

## Circular Economy in Action: Valorizing Eggshell Waste for Sustainable Construction Practices

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### Abstract

The management of construction materials is increasingly intertwined with sustainability and circular economy priorities. Calcium carbonate, a key component in spackle and other building materials, is still predominantly sourced through mining, raising concerns related to environmental degradation and resource depletion. Eggshell-derived calcium carbonate (ESP) offers a valuable example of waste valorization, wherein by-products from the food industry are repurposed as inputs for construction materials. This review examines ESP not only in terms of material performance but also within the broader context of sustainable resource management. Existing studies indicate that incorporating ESP at replacement levels of 10–20% can improve compressive strength, decrease permeability, and enhance overall durability, aligning with sustainability-driven innovations in construction supply chains. Nonetheless, critical gaps remain in relation to standardization, scalability, and long-term performance under varying environmental conditions. By situating ESP within circular economy and sustainability frameworks, this review highlights its dual potential to advance eco-innovation in construction while reducing waste management pressures. The findings emphasize the need for cross-sectoral approaches that integrate material science, waste valorization, and sustainability-oriented decision-making within the built environment sector.

**Keywords:** *Waste Valorization; Sustainable Resource Management; Circular Economy; Construction Industry; Eggshell-Derived Calcium Carbonate.*

### Introduction

Spackle, also known as joint compound, is a widely used material in drywall construction, primarily applied to seal seams between wallboards, repair cracks, and fill nail indentations to create smooth, uniform wall surfaces before painting or finishing (Millette et al., 2023). Over time, spackle formulations have evolved, incorporating fillers, binders, and various additives designed to improve adhesion, flexibility, workability, and finish quality.

Historically, many joint compound formulations contained chrysotile asbestos in concentrations ranging from 0.5% to 23%, with some products reaching as high as 45.2% (Millette et al., 2023). The inclusion of asbestos generated significant occupational health risks, particularly during mixing, application, and sanding, when airborne fiber concentrations frequently exceeded regulatory safety limits (Fischbein et al., 1979). Prolonged exposure to chrysotile fibers was closely associated with severe respiratory illnesses including asbestosis, lung cancer, and mesothelioma (Millette et al., 2023). In response to these hazards, the U.S. Consumer Product Safety Commission banned the sale of asbestos-containing joint compounds for consumer use in 1977, prompting the development of safer, asbestos-free alternatives.

Contemporary spackle formulations typically incorporate lightweight fillers, bulking agents, binders, and starch-based bodying agents to achieve smooth consistency and ease of application (SenthilKumarA. & Banu, 2007). Some products also include polymer-based additives to enhance flexibility and reduce cracking. The origins of these formulations can be traced back to the long-standing use of gypsum-based plasters, as gypsum has served as a construction binder since the 9th millennium BC, with its use documented in ancient civilizations such as Asia Minor, Sumeria, Babylon, and Egypt (Stark & Wicht, 1999).

As a material extensively used for wall finishing and architectural repair, spackle must exhibit high compressive strength, strong adhesion, low permeability, and long-term durability. However, conventional spackle formulations rely heavily on mined calcium carbonate, contributing to environmental degradation and resource depletion. Increasing global emphasis on sustainable construction practices has therefore stimulated interest in alternative filler materials, particularly eggshell-derived calcium carbonate (ESP), which offers dual benefits: waste valorization from the food industry and potential performance enhancement in construction applications.

Despite its promise, research on ESP substitution in construction materials has produced varied findings, particularly regarding long-term durability and optimal replacement levels. Many studies suggest that 10–20% ESP replacement can improve compressive strength, reduce permeability, and enhance moisture resistance. Razali et al. (2020) reported that a 20% ESP replacement improved carbonation resistance and sorptivity, indicating better protection against moisture ingress and increased service life. Similarly, Paruthi et al. (2023) found significant reductions in permeability for concrete mixtures containing up to 20% ESP, suggesting enhanced structural cohesion. However, other studies have raised concerns about ESP's long-term performance in chemically aggressive environments. Murthi et al. (2022) highlighted the need for further investigation into ESP's behavior under acidic or sulfate-rich conditions, where potential durability limitations may arise.

