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Post-Thermal Performance of Concrete Containing Clamshell

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Abstract

This study investigates the post-thermal mechanical performance of concrete incorporating clamshell powder (CSP) as a partial cement replacement at 0%, 4%, 6%, and 8% by weight. Grade M20 concrete specimens were tested for workability, rebound hardness, compressive strength, and splitting tensile strength at ambient temperature and after exposure to elevated temperatures of 150 °C, 300 °C, and 400 °C. Results showed that workability decreased progressively with higher CSP content due to increased water absorption and coarser particle texture. At ambient conditions, the highest compressive strength (40.35 MPa) was recorded for 8% CSP, an 51.63% improvement over the control mix. Thermal exposure up to 300 °C enhanced compressive strength by approximately 12.2%, attributed to matrix densification and improved bonding, while exposure to 400 °C caused a slight reduction (3.93%) due to microcracking and C–S–H decomposition. Splitting tensile strength peaked at 6% CSP and 300 °C (2.86 MPa), 75.5% higher than the control specimen CS0 (1.63MPa) at the same temperature. A strong positive correlation (R^2 = 0.72) was observed between compressive and tensile strengths. The findings demonstrate that optimal CSP incorporation (6–8%) can improve both compressive and tensile performance after moderate heat exposure, offering a sustainable and thermally resilient alternative to conventional cement in structural applications.

Keywords: Clamshell Concrete, Thermal Performance, Compressive Strength, Sustainable Construction, Elevated Temperature

1. Introduction

Concrete is the backbone of modern infrastructure, serving as a primary construction material in buildings, bridges, and a wide range of civil engineering applications due to its versatility, durability, and availability. However, the environmental footprint of Portland cements the key binding ingredient in concrete has become a pressing concern. Cement manufacturing is responsible for approximately 7 – 8% of global CO_2 emissions, largely due to the energy-intensive clinker production process and the calcination of limestone (Ahmed et al., 2024; Bamigboye et al., 2021). This has driven researchers and industry stakeholders to explore alternative materials that can partially replace cement, thereby reduce environmental impact while maintain or improving concrete performance (Jasni et al., 2024; Maglad et al., 2023).

Among these alternatives, clamshell waste, an abundant byproduct of the seafood industry, has attracted growing interest due to its high calcium carbonate ($CaCO_3$) content, which is chemically comparable to limestone. Valorising clamshells not only addresses waste disposal challenges but also contributes to resource conservation and the development of sustainable construction materials (Bee Poh Ong & Umar Kassim, 2019; El Mendili & Benzaama, 2022). Previous studies have shown that clamshell powder (CSP), when used as a supplementary cementitious material, can enhance mechanical properties such as compressive and tensile strength through improved hydration and matrix densification (Olivia et al., 2017; Tayeh et al., 2020; Essalem et al., 2023). Optimal replacement levels, particularly around 6%, have been associated with significant performance gains without compromising workability due to improved hydration and densified microstructure, reinforcing the feasibility of this approach for structural applications. (Olivia et al., 2017; Bee Poh Ong & Umar Kassim, 2019).

Despite these promising findings, most research on CSP concrete has been conducted under standard curing and ambient conditions. The performance of such sustainable mixes under elevated temperatures remains relatively underexplored, even though many concrete structures are exposed to high thermal loads during fire incidents or prolonged heat exposure in hot climates. Elevated temperatures can cause significant degradation in concrete microstructure and mechanical properties, including strength loss, cracking, and chemical decomposition of hydration products (Bahadori et al., 2021; Khan & Siddique, 2017). Understanding the thermal behaviour of CSP concrete is essential for its application in fire-prone or high-temperature environments.

This study addresses this knowledge gap by evaluating the thermal resistance and post-exposure mechanical performance of concrete incorporating varying levels of clamshell powder. By subjecting specimens to 150 °C, 300 °C, and 400 °C, the work simulates realistic thermal scenarios encountered in infrastructure applications. In addition to compressive and tensile strength, workability is also assessed to provide a comprehensive understanding of CSP's impact on both fresh and hardened properties under thermal stress.

