important material in the construction industry, indispensable for infrastructure development. With advances in technology and population growth, the use of this component has increased over the years. However, its production generates a high carbon footprint due to the extraction of cement.

By 2024, cement production was estimated to be 4,39 billion tons, and it is expected to reach 5,96 million tons by 2030. The region with the largest share of production is Asia-Pacific with 72,53 % of total production, followed by Saudi Arabia with 12 % and the United Arab Emirates with 3 %.[2]

During cement production, CO2 emissions are divided into two processes. The first is through the calcination of minerals for the production of clinker, which accounts for 60-70 %, while the remaining 30-40 % is caused by the use of fuels in the kilns used to manufacture the material.[3]

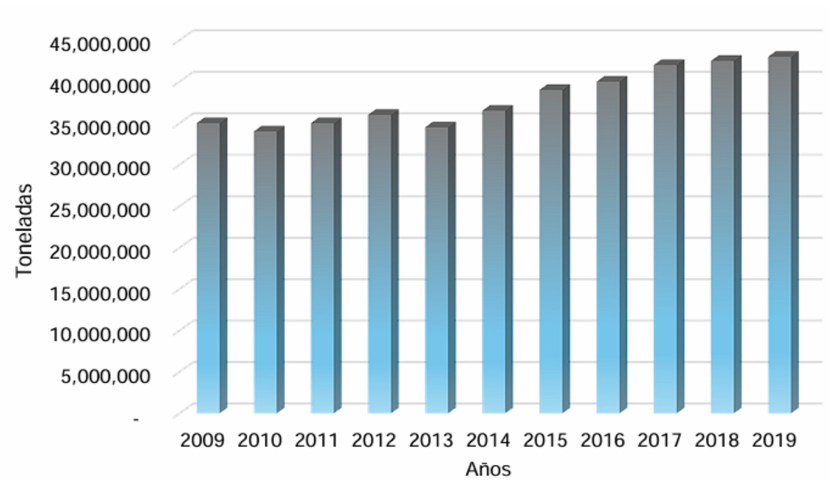

Figure 1. Cement production in Mexico 2009-2019[4]

Use of mollusk mineral waste for concrete production

In relation to seashells, as cited by Martínez García, various studies carried out on the composition of mollusks in relation to the chemical structure of the valves highlight the presence of a high percentage of calcium carbonate, ranging from 95-99 % compared to the weight of the product. Similarly, the existence of potassium oxide, silicon oxide, and iron oxide on a smaller scale can be corroborated.[5] This author confirms that these results are consistent after the use of fluorescence through X-ray exposure (XRF). In the case of clam shells, they contain 100 % aragonite, while mussel shells contain 13 % calcite and 78 % aragonite.[5]

In areas such as Magdalena Bay-Almejas and Loreto, fishing plans have been established that encourage the harvesting of chocolate clams to be viewed from a sustainable perspective and applicable for multiple purposes. One of these purposes is to use clam shells as a by-product. Using the shells in this way not only reduces the amount of waste, but also contributes to the creation of a more sustainable construction model.

Internationally, extensive research has been conducted on the use of clam shells, including Megapitaria squalida, as additives in concrete. These studies report the latent potential for clam shells to be considered as a usable alternative and sustainable material, with the aim of providing varied options to offset the significant environmental impact caused by the production of cement and other common materials, using resources that are considered waste.

Mexico has carried out a wide variety of studies on the use of calcium carbonate, which is found in large quantities in the shells of marine ecosystems, such as the clam colloquially known as chocolata, as a viable alternative for concrete manufacturing.

In states such as Tabasco and Veracruz, experimental tests have been carried out that consist of grinding the shells and using them as a substitute for gravel in concrete mixtures, with the intention of mitigating the environmental impact this causes on the environment and making practical use of the waste generated by the local fishing industry.[6]

The pozzolanic properties of the material

To evaluate the characteristics of mineral additives from seashells as a sustainable alternative for the production of concrete mixtures, it is necessary to carry out laboratory tests similar to those carried out on traditional concrete for comparison.

In accordance with Mexican Standard NMX-C-083-ONNCCE-2014 for determining the compressive strength of specimens (test method) and with reference to NMX-C-159-ONNCCE-2016 for the preparation and curing of test specimens, it is possible to determine the compressive strength of concrete for molded cylindrical pieces and to evaluate the use of mineral additives from seashells as an alternative pozzolanic material for concrete production using replacement percentages ranging from 10 % to 15 %, according to results presented by different researchers.