Optimizing ESP performance requires careful consideration of application type, replacement level, and material compatibility. While many studies identify 10–20% substitution as the most effective range for enhancing mechanical properties, higher replacement ratios may yield diminishing returns or introduce durability challenges. In addition, the specific constituent being replaced—whether cement, fine aggregate, or other components—significantly influences the resulting mechanical and durability performance. A key limitation that persists across existing research is the absence of standardized processing, grinding, and purification methods for ESP, which contributes to variability in results.

This review synthesizes and critically evaluates empirical and review-based studies on the use of eggshell powder as a replacement material in construction applications. It serves as a preliminary investigation within a broader research program exploring the potential of ESP as a sustainable alternative ingredient in spackle formulation.

### **Research Methodology**

This study adopts a systematic review methodology to evaluate the potential of eggshell-derived calcium carbonate (ESP) as a sustainable replacement for conventional calcium carbonate in spackle and other construction materials. The review synthesizes evidence from peer-reviewed journal articles, conference proceedings, and technical reports published within the past two decades. Relevant literature was identified through comprehensive searches of

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major academic databases, including Scopus, ScienceDirect, Web of Science, and Google Scholar, using keywords related to eggshell powder, sustainable fillers, calcium carbonate substitution, and construction materials.

To ensure the relevance and scientific rigor of the included studies, literature selection was guided by the following criteria:

1. Studies examining ESP as a filler or partial/full replacement for calcium carbonate in spackle, cement-based materials, or other construction composites.
2. Experimental research reporting mechanical, durability, permeability, or microstructural properties of ESP-based mixtures.
3. Comparative studies evaluating the performance of ESP relative to conventional calcium carbonate or other common fillers.
4. Research addressing sustainability dimensions, including waste valorization, circular economy implications, and environmental performance of ESP utilization.

Data extracted from the selected studies included ESP processing methods, replacement levels, mechanical strength outcomes, durability indicators, permeability results, and compatibility with spackle or cementitious formulations. The synthesis focused on identifying performance patterns, summarizing optimal replacement ranges, and evaluating ESP's suitability for enhancing compressive strength, structural stability, moisture resistance, and material longevity.

In addition, the review examined broader sustainability contributions of ESP, including reductions in waste disposal burdens and mitigation of environmental impacts associated with mining-based calcium carbonate. Attention was also given to identifying remaining research gaps—particularly regarding standardized ESP processing, long-term durability in aggressive environments, and the feasibility of large-scale industrial application in spackle production.

The findings of this systematic review provide a conceptual and empirical foundation for future experimental work and inform potential pathways for integrating ESP into sustainable material practices within the construction industry.

## **Research Results and Discussion**

### *Eggshell Powder (ESP)*

Egg consumption in Indonesia is considerably higher than other animal-based protein sources, making eggs one of the most frequently consumed proteins nationwide (Hurek et al., 2021). This high consumption generates substantial quantities of eggshell waste, particularly from food processing sectors such as bakeries, fast-food industries, and large-scale manufacturing facilities. Because eggs serve as a key ingredient in products ranging from cakes and salad dressings to processed foods, several tons of eggshell waste are produced daily, contributing to growing disposal costs at both national and global levels (Faridi & Arabhosseini, 2018). In 2023, Indonesia's laying-hen production reached an estimated 6,117,905.4 tonnes, with Lampung Province alone accounting for 235,555.6 tonnes (BPS Indonesia, 2024). As eggshells constitute roughly 10% of the total egg weight, this volume translates into a significant accumulation of poultry eggshell waste (Figure 1) (Shi et al., 2021).

Most of this waste remains untreated, frequently accumulating on-site or ending up in landfills.

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This practice contributes to environmental degradation, including odour emissions from biodegradation, soil contamination, and wider ecological disturbance. Globally, the mismanagement of agricultural waste—eggshell waste included—has emerged as a critical issue, as improper disposal can contaminate water sources, disrupt ecosystems, and facilitate the spread of pathogens harmful to humans and animals (Ngayakamo & Onwualu, 2022; Obi et al., 2016). In response, recent research has increasingly focused on strategies for valorising eggshell waste, with the aim of reducing environmental impacts while unlocking the economic potential of this largely underutilized resource.