Ultimately, the aim is to determine whether clamshell powder can serve as a sustainable, high-performance cement replacement capable of maintaining structural integrity after exposure to elevated temperatures. The findings are expected to support the advancement of environmentally responsible construction practices while enhancing the resilience of infrastructure to thermal hazards.

2. Methodology

2.1 Materials and Samples Preparation

This research uses clamshell powder as a partial substitute for cement in concrete. The materials comprise Ordinary Portland Cement (Type I), fine aggregates (sand), coarse aggregates, and water. Clamshells were procured from local businesses, meticulously cleaned to eliminate contaminants, desiccated, and then pulverized into tiny pieces. The materials were further pulverized into a fine powder with an electrical powder grinder to ensure actual size range (passing 75 µm sieve) as shown in Figure 2.1 based on ASTM C136-14 for particle size analysis (ASTM Internation, 2019). The coarse aggregates utilized in the mixture passed through a 10 mm sieve, and the fine aggregates passed through a 4.7 mm sieve, assuring compliance with conventional size specifications. The water utilized for the mixture was obtained from a reputable laboratory supplier and complied with ASTM C1602 criteria to guarantee no detrimental impact on the durability and strength of the concrete (ASTM International, 2023). The preparation method involved screening the clamshell powder to eliminate large particles, assuring uniform fineness that complies with cement specifications.

a) b) c)

Figure 2.1 (a) Clamshells were crushed into tiny pieces (b) Clamshells were grinded using electrical powder grinder (c) Clamshell powder.

2.2 Samples Preparation

The concrete mixture was formulated for grade M20 in compliance with BS 8500-2 guidelines. The water-cement ratio was established at 0.6 to provide uniformity and ease of handling. Cement was partially substituted with clamshell powder at 0%, 4%, 6%, and 8% by weight. Each mixture was formulated with precise cement, fine aggregates, coarse aggregates, and water ratios as tabulated in Table 2.1. The proportions were determined to attain the desired mechanical qualities while considering the influence of clamshell powder.

A total of 36 samples comprised 100 mm × 100 mm × 100 mm cubes for compressive strength testing and 36 samples with 100 mm diameter × 200 mm cylinder moulds for splitting tensile strength testing. Three specimens were constructed for 0%, 4%, 6%, and 8% of clamshell powder as cement replacement. Each specimen was assigned a unique identification code indicating the mix proportion as shown in Table 2.1. The specimens were demoulded after 24 hours and subjected to water curing in a controlled curing tank at 27 ± 2 °C for 28 days to ensure adequate hydration as shown in Figure 2.2. During curing, the specimens were arranged to avoid direct contact with one another, preventing surface abrasion or localized hydration differences.

After 28 days of curing ages, the 18 samples (nine cubes and nine cylinders) with 0%, 4%, 6% and 8% of CSP replacement were tested under compressive and splitting tensile test at ambient temperature. Meanwhile, a total 54 samples with 0%, 4%, 6% and 8% of CSP replacement were exposed to elevated temperature exposure up to 150°C, 300°C, and 400°C for about 1-hour after it reached targeted temperature by using a furnace from Universiti Teknologi MARA as shown in Figure 2.3. After one hour of steady state targeted temperature, all the 54 samples (27 cubes and 27 cylinders) were left undergo cooling process before undergoing compressive and splitting tensile test in order to obtain the post-mechanical performances of the concrete.

Table 2.1 The Design Mix Proportion

Specimens	Percentage of Clamshell Powder (%)	Cement (kg/m^3)	Water	Clamshell Powder (kg/m^3)	Fine Aggregates (kg/m^3)	Coarse Aggregates (kg/m^3)
CS0	0	411.00	246.60	0.00	667.1	1438.08
CS4	4	394.56	246.60	16.44	667.1	1438.08
CS6	6	386.34	246.60	24.66	667.1	1438.08
CS8	8	378.12	246.60	32.88	667.1	1438.08

Figure 2.2 Curing the specimens into curing tank for 28 days.

