Performance Evaluation of Sustainable Self Compacting Concrete Using Turitella Shell Waste

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***Abstract*—The disposal of seashell waste and the intensive consumption of natural construction materials motivate the development of alternative constituents for concrete. This experimental study evaluates processed Turritella shell powder as a partial replacement for fine aggregate in M40 self-compacting concrete. Five mixtures containing 0, 5, 10, 15, and 20 percent Turritella were assessed. Fresh-state performance was measured using slump-flow, T50-time, V-funnel, and L-box tests, while compressive, flexural, and split-tensile strengths were determined after 7, 14, and 28 days of curing. Increasing the Turritella content raised slump flow from 650 to 690 mm and improved the L-box ratio from 0.86 to 0.94. T50 and V-funnel times increased moderately, indicating a greater final spread accompanied by a slightly slower rate of flow. At 28 days, the mixture containing 20 percent Turritella achieved the highest compressive strength of 48.80 MPa and flexural strength of 4.88 MPa. These values exceeded the control by only 0.62 and 0.21 percent, respectively, and therefore represent practical equivalence rather than substantial enhancement. The maximum split-tensile strength of 5.96 MPa was recorded at 10 percent Turritella, corresponding to an improvement of 5.86 percent over the control. The findings demonstrate that processed Turritella shell powder can be incorporated into M40 self-compacting concrete without materially reducing its overall mechanical performance. A 20 percent content produced the strongest combined fresh, compressive, and flexural response, whereas 10 percent was preferable when split-tensile strength was prioritized.**

***Index Terms*—self-compacting concrete; Turritella shell powder; seashell waste; sustainable concrete; compressive strength; split-tensile strength.**

I. INTRODUCTION

Self-compacting concrete (SCC) is a high-flow concrete capable of filling formwork, passing through congested reinforcement, and achieving adequate consolidation under its own weight without mechanical vibration. Its successful performance depends on a controlled balance among filling ability, passing ability, viscosity, and resistance to segregation [1], [2]. These requirements make SCC sensitive to changes in powder content, aggregate grading, particle morphology, and chemical admixture dosage.

The concrete industry is simultaneously under pressure to conserve virgin resources and divert suitable wastes from disposal. Seashell residues generated by seafood-processing activities and coastal communities are primarily calcium-carbonate based and degrade slowly when discarded. When properly washed, dried, crushed, and ground, shell-derived particles may influence particle packing, paste rheology, hydration kinetics, and the interfacial transition zone of cementitious materials [6], [7], [12].

The response of shell waste cannot be generalised across species or replacement modes. Shell powder used as a binder replacement behaves differently from shell particles used as fine or coarse aggregate. Turritella shell powder is comparatively less studied in M40 SCC, particularly across a combined programme of fresh-state tests and mechanical-strength tests at several curing ages. This study therefore evaluates five mixtures containing 0–20% Turritella and identifies the proportion that offers the most balanced performance.

The objectives are to: (i) assess slump flow, T50-time, V-funnel time, and L-box ratio; (ii) determine compressive, flexural, and split-tensile strengths at 7, 14, and 28 days; and (iii) compare each modified mixture with the control to identify property-specific and overall optimum contents.

II. LITERATURE REVIEW

Okamura and Ouchi established the core performance con-cept of SCC and emphasised that high flow alone is insuffi-cient unless the concrete also resists segregation and passes reinforcement without blockage [1]. The European SCC guidelines consequently recommend multiple complementary tests, including slump flow, T50, V-funnel, and L-box measurements [2].

Reviews of seashell-containing concrete show that performance depends on shell species, cleaning and grinding procedures, particle size, replacement basis, and content [6,7,9]. Finely ground shell particles may fill voids and provide nucleation surfaces; however, excessive replacement can reduce the effective quantity of reactive cement or create weaker interfaces. Uncalcined seashell powder is generally domi-nated by calcium carbonate and should not automatically be described as a conventional pozzolan without chemical, mineralogical, and reactivity evidence [11],[12].

Investigations involving oyster, mussel, scallop, and mixed seashell wastes have reported satisfactory mechanical performance at carefully selected contents, but the optimum varies between concrete systems [8], [10], [13], [14]. Few studies have addressed processed Turritella shell powder in M40 SCC while simultaneously measuring all four fresh properties and three mechanical properties at multiple ages. The present work addresses this specific experimental gap.