Chemically, eggshells consist predominantly of calcium carbonate ( $\text{CaCO}_3$ ), which comprises approximately 94–95% of their total mass (Dolińska et al., 2016; Shi et al., 2021; Lertchunhakiat et al., 2016; King'ori, 2011). The remaining fraction consists of an organic matrix rich in proteins, glycoproteins, and proteoglycans, which contribute to the structural integrity and mechanical strength of the shell. The eggshell membrane (ESM) further enhances this complexity, containing cross-linked collagens (types I, V, and X), glycosaminoglycans (GAGs), and proteins such as ovotransferrin, lysozyme, and ovocalyxin-36 (Shi et al., 2021). This combination of mineral and organic components positions eggshell waste as a versatile and valuable material with potential applications in biomedical fields, pharmaceuticals, and, increasingly, sustainable construction materials. Consequently, eggshells represent a promising resource within waste valorization and circular economy strategies, highlighting significant untapped potential for environmentally aligned material innovation.

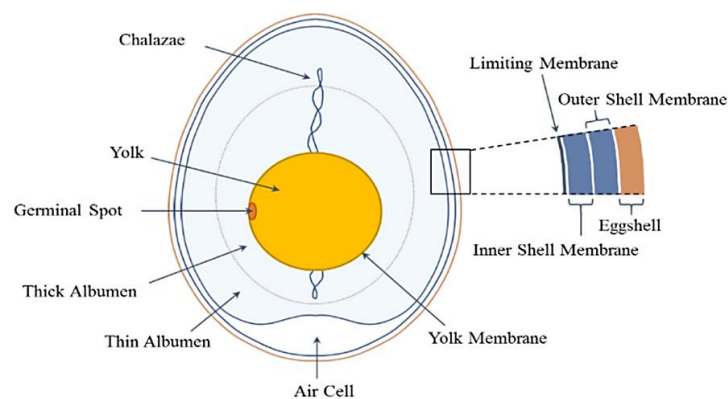


Figure 1. Hen egg structure

Source: Shi et al., (2021)

Eggshell powder (ESP) (Figure 2), a calcium carbonate-rich waste by-product, has gained increasing attention as a sustainable supplementary material for concrete and other construction applications. Following collection, eggshells are typically washed to remove residual contaminants and subsequently dried either naturally under sunlight (Doh & Chin, 2014) or at ambient room temperature. The dried shells are then crushed and ground into a fine powder. Several studies have reported different grinding procedures, including the use of flour mills to produce ESP capable of passing through a 90  $\mu\text{m}$  sieve (Divya et al., 2017; Sharma & Netula, 2018). Other researchers have adopted a finer gradation, utilizing ESP that passes through a 75

µm sieve (Al-Safy, 2015), reflecting ongoing variations in preparation techniques across studies.

Based on its chemical composition (Table 1), ESP exhibits notable pozzolanic characteristics and can be classified as a Class F pozzolan according to ASTM standards (Afolayan, 2017). This classification underscores its potential suitability as a partial replacement for conventional calcium carbonate or cementitious components in building materials, particularly within sustainability-oriented construction practices.



Figure 2. Preparation process of ESP

Table 1.  
Chemical Composition of ESP (%)

Oxides (%)									Ref.
CaO	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Na <sub>2</sub> O	K <sub>2</sub> O	MgO	SO <sub>3</sub>	LOI	
50.7	0.05	2.6	0.11	0.14	1.88	-	-	6.00	(Afolayan, 2017)
79.28	0.34	0.004	0.44	0.19	0.11	1.12	0.79	17.48	(Ngayakamo et al., 2021)
50.70	0.03	0.02	0.09	-	-	-	0.57	47.80	(Amaral et al., 2013)
52.10	0.06	0.02	0.58	0.15	0.25	0.06	0.62	45.42	(Yu et al., 2017)
52.10	0.03	0.02	0.08	0.14	-	0.01	0.62	45.42	(Bhaskaran et al., 2016)
46.69	0.12	0.32	0.49	0.19	0.21	0.18	0.57	-	(J.O et al., 2017)
64.83	0.13	0.06	0.79	1.48	0.08	0.29	0.06	14.4	(Adogla et al., 2016)
52.1	0.03	0.02	0.08	0.15	-	0.01	0.62	45.42	(Yerramala, 2014)
62.35	0.07	0.63	0.61	-	0.22	0.36	1.32	-	(Tan et al., 2018)
52.7	0.01	0.01	0.01	0.05	0.04	0.51	-	46.62	(Shiferaw et al., 2019)
53.8	-	-	0.06	0.02	0.07	0.75	0.98	42.2	(Ghorab et al., 2014)
52.10	0.06	0.02	0.58	0.15	0.25	0.06	0.62	45.42	(Mohd Arif et al., 2021)