Figure 2.3 UiTM Laboratory furnace

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2.3 Workability Test

The workability of the concrete was evaluated using the slump cone test by ASTM C143 (ASTM International, 2020). According to the standard, the typical slump value for concrete grade M20 in range 25 to 50 mm (ASTM International, 2020). The concrete mixture was deposited into a slump cone in three layers, with every layer compacted 25 times using a steel rod to guarantee adequate compaction. The cone was elevated vertically, and the slump height was determined by the difference between the cone's height and the top of the slumped concrete illustrated in Figure 2.4. This assessment examined the mixture's consistency and fluidity, which are critical for appropriate placement and compaction in construction.

The water content and mixing ratios were meticulously observed to address discrepancies resulting from clamshell powder substitution. Observations were documented at all replacement levels to identify workability trends as the clamshell powder percentage escalated.

Figure 2.4 Slump test.

2.4 Rebound Hammer Test

The rebound hammer test as shown in Figure 2.5, a non-destructive technique, was performed in compliance with ASTM C805 (ASTM International, 2018). This assessment evaluated the surface hardness of the concrete and offered an indirect estimation of its compressive strength. A spring-operated steel hammer exerted force on the concrete surface, and the rebound distance of the hammer was measured.

Calibration curves tailored to the concrete mix were established to associate rebound values with compressive strength. The experiment was conducted on cubic and cylindrical specimens at various replacement levels and temperature exposures to evaluate the effect of clamshell powder on surface hardness and overall strength.

For the rebound hammer test, the cured specimens were removed from the curing tank, gently surface-dried with a clean cloth, and allowed to acclimatize at laboratory temperature for at least 2 hours before testing. The rebound hammer was applied on three distinct points on each exposed face of the cube and cylinder, maintaining a minimum distance of 25 mm from edges and corners to avoid stress concentration effects, in accordance with ASTM C805. The hammer was held perpendicular to the surface at each test point to ensure consistent impact energy (ASTM International, 2018). The readings from all test points were recorded, and the mean value was calculated as the representative surface hardness for each specimen. All data were documented alongside the corresponding specimen identification code to ensure traceability during analysis.

Figure 2.5 Rebound hammer apparatus.

2.5 Compressive Strength Test

Compressive strength tests were conducted on cube specimens utilizing a compression testing machine by BS EN 12390-3 requirements as shown in Figure 2.6. The specimens were removed from their moulds after 24 hours and immersed in water for curing over 28 days. Following post-curing, the specimens were subjected to higher temperatures of 150°C, 300°C, and 400°C for one hour to replicate fire and high-temperature conditions.

After exposure, the specimens were acclimatized to ambient temperature before testing. The compressive strength of each specimen was documented, and the findings were averaged to guarantee uniformity. Observations were conducted on variations in strength attributable to temperature and replacement levels.

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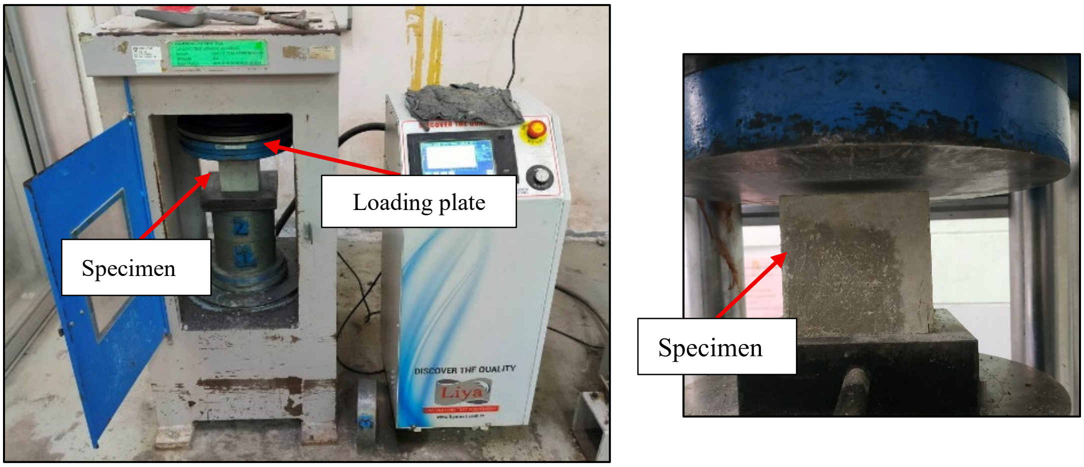

Figure 2.6 Compressive strength test machine.