METHOD

This research was based on a quantitative approach which, through data collection, allowed the hypothesis to be verified and justified with the intention of establishing patterns of behavior and validation.

The sample space consisted of clam shells (Megapitaria squalida) collected from various dumping sites located in the city of Mazatlán, Sinaloa, as well as from mollusk vendors and commercial establishments. It is important to note that the sampling was intentional and non-probabilistic.

Initially, the experimental phase began with the process of cleaning the residual biomaterial. This consisted of removing any organic and inorganic residues from the clam shells (Megapitaria squalida) using both physical and chemical deep cleaning techniques, which were supported by the literature, in order to maintain a suitable sample that did not present any modifications in the chemical structure of the sample. This stage ensured that the study material was free of any impurities that could affect the subsequent phases of the experimentation process. It should be noted that calcareous remains, originating from marine areas, generally contain algae, microorganisms, and other impurities from natural contaminants, which, if not removed, could influence the physical and chemical properties of the final result.

As a first step, the clam shells (Megapitaria squalida) were treated with hydrated lime to begin the cleaning process, removing unwanted particles adhering to the valves and eliminating unpleasant odors, allowing the subsequent stages of the process to continue.

Figure 2. Pouring lime on clam shells (Megapitaria squalida)

https://doi.org/10.56294/evk2026381 ISSN: 3072-7944

In addition, the shells were thermally and chemically sterilized in a diluted acetic acid solution so that the combination of heat and the acidity of the vinegar would destroy the microbial particles, organic debris, and mineral salts that had become encrusted when they were in contact with the environment.

Figure 3. Thermal-chemical disinfection in diluted acetic acid solution

Subsequently, the grinding stage was carried out using various mechanisms for both coarse and fine crushing of the clam shells. This activity consisted of reducing the particle size of the biomaterial until it was pulverized.

Once the sample was processed, the calcination stage continued, which consisted of converting the crushed clam shells to an optimal state for analyzing the physical properties and chemical composition of the residual sample.

In the muffle calcination process, it is necessary to manually refine the fragments using a laboratory mortar. Grinding continued until the pulverized raw material passed completely through a 0,075 mm (No. 200) mesh.

After achieving the complete transformation of $CaCO_3$ into CaO, the product obtained must achieve 95 % organic matter removal. Once this condition is met, the material is ideal for applications in concrete as a mineral additive.

To perform the compressive strength tests, cylindrical specimens with dimensions of 20 cm in height and 10 cm in diameter were prepared in accordance with the standard. Prior to the stress tests, these specimens were subjected to a curing process under controlled conditions for a period of 28 days, submerged in water with portions of lime (6 g/l).

In order to ensure that the test specimens remained level during the study, the pieces were tilted using neoprene covers placed on both horizontal sides.

The test specimens were placed in the testing machine equipped with two steel blocks for applying the load with a contact surface in order to prevent deformation during the application of the loads.

RESULTS

The information obtained from this experimental phase yielded compressive strength values that allow us to identify that the mixtures with added mineral residues from clams (Megapitaria squalida) are superior to the values obtained in the reference concrete specimens.

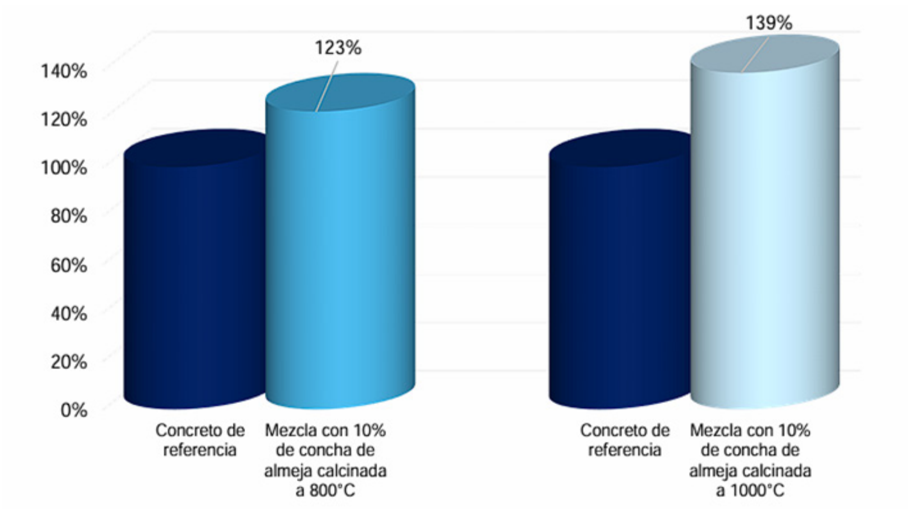

Figure 4. Comparative results of specimens made with a mixture with added clam shell mineral and the reference concrete