### Effect of ESP Replacement

Recent studies have explored the potential of waste eggshells as a sustainable additive in construction materials (Table 2). ESP can partially replace cement or fine aggregate in concrete, enhancing mechanical properties and durability when used at up to 25% replacement (Yang et al., 2022). Research has shown that 10% eggshell powder addition can increase concrete compressive strength by 57% and improve flexural strength and water resistance (Doh & Chin, 2014). ESP have also been investigated as fillers in polymer and metal matrix composites, potentially improving strength while addressing waste disposal issues (Chandrappa & Kamath, 2021). Furthermore, eggshell-containing gypsum boards have demonstrated formaldehyde

adsorption capabilities, with  $\geq 5\%$  eggshell content effectively reducing formaldehyde concentrations to  $\leq 0.08$  ppm (Tsubouchi et al., 2024). These findings suggest that eggshells offer promising applications in construction materials, potentially enhancing performance and contributing to healthier indoor environments.

The incorporation of eggshell powder into concrete not only addresses waste disposal issues but also enhances the mechanical properties of the material. In an experimental study conducted by Doh and Chin (Doh & Chin, 2014), different percentages of ESP (0%, 5%, 10%, 15%, and 20%) were added to concrete, with notable improvements in strength and durability observed. The concrete mix containing 10% ESP exhibited the highest compressive strength of 42.82 N/mm<sup>2</sup>, representing a 57% increase compared to the control specimen. Additionally, the flexural strength showed a consistent increasing trend, reaching 3.50 N/mm<sup>2</sup> at 20% eggshell replacement (Doh & Chin, 2014).

Apart from mechanical improvements, ESP significantly enhanced the durability of concrete by reducing water absorption and penetration. The water penetration depth was reduced by up to 82.3%, indicating improved resistance to moisture ingress and potential corrosion in reinforced structures (Doh & Chin, 2014).

Table 2.  
Effect of EPS replacement in various studies

	Replacement Percentage	Strength Impact	Durability Impact	Performance Notes	Ref.
High strength concrete	8-10%	No compromise in mechanical strength	Negative impact on durability properties in chemical environments	Increases hydration process during early periods	(Murthi et al., 2022)
Concrete	Up to 20%	Increases material strength	No mention found	Reduces permeability of concrete	(Paruthi et al., 2023)
Mortar	20%	Advantageous for early compressive strength	Improved carbonation rate and sorptivity	No significant differences in pH for control and modified mortars	(Razali et al., 2020)
High strength concrete	Up to 15%	10% EPS resulting the highest compressive strength of 68.4 MPa	Replacing cement with EPS will decrease concrete workability	Increased rebound number and pulse velocity	(Mohd Arif et al., 2021)

In some cases, ESP has similar compounds to limestone. Limestone is a type of sedimentary rock that generally contains carbonate compounds, especially calcium carbonate (CaCO<sub>3</sub>). The natural limestone obtained is processed by burning it to produce quicklime known by the chemical term calcium oxide (CaO). The results of this combustion are sold for building materials for houses, mining factories, fisheries and so on (Megawati et al., 2019). Existing research related to infrastructure so far used eggshells as a mixture of cement and concrete. Sustainable research for materials in the construction industry has triggered the hunt for

substitute materials that can replace cement (Awang et al., 2020). It is also known that the eggshell membrane (ESM) can act as a biosorbent. Due to its potential for chemical modifications, ESM is also an excellent biosorbent and is used to absorb various inorganic substances, dyes, and other substances in an aqueous solution (Shi et al., 2021). The use of eggshell waste instead of natural lime to replace cement in concrete can have benefits like minimizing the use of cement, conserving natural lime and utilizing waste material (Yerramala, 2014). From the explanation above, it is known that eggshells have the potential to be a mixture for making eco-friendly building materials in the hope of reducing rubbish/waste that is often found in the environment.