2.6 Splitting Tensile Strength Test

Splitting tensile strength testing was performed on cylindrical specimens by ASTM C496 standards (ASTM International., 2017). The specimens were cured for 28 days, equivalent to those utilized in compressive strength tests. After curing, the specimens were exposed to elevated temperatures for one hour and then cooled to ambient temperature.

During the test process, the specimens were oriented horizontally between the loading plates of a universal testing machine in Figure 2.7. The load was incrementally added until the specimen fractured along its vertical axis. The tensile strength was measured, and the findings were averaged for each replacement level and temperature exposure. The test results revealed information regarding the bonding and cohesiveness of the concrete matrix, especially at high temperatures.

Figure 2.7 Universal Testing Machine

3. Results and Discussion

3.1 Workability Test

The slump test findings indicated a distinct trend: workability diminished as the proportion of clamshell powder increased as illustrated in Figure 3.1. The CS0 which is concrete with 0% replacement of clamshell mixture demonstrated the most significant slump value of 54.3 mm, signifying excellent workability and fluidity. CS8 with 8% replacement mix exhibited the lowest slump value of 20.7 mm, indicating diminished fluidity and heightened stiffness. Based on ASTM C143, the typical slump value for concrete grade M20 in range 25 to 50 mm (ASTM International, 2020). The diminished workability is due to the coarser texture and increased water absorption capacity of clamshell powder relative to cement. The results underscore the necessity to modify water content or integrate plasticizers at elevated replacement levels to preserve optimal workability. Notwithstanding the reduction, all mixtures displayed authentic slump profiles devoid of segregation, affirming their appropriateness for practical applications.

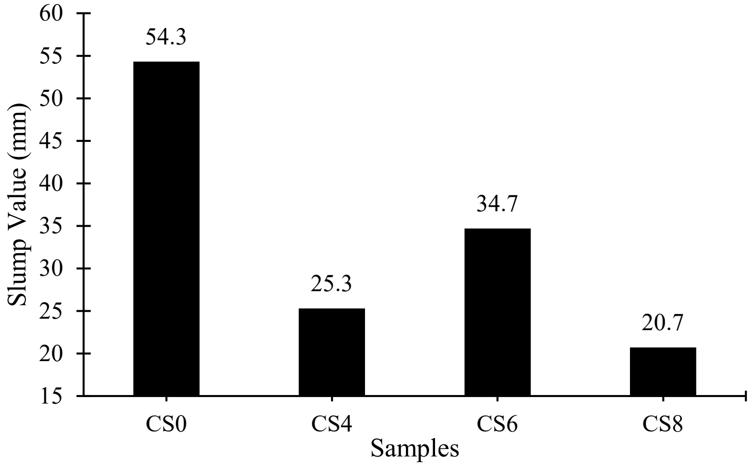

Figure 3.1 The results of workability test of concrete.

3.2 Rebound Hammer Test

Rebound hammer testing revealed notable variations in surface hardness among the different mixtures and temperature exposures. As shown in Figure 3.2, the compressive strength of cubic specimens ranged between approximately 21.2 MPa and 25.5 MPa across all replacement levels and temperatures. Although slight fluctuations were observed, the results indicate relatively stable performance regardless of clamshell powder content or heating conditions.

In contrast, Figure 3.3 shows that cylindrical specimens generally exhibited higher compressive strength values than their cubic counterparts. The highest strength was recorded for the CS6 mix (6% clamshell powder replacement) at 300 °C, achieving 33.6 MPa. Other mixes, particularly CS4 and CS6, also demonstrated improved performance after moderate temperature exposure (150 °C–300 °C), suggesting a possible densification of the cement matrix and enhanced interfacial bonding due to the partial cement replacement with clamshell powder.

The superior performance of certain mixes at elevated temperatures may be attributed to microstructural refinement, where moderate heating can promote additional hydration reactions and reduce internal microcracking. Similar trends have been reported by Coa et al. (2022), who observed that partial cement replacement with calcium carbonate-rich materials can improve high-temperature resistance by refining pore structure and increasing matrix density. Furthermore, Khan and Siddique (2017) found that moderate thermal exposure (200–300 °C) can lead to strength gains in concrete mixes containing mineral additives due to enhanced crystalline bonding and reduced free water content. These findings support the applicability of the rebound hammer test as a reliable, rapid, and non-destructive method for estimating surface hardness and predicting compressive strength, especially when complemented by standard destructive testing methods.