According to the experimental data, the compressive strength was 23 % higher than the reference concrete considering a 10 % addition of mineral calcined at 800˚C, while for mixtures with clam shell waste calcined at 1000˚C with the same replacement percentage, the value exceeded 39 % compared to the reference concrete.

With regard to the risk of chloride penetration in concrete according to the electrical resistivity test performed in accordance with ASTM C1202, a qualitative assessment of the concrete was obtained in relation to chloride penetrability.

To assess the durability of sustainable concrete, concrete samples labeled M1 were examined for specimens made with the reference concrete, M2A for test specimens with mineral residue from clam shells calcined at 800˚C added, and M3A for cylindrical pieces of biomaterial calcined at 1000˚C.

The average electrical resistance (Ω-m) obtained in the M1 reference concrete specimens was 73,29, while the M2A pieces made with mineral added and calcined at 800˚C obtained an average value of 66,89. For the tests carried out on the M3A specimens, the resulting average was 49,51.

Muestra	Fecha	Resistencia eléctrica (Ω)	Longitud (m)	Área de la cara (m^2)	Constante de celda	Resistividad eléctrica (Ω-m)	Riesgo de penetración de cloruros
M1	08/04/2025	892000	0.0943	0.0079	0.0833	74.29	MUY BAJA
M1	08/04/2025	878000	0.0954	0.0079	0.0823	72.28	MUY BAJA
M2A	09/04/2025	828000	0.0965	0.0079	0.0814	67.39	MUY BAJA
M2A	09/04/2025	820000	0.0970	0.0079	0.0810	66.39	MUY BAJA
M3A	10/04/2025	620000	0.0970	0.0079	0.0810	50.20	MUY BAJA
M3A	10/04/2025	603000	0.0970	0.0079	0.0810	48.82	MUY BAJA

Figure 5. Resistance to chloride penetration (durability parameters)

The above results related to the average electrical resistivity value reveal that the risk of chloride penetration of the specimens made with clam shell (Megapitaria squalida) mineral addition for both calcination temperatures is lower than that of the reference concrete. In particular, the specimens classified as M2A are 9 % below the average electrical resistivity obtained for the reference concrete M1, while the M3A specimens have average values 32 % lower than M1.

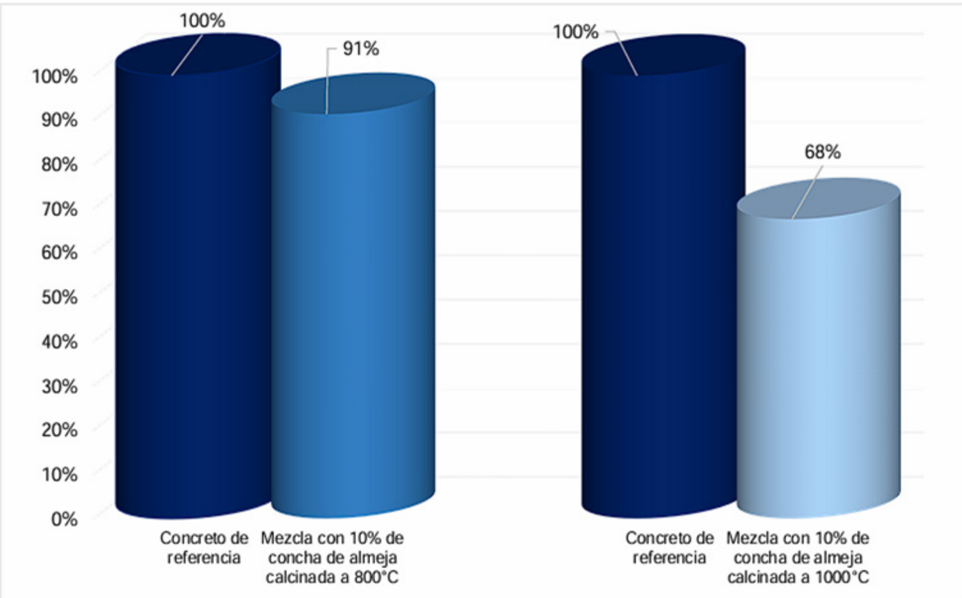

Figure 6. Percentage comparison of the electrical resistivity of the test specimens