Murthi et al. (Murthi et al., 2022) noted that eggshell powder replacement increases the hydration process during early periods, which could explain the improvements in early compressive strength reported by several studies. Paruthi et al. (Paruthi et al., 2023) mentioned that eggshell powder helps reduce the permeability of concrete, indicating a potential pore-filling effect. Ramathilagam, et.al. (Ramathilagam et al., 2018) and Afolayan, et al. (J.O et al., 2017) observed that ESP shortens the setting time of cement, making ESP taken as an accelerator. The shortens of ESP setting time is similar to limestone in which tri-calcium silicate was accelerated due to the hydration reaction (Moon et al., 2017).

When applying eggshell powder as a replacement in construction materials, several factors should be considered. The material being replaced plays a crucial role, as some studies have used eggshell powder to replace cement, while others have used it to replace fine aggregate (sand), affecting the optimal percentage and resulting properties. The type of application also matters, with studies covering both mortar and concrete, where differences in composition and structural requirements may lead to varying optimal replacement percentages. The desired properties should be taken into account, as the replacement percentage needs to align with specific performance goals; for instance, if high early compressive strength is required, a higher replacement percentage (around 20%) might be beneficial. Environmental conditions must also be considered, as findings by Murthi et al. (Murthi et al., 2022) indicate that chemical environments may negatively impact durability, necessitating adjustments in the replacement percentage based on exposure conditions. Additionally, the processing method of eggshell powder remains an area with limited information, yet standardizing and optimizing this process could be key to achieving consistent results. Lastly, the long-term performance of eggshell powder replacement remains uncertain, as most studies focus on short-term or early-age properties, with little available data on its long-term effects on durability and overall material performance.

#### *ESP as Calcium Carbonate Replacement*

Calcium carbonate is a chemical compound with the formula  $\text{CaCO}_3$ . It is a common substance found in rocks as the mineral's calcite and aragonite. Calcium carbonate is also occurred in the main component of pearls, shells of marine organisms, snails, and eggs also it is extracted by mining or quarrying (Kolekar et al., 2020). Recent studies have explored the potential of

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eggshell-derived calcium carbonate ( $\text{CaCO}_3$ ) as a sustainable alternative to conventional  $\text{CaCO}_3$  in various applications. Eggshell powder, containing 93.70-95% calcium carbonate ( $\text{CaCO}_3$ ), has shown potential as a sustainable alternative to conventional  $\text{CaCO}_3$  in various applications (Kolekar et al., 2020);(Sathvik et al., 2019). Calcinated eggshell powder has shown improved carbonation rates and compressive strength when used as a fine aggregate replacement in concrete (Razali et al., 2020).

Studies have demonstrated its efficacy as a weighting agent in drilling fluids, with improved rheological properties compared to commercial  $\text{CaCO}_3$  (Iqbal et al., 2019). Raman spectroscopy and photoluminescence analyses reveal that eggshell powder exhibits more intense and Raman-sensitive calcite bands than conventional  $\text{CaCO}_3$ , indicating its purity and potential as a substitute (Kaur & Singh, 2023). In concrete production, eggshell powder can partially replace cement, conserving natural limestone and utilizing waste material (Sathvik et al., 2019). The use of eggshell-derived  $\text{CaCO}_3$  not only provides an affordable solution but also addresses environmental concerns by repurposing waste from the poultry industry (Kolekar et al., 2020);(Iqbal et al., 2019). These findings suggest that eggshell powder is a promising, eco-friendly replacement for conventional calcium carbonate in various industries.

### **Conclusions and Recommendations**

This review synthesizes evidence on the use of eggshell-derived calcium carbonate (ESP) as a sustainable alternative to mined calcium carbonate in spackle and related construction materials. The principal result emerging from the literature is that ESP, particularly at 10–20% substitution levels, can enhance strength, durability, and moisture resistance while reducing permeability. Taken together, these studies suggest that agricultural by-products can be successfully valorized within construction, answering the review question of whether ESP has the potential to support both material performance and sustainability goals.