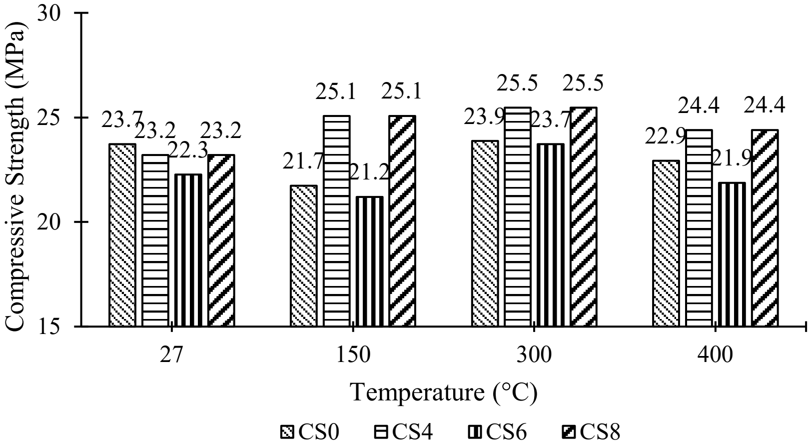

Figure 3.2 Compressive strength for cubic specimen based on R-value.

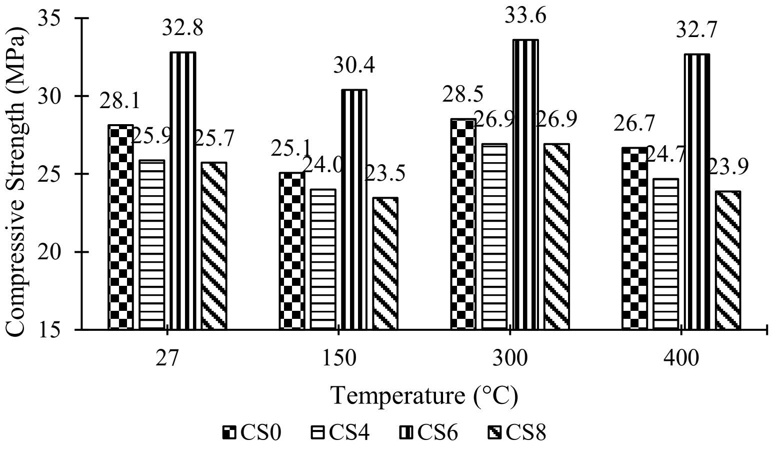

Figure 3.2 Compressive strength for cylindrical specimen based on R-value.

3.3 Compressive Strength Test

The compressive strength of clamshell concrete exhibited considerable variation based on replacement percentage and temperature in Figure 3.4. At ambient temperature, CS8 with 8% replacement of clamshell mix regularly surpassed others, attaining the maximum strength of 40.35 MPa after 28 days of curing. Exposure to temperatures of up to 300°C significantly improved the strength about 12.2% due to heightened hydration processes and matrix densification. At 400°C, a slight decrease about 3.93% in strength was noted, ascribed to thermal degradation, including microcracking and the disintegration of calcium silicate hydrate.

The results demonstrate that clamshell powder effectively improves compressive strength at moderate temperatures, rendering it appropriate for heat resistance applications. Overall, all CS4, CS6 and CS8 show an increment in compressive strength after elevate temperature exposure up to 300°C. These findings align with those reported by Jasni et al. (2024), who found that the clamshell powder can enhance the compressive strengths of the concrete.