CONCLUSIONS

The experimental phase reveals that, taking into account a concrete mix made with a 10 % replacement percentage and calcination temperatures of 800˚C and 1000˚C, the data obtained with respect to the compressive strength tests are higher than the values obtained in the tests carried out on the reference concrete specimens.

This allows us to initially highlight that temperature is not a significant parameter of differentiation, given that the values obtained during the experiment are similar for both calcination temperatures. In other words, the variation is not significant; the procedures carried out for the production of concrete cylinders with the incorporation of calcined clam shell waste material at different temperatures yield similar results in terms of concrete strength, even producing values above those of the reference concrete, regardless of whether the calcination process originated at 800°C or 1000°C.

It should be noted that, in terms of compressive strength, the temperature factor does not trigger a significant difference between the tests. The use of calcined clam as a partial replacement for cement not only means that values equal to the reference are achieved, but also that there is an improvement in the values, which leaves open the possibility of replacing more than 10 % of the cement with mineral additions of clam.

It is concluded that it may be feasible to reduce the amount of cement in the concrete mix and replace it with a higher proportion of calcined clam shells (Megapitaria squalida).

The use of marine mollusk waste as a construction input is an effective solution to mitigate negative environmental effects. In perspective, the amount of shells discarded in different environmental settings is minimized; another benefit is the reduction in cement use, which causes large volumes of CO_2 to be released into the atmosphere.

REFERENCES

1. CONAPESCA. Anuario estadístico de acuacultura y pesca 2023. Comisión Nacional de Acuacultura y Pesca; 2023. Disponible en: https://nube.conapesca.gob.mx/sites/cona/dgppe/2023/ANUARIO_ESTADISTICO_DE_ACUACULTURA_Y_PESCA_2023.pdf

2. Mordor Intelligence. Mercado del cemento ANÁLISIS DE TAMAÑO Y PARTICIPACIÓN - TENDENCIAS DE CRECIMIENTO Y PRONÓSTICOS HASTA 2023. 2025. Disponible en: https://www.mordorintelligence.com/es/industry-reports/cement-market

3. Hinkel M, Blume S, Hinchliffe D, Mutz D, Hengevoss D. Directrices sobre Pre- y Co-procesamiento de Residuos en la Producción de Cemento. 1st ed. Vol. 1. Alemania: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; 2020.

4. Secretaría de Economía. Perfil de mercado de la caliza. Gobierno de México; 2022. Disponible en: https://www.gob.mx/cms/uploads/attachment/file/692310/10._Perfil_Caliza_2021__T_.pdf

5. Martínez García C. Estudio del comportamiento de la concha de mejillón como árido para la fabricación de hormigones en masa: aplicación en la cimentación de un módulo experimental (Módulo Biovalvo). Tesis de licenciatura. Coruña: Universidade da Coruña. Escola Universitaria de Arquitectura Técnica; 2016. Disponible en: http://hdl.handle.net/2183/17489

6. Underdog. Un material como el concreto pero hecho de conchas de mar. 2020 Sep 10. Disponible en: https://underdogmexico.com/un-material-como-el-concreto-pero-hecho-deconchas-de-mar/

FUNDING

The authors did not receive funding for the development of this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTION

Conceptualization: Alicia Zulema Rodríguez Lizárraga.
Data curation: Jesús Manuel Bernal Camacho.
Formal analysis: Víctor Manuel Martínez García.
Research: Alicia Zulema Rodríguez Lizárraga.
Methodology: Karla Karina Romero Valdez.
Project management: Karla Karina Romero Valdez.
Resources: Jesús Manuel Bernal Camacho.
Software: Víctor Manuel Martínez García.
Supervision: Alicia Zulema Rodríguez Lizárraga.
Validation: Jesús Manuel Bernal Camacho.

Visualization: Karla Karina Romero Valdez.
Writing – original draft: Alicia Zulema Rodríguez Lizárraga.
Writing – review and editing: Víctor Manuel Martínez García.