At the same time, the review highlights limitations within the current body of research: inconsistent findings on long-term durability, lack of standardized processing methods, and limited evidence on large-scale application. These gaps point to the need for further studies that examine performance under varied environmental conditions, assess lifecycle impacts, and evaluate adoption pathways across industries. Beyond the technical domain, the findings also imply social and environmental benefits, such as reducing waste streams, promoting circular economy practices, and fostering more responsible resource management in construction.

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**References**

- Adogla, F., Yalley, P. P. K., & Arkoh, M. (2016). Improving Compressed Laterite Bricks using Powdered Eggshells. *The International Journal Of Engineering And Science (IJES)*, 5(4), 71–75.
- Afolayan, J. O. (2017). Experimental Investigation of the Effect of Partial Replacement of Cement with Eggshell Ash on the Rheological Properties of Concrete. *International Journal of Engineering and Applied Sciences*, 4(12), 1–7.
- Al-Safy, R. A. (2015). Experimental investigation on properties of cement mortar incorporating eggshell powder. *Journal of Engineering and Sustainable Development*, 19(6), 198–209.
- Amaral, M. C., Siqueira, F. B., Destefani, A. Z., & Holanda, J. N. F. (2013). Soil-cement bricks incorporated with eggshell waste. *Proceedings of Institution of Civil Engineers: Waste and Resource Management*, 166(3), 137–141. <https://doi.org/10.1680/warm.12.00024>
- Awang, H., Richard, A. O., & Arminda, W. (2020). Design of Green Hybrid Cementitious Composite for Sustainability Enhancement. *International Journal of Sustainable Construction Engineering and Technology*, 11(1 SE-Articles), 185–193. <https://publisher.uthm.edu.my/ojs/index.php/IJSCET/article/view/6257>
- Badan Pusat Statistik Indonesia. (2024). *Produksi Telur Ayam Petelur menurut Provinsi*. 13 March 2023. <https://www.bps.go.id/id/statistics-table/2/NDkxIzI%3D/produksi-telur-ayam-petelur-menurut-provinsi.html>
- Bhaskaran, H., John, L., Neethu, P. M., & Sebastian, T. (2016). Study on Egg Shell Concrete. *International Journal of Engineering Research & Technology (IJERT)*, 4(13), 4–6. <https://www.ijert.org/research/study-on-egg-shell-concrete-IJERTCONV4IS13001.pdf>
- Chandrappa, D. R. K., & Kamath, M. S. S. (2021). The Egg shell as a filler in composite materials - a review. *Journal of Mechanical and Energy Engineering*, 4(4), 335–340. <https://doi.org/10.30464/jmee.2020.4.4.335>
- Divya, B., Vasanthavalli, K., & Ambalavanan, R. (2017). Investigation on cement concrete at mixed with egg shell powder. *International Journal of Innovative Research in Science, Engineering and Technology*, 6(3).
- Doh, S. I., & Chin, S. C. (2014). Eggshell powder: potential filler in concrete. *8th MUCET, November 2014*, 10–11.
- Dolińska, B., Jelińska, M., Szulc-Musioł, B., & Ryszka, F. (2016). Use of eggshells as a raw material for production of calcium preparations. *Czech Journal of Food Sciences*, 34(4), 313–317. <https://doi.org/10.17221/59/2016-CJFS>
- Faridi, H., & Arabhosseini, A. (2018). Application of eggshell wastes as valuable and utilizable products: A review. *Research in Agricultural Engineering*, 64(2), 104–114. <https://doi.org/10.17221/6/2017-RAE>
- Fischbein, A., Rohl, A. N., Langer, A. M., & Selikoff, I. J. (1979). Drywall construction and asbestos exposure. *American Industrial Hygiene Association Journal*, 40(5), 402–407. <https://doi.org/10.1080/15298667991429750>
- Ghorab, H. Y., Rizk, M., Ibrahim, B., & Allam, M. M. (2014). High belite cement from alternative raw materials. *Materiales de Construcción*, 64(314), e012–e012.
- Hurek, D. T., Rihi, D. M., Pello, P. S., Beti, V. N., Moi, M. M., Boru, M. J., Manafe, R. Y., Parera, M. V., Kale, N. D., Kallau, N. H., Detha, A. I., Wuri, D. A., & Toha, L. R. (2021). Tips Memilih dan Menyimpan Telur yang Aman untuk Dikonsumsi. *Media Tropika: Jurnal Pengabdian Masyarakat*, 1(1), 88–93.