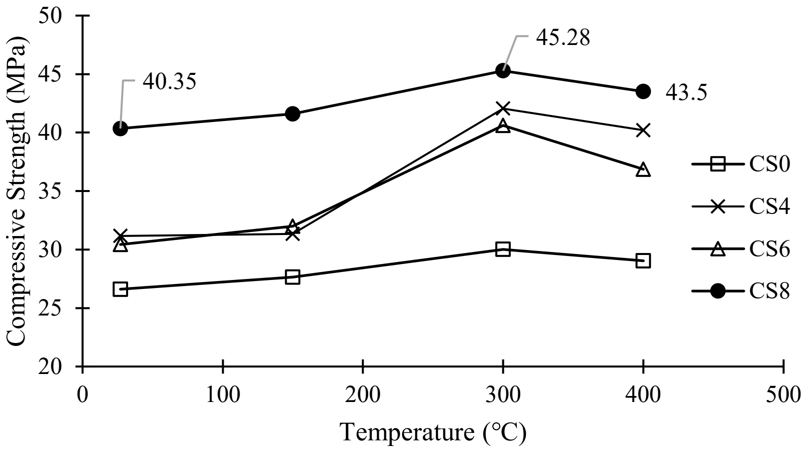

Figure 3.4 Compressive strength of clamshell concrete at elevated temperature.

3.4 Splitting Tensile Strength Test

The findings of the splitting tensile strength test reflected the trends seen in compressive strength as shown in Figure 3.5. The CS6 with 6% CSP replacement mixture demonstrated the greatest tensile strength at 2.86 MPa. Strength enhanced with temperatures up to 300°C, indicating greater cohesion and bonding inside the matrix. A drop was observed at 400°C due to thermal pressures inducing microcracks. The findings highlight the significance of clamshell powder in improving tensile characteristics, especially at ideal replacement ratios, and its applicability in tensile-critical scenarios subjected to heat stress. The study's findings align positively with previous research, Bee Poh Ong and Umar Kassim (2019) reported that seashell concrete containing 6% clamshell as a replacement for Ordinary Portland Cement demonstrated better adhesion between the aggregate and cement paste compared to a composition with 8%.

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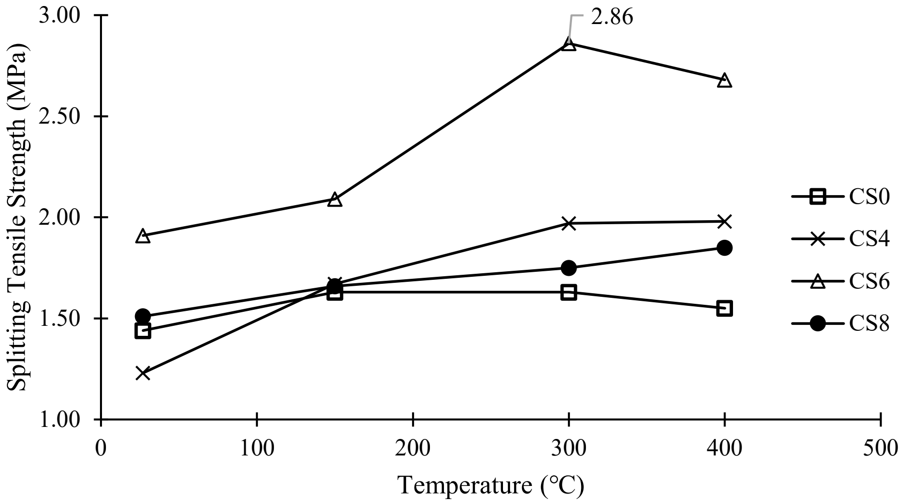

Figure 3.5 Splitting tensile strength of clamshell concrete at elevated temperature

3.5 The Correlation Between Compressive Strength Test and Splitting Tensile Strength Test

A significant positive correlation (R^2 = 0.72) was identified between compressive strength and splitting tensile strength as plotted in Figure 3.6. This suggests that enhancements in compressive strength directly improve tensile properties, confirming the balanced performance of clamshell concrete in both tests.