III. METHODOLOGY

A. Constituent Materials

The concrete was prepared using 53-grade ordinary Portland cement, natural river sand, crushed coarse aggregate with a nominal maximum size of 20 mm, potable water, a high-range water-reducing admixture, and processed Turritella shell powder. The cement had a specific gravity of 3.07, standard consistency of 29%, initial setting time of 45 min, and final setting time of 7 h 40 min. The measured 3-day and 7-day mortar strengths were 27 and 36 MPa.

The fine aggregate had a specific gravity of 2.54. The coarse aggregate had bulk and apparent specific gravities of 2.61 and 2.64, respectively, and water absorption of 0.35%. The measured 3-day and 7-day cement-mortar compressive strengths were 27 MPa and 36 MPa, respectively.

Table I: Reported Composition of Turritella Shell Powder

Constituent	Reported content
Calcium carbonate	90–95%
Silica	2–5%
Magnesium carbonate	< 1%
Iron oxide	< 1%
Aluminium oxide	< 1%
Other trace constituents	< 1%

Table II: Concrete-Mixture Designations

Mixture	Turritella content (%)
TS0	0
TS5	5
TS10	10
TS15	15
TS20	20

The reported composition of the shell powder is given in Table I. Because no mineralogical or direct reactivity tests were available, the material is treated as a shell-derived mineral filler/replacement material rather than a confirmed pozzolan.

B. Mixture Matrix

Five mixtures were identified as TS0, TS5, TS10, TS15, and TS20 according to Turritella content. The recorded base quantities were 400 kg/m3 cement, 620 kg/m3 fine aggregate, 980 kg/m3 coarse aggregate, and 14 kg/m3 superplasticizer. The available laboratory record did not specify the water content or water-to-binder ratio; these values are therefore not inferred in this paper. Concrete mix proportioning and general structural requirements were considered with reference to IS 10262:2019 and IS 456:2000 [3], [4]. The compressive, flexural, and split-tensile testing procedures were interpreted with reference to IS 516 (Part 1/Sec 1):2021 [5].

C. Fresh-State Tests

Slump flow measured unrestricted spread and filling ability. During the same test, T50-time was recorded as the time required for the spread to reach a diameter of 500 mm. V-funnel time represented restricted-flow behaviour and relative viscosity. The L-box ratio assessed passing ability through reinforcement-like obstructions. These indicators were interpreted together because a large final spread does not alone demonstrate satisfactory SCC performance.

D. Mechanical Tests

Compressive strength was measured using 150 mm cubes, flexural strength using prism specimens, and split-tensile strength using cylinders. Tests were performed after 7, 14, and 28 days of water curing. The governing expressions were

$$f\_c = \frac{P}{A} \quad (1)$$

$$f_r = \frac{PL}{bd^2} \quad (2)$$

$$f_{ct} = \frac{2P}{\pi LD} \quad (3)$$

where P is the failure load, A is the loaded area, L is the effective span or cylinder length, as applicable, b and d are the prism width and depth, respectively, and D is the cylinder diameter.

IV. RESULTS AND DISCUSSION

A. Fresh Properties

The fresh-state results are summarised in Table III. Slump flow increased continuously from 650 mm for the control mixture to 690 mm for TS20. The L-box ratio similarly increased from 0.86 to 0.94, indicating improved filling and passing ability. T50-time rose from 2.1 to 2.5 s, while V- funnel time increased from 8.5 to 11.0 s. Thus, the modified mixtures achieved a greater final spread but flowed at a moderately slower rate.

The combined trend may reflect changes in packing and flow resistance produced by the processed powder. TS20 provided the highest spread and passing ratio, but it also recorded the highest relative-viscosity indicators. No seg-regation measurements were available, so the fresh-state conclusions are restricted to the reported tests.

B. Compressive Strength

Compressive strength increased with curing age for every mixture. At 28 days, TS5, TS10, and TS15 remained below the control by 7.63%, 6.08%, and 4.64%, respectively. TS20 reached 48.80 MPa, only 0.30 MPa or 0.62% above TS0. The result is best interpreted as