- Iqbal, R., Abro, F., Zubair, M., Ali, M., Pirzada, F., & Valasai, A. (2019). An Experimental Study on the Performance of Calcium Carbonate Extracted from Eggshells as Weighting Agent in Drilling Fluid. *Engineering, Technology and Applied Science*
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- Research*, 9(1), 3859–3862. <https://doi.org/10.48084/etasr.2538>
- J.O, A., F.O.P, O., G, M., & J.E, S. (2017). Investigating the Effect of Eggshell Ash on the Properties of Sandcrete Block. *International Journal of Civil Engineering, Construction and Estate Management*, 5(3), 43–54. [www.eajournals.org](http://www.eajournals.org)
- Kaur, N., & Singh, K. (2023). A comparative study of Raman spectroscopic and photoluminescence properties of the eggshell powder and conventional calcium carbonate. *Journal of Physics: Conference Series*, 2426(1), 0–7. <https://doi.org/10.1088/1742-6596/2426/1/012001>
- King`ori A.M. (2011). a Review of Using Poultry Eggshell. In *International Journal of Poultry Science* (Vol. 10, pp. 908–912).
- Kolekar, M. S., Deshmukh, M. S., Hiwale, M. V., & Dutta, M. A. (2020). Analyzation of Calcium Carbonate (CaCO<sub>3</sub>) in Eggshells and their Applications. *International Research Journal of Innovations in Engineering and Technology*, 4(8), 37–46. <https://doi.org/10.47001/irjiet/2020.408007>
- Lertchunhakiat, K., Saenphoom, P., Nopparatmaitree, M., & Chimthong, S. (2016). Effect of Eggshell as a Calcium Source of Breeder Cock Diet on Semen Quality. *Agriculture and Agricultural Science Procedia*, 11, 137–142. <https://doi.org/10.1016/j.aaspro.2016.12.023>
- Megawati, M., Alimuddin, A., & Abdul Kadir, L. (2019). Komposisi Kimia Batu Kapur Alam dari Industri Kapur Kabupaten Kolaka Sulawesi Tenggara. *Saintifik*, 5(2), 104–108. <https://doi.org/10.31605/saintifik.v5i2.230>
- Millette, J. R., Compton, S. P., & DePasquale, C. (2023). Microscopy in the Study of Asbestos-Containing Joint Compound and Patching Products, Including Spackling. *The Microscope*. <https://api.semanticscholar.org/CorpusID:270019322>
- Mohd Arif, S., Rokiah, O., Khairunisa, M., Chong, B. W., Chek, Y. C., Youventharan, D., Ramadhansyah, P. J., & Doh, S. I. (2021). Compressive Strength of Concrete containing Eggshell Powder as Partial Cement Replacement. *IOP Conference Series: Earth and Environmental Science*, 682(1). <https://doi.org/10.1088/1755-1315/682/1/012031>
- Moon, G. D., Oh, S., Jung, S. H., & Choi, Y. C. (2017). Effects of the fineness of limestone powder and cement on the hydration and strength development of PLC concrete. *Construction and Building Materials*, 135, 129–136. <https://doi.org/https://doi.org/10.1016/j.conbuildmat.2016.12.189>
- Murthi, P., Lavanya, V., & Poongodi, K. (2022). Effect of eggshell powder on structural and durability properties of high strength green concrete for sustainability: A critical review. *Materials Today: Proceedings*, 68, 1311–1318. <https://doi.org/10.1016/j.matpr.2022.06.346>
- Ngayakamo, B., Aboubakar, A. M., Komadja, C. G., Bello, A., & Onwualu, A. P. (2021). Eco-friendly use of eggshell powder as a bio-filler and flux material to enhance technological properties of fired clay bricks. *Metallurgical and Materials Engineering*, 27(3), 371–383. <https://doi.org/10.30544/628>
- Ngayakamo, B., & Onwualu, A. P. (2022). Recent advances in green processing technologies for valorisation of eggshell waste for sustainable construction materials. *Heliyon*, 8(6), e09649. <https://doi.org/10.1016/j.heliyon.2022.e09649>
- Obi, F. O., Ugwuishiwu, B. O., & Nwakaire, J. N. (2016). Agri Wastes. *Nigerian Journal of Technology*, 35(4), 957–964. <http://dx.doi.org/10.4314/njt.v35i4.34>
- Paruthi, S., Khan, A. H., Kumar, A., Kumar, F., Hasan, M. A., Magbool, H. M., & Manzar, M. S. (2023). Sustainable cement replacement using waste eggshells: A review on mechanical properties of eggshell concrete and strength prediction using artificial neural network. *Case Studies in Construction Materials*, 18(March), e02160.