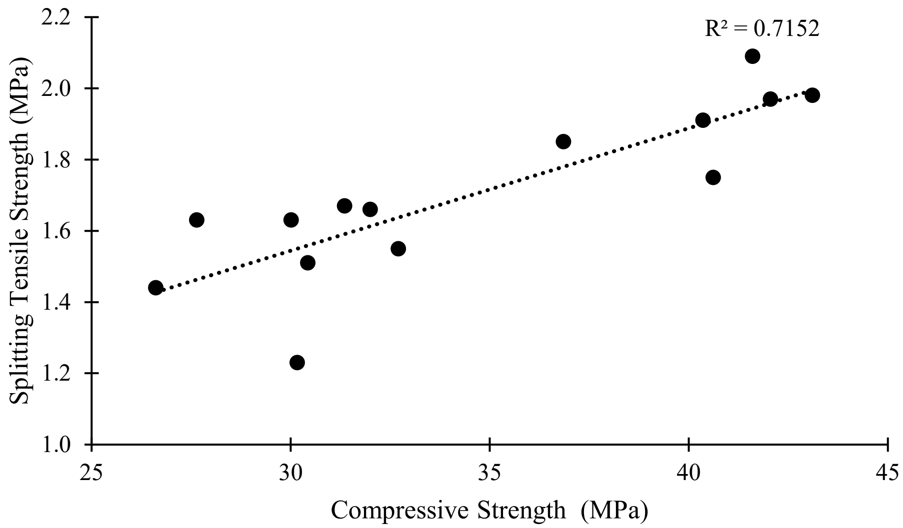

Figure 3.6 The correlation graph between compressive strength and splitting tensile strength

4. Conclusion

The research indicates that including clamshell powder as a partial substitute for cement improves concrete's mechanical and thermal characteristics. It can be concluded that workability decreased progressively with higher CSP content, with slump values dropping 61.9% from 5.43 cm (CS0) to 2.07 cm (CS8). This reduction is attributed to the coarser texture and greater water absorption of CSP, which increases internal friction in the mix. Although negative for fresh concrete handling, this drawback can be mitigated with water adjustments or admixtures without compromising hardened performance.

As for compressive strength, at ambient conditions, the highest compressive strength was recorded for CS8, achieving 40.35 MPa, an 51.63% increase compared to CS0 (26.61 MPa) at ambient temperature. Thermal exposure up to 300 °C increased strength by approximately 12.2% due to matrix densification and enhanced bonding. At 400 °C, compressive strength declined by 3.93%, reflecting the onset of microcracking and C-S-H decomposition, but structural integrity was still retained.

Splitting tensile strength trends, the maximum splitting tensile strength was achieved by CS6 at 300 °C, reaching 2.86 MPa, which is 75.5% higher than CS0 at the same temperature (1.63 MPa). This suggests that moderate heating can enhance tensile cohesion, particularly at optimal CSP content, before degradation effects dominate at higher temperatures.

Although CS8 provided the highest compressive strength at ambient conditions, CS6 offered the best combined performance across both compressive and tensile tests under thermal exposure, balancing mechanical gain, durability, and workability. Correlation between strength parameters, a strong positive correlation (R^2 = 0.72) between compressive and tensile strengths confirms that improvements in one property translate proportionally to the other. Incorporating CSP not only enhances mechanical performance at moderate heat exposure but also contributes to sustainable construction by reusing calcium carbonate-rich waste. The observed performance gains, particularly the over 50% increase in tensile strength at optimal CSP content and temperature, demonstrate CSP's potential in structural applications where thermal resilience is critical.

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Declaration of Conflicting Interests

All authors declare that they have no conflicts of interest.

Author Contribution

Conceptualisation, Nurizaty Zuhan; Methodology, Athirah Izazi Ahim; Validation, Athirah Izazi Ahim; Analysis, Athirah Izazi Ahim; Investigation, Athirah Izazi Ahim; Resources, Nurizaty Zuhan; Data Curation, Name; Writing-Draft Preparation, Nurizaty Zuhan; Writing-Review & Editing, Nurizaty Zuhan; Visualisation, Nurizaty Zuhan; Supervision, Nurizaty Zuhan, Norharyati Saleh,Mazlina Mohamad & Bishir Kado; Project Administration, Universiti Teknologi MARA (UiTM); Funding Acquisition, Ministry of Education Malaysia for providing the financial support under grant FRGS-EC/1/2024/TK06/UITM/02/20.