- <https://doi.org/10.1016/j.cscm.2023.e02160>
- Ramathilagam, B. H., Aravinth, K., Ananth, C., & Arisivamani, L. (2018). An experimental investigation of eggshell powder as a partial replacement of cement in paver block. *Int J Eng Sci Comput (IJESC)*, 8(6), 17083–17085.
- Razali, N., Azizan, M. A., Pa'ee, K. F., Razali, N., & Jumadi, N. (2020). Preliminary studies on calcinated chicken eggshells as fine aggregates replacement in conventional concrete. *Materials Today: Proceedings*, 31, 354–359.  
<https://doi.org/10.1016/j.matpr.2020.06.232>
- Sathvik, S., Edwin, A., Basnett, A., Sharma, P., & Carmicheal, J. (2019). Experiment of partial replacement of egg shell powder and coconut fibre in concrete. *International Journal of Innovative Technology and Exploring Engineering*, 8(6 Special Issue 4), 1034–1038. <https://doi.org/10.35940/ijitee.F1213.0486S419>
- SenthilKumarA., V., & Banu, R. S. D. W. (2007). An Algorithm for Mining Association Rules Using an Efficient Hashing with Transaction Trimming. *International MultiConference of Engineers and Computer Scientists*.  
<https://api.semanticscholar.org/CorpusID:38245152>
- Sharma, S., & Netula, N. (2018). Experimental investigation of partial replacement of OPC (43 Grade) cement by egg shell powder for M-35 concrete grade. *International Conference on Recent Research and Innovations in Social Science, Humanities, India*, 1–9.
- Shi, Y., Zhou, K., Li, D., Guyonnet, V., Hincke, M. T., & Mine, Y. (2021). Avian eggshell membrane as a novel biomaterial: A review. *Foods*, 10(9), 1–15.  
<https://doi.org/10.3390/foods10092178>
- Shiferaw, N., Habte, L., Thenepalli, T., & Ahn, J. W. (2019). Effect of eggshell powder on the hydration of cement paste. *Materials*, 12(15), 2483.
- Stark, J., & Wicht, B. (1999). Zur Historie des Gipses. *Zkg International*, 52, 527–533.  
<https://api.semanticscholar.org/CorpusID:114064888>
- Tan, Y. Y., Doh, S. I., & Chin, S. C. (2018). Eggshell as a partial cement replacement in concrete development. *Magazine of Concrete Research*, 70(13), 662–670.
- Tsubouchi, K., Tsukaguchi, Y., Shimizu, T., Yoshikawa, H., Hino, E. I., Date, Y., Aoki, K., & Tanifuji, N. (2024). Fabrication of Functional Gypsum Boards Using Waste Eggshells to Prevent Sick Building Syndrome. *Sustainability (Switzerland)*, 16(7).  
<https://doi.org/10.3390/su16073050>
- Yang, D., Zhao, J., Ahmad, W., Nasir Amin, M., Aslam, F., Khan, K., & Ahmad, A. (2022). Potential use of waste eggshells in cement-based materials: A bibliographic analysis and review of the material properties. *Construction and Building Materials*, 344(January), 128143. <https://doi.org/10.1016/j.conbuildmat.2022.128143>
- Yerramala, A. (2014). Properties of concrete with eggshell powder as cement replacement. *Indian Concrete Journal*, 88(10), 94–102.
- Yu, T. Y., Ing, D. S., Choo, C. S., & Azed, M. A. (2017). Natural lime treated as partial cement replacement to produce concrete. *International Journal on Advanced Science, Engineering and Information Technology*, 7(5), 1798–1804.  
<https://doi.org/10.18517/ijaseit.7.5.2559>