References

Ahmed, S. M., Chávez-Delgado, M., & Siva Avudaiappan. (2024). Experimental investigations on sustainable mortar containing recycled seashell powder as cement partial replacement. *Engineering Research Express*, *6*(2), 025101–025101. https://doi.org/10.1088/2631-8695/ad3717

ASTM International. (2019). ASTM C618-19: Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. ASTM International. https://doi.org/10.1520/C0618-19

ASTM International. (2018). ASTM C805/C805M-18: Standard Test Method for Rebound Number of Hardened Concrete. ASTM International. https://doi.org/10.1520/C0805_C0805M-18

ASTM International. (2023). ASTM C1602/C1602M-23: Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete. ASTM International. https://doi.org/10.1520/C1602_C1602M-23

ASTM International. (2020). ASTM C143/C143M-20: Standard Test Method for Slump of Hydraulic-Cement Concrete. ASTM International. https://doi.org/10.1520/C0143_C0143M-20

ASTM International. (2017). ASTM C496/C496M-17: Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. ASTM International. https://doi.org/10.1520/C0496_C0496M-17

Bahadori, H. R., Hedayat, A. A., & Karbakhsh, A. (2021). Effects of Seashell and Lumashell limestone powder on concrete thermal resistance. *Modares Civil Engineering Journal*, *21*(5), 173–183. https://mcej.modares.ac.ir/article-16-50567-en.html

Bamigboye, G. O., Nworgu, A. T., Odetoyan, A. O., Kareem, M., Enabulele, D. O., & Bassey, D. E. (2021). Sustainable use of seashells as binder in concrete production: Prospect and challenges. *Journal of Building Engineering*, *34*, 101864. https://doi.org/10.1016/j.jobe.2020.101864

Bee Poh Ong, & Umar Kassim. (2019). View of Performance of Concrete Incorporating of Clamshell as Partially Replacement of Ordinary Portland Cement (OPC). Akademiabaru.com. https://www.akademiabaru.com/submit/index.php/aram/article/view/1834/822

Cao, M., Yuan, X., Ming, X., & Xie, C. (2022). Effect of high temperature on compressive strength and microstructure of cement paste modified by micro-and nano-calcium carbonate particles. *Fire Technology*, *58*(3), 1469-1491.

El Mendili, Y., & Benzaama, M.-H. (2022). Investigation of Mechanical and Thermal Performance of Concrete with Scallop Shells as Partial Cement Replacement: Alternative Binder and Life Cycle Assessment. *CivilEng*, *3*(3), 760–778. https://doi.org/10.3390/civileng3030044

Essalem, M. L. M., Cherradi, T., Amziane, S., & Teguedy, M. C. (2023). Influence of Seashell on the Physical, Mechanical, and Thermal Properties of Brick Mortar Mixtures. *The Open Civil Engineering Journal*, *17*(1). https://doi.org/10.2174/18741495-v17-e230113-2022-69

Jasni, S. A., Muthusamy, K., Ruslan, H. N., Hamada, H., & Wahab, E. S. A. (2024). Use of Seashell as Cement Replacement in Construction Material: A Review. CONSTRUCTION, 4(1), 7–20. https://doi.org/10.15282/construction.v4i1.10001

Khan, M. I., & Siddique, R. (2017). Utilization of silica fume in concrete: Review of durability properties. Resources, Conservation and Recycling, 57, 30–35.

Maglad, A. M., Othuman Mydin, M. A., Dip Datta, S., & Tayeh, B. A. (2023). Assessing the mechanical, durability, thermal and microstructural properties of seashell ash based lightweight foamed concrete. *Construction and Building Materials*, *402*, 133018. https://doi.org/10.1016/j.conbuildmat.2023.133018

Olivia, M., Oktaviani, R., & Ismeddiyanto. (2017). Properties of Concrete Containing Ground Waste Cockle and Clam Seashells. Procedia Engineering, 171, 658–663. https://doi.org/10.1016/j.proeng.2017.01.404

Tayeh, B. A., Hasaniyah, M. W., Zeyad, A. M., Awad, M. M., Alaskar, A., Mohamed, A. M., & Alyousef, R. (2020). Durability and mechanical properties of seashell partially replaced cement. *Journal of Building Engineering*, *31*, 101328. https://doi.org/10.1016/j.jobe.2020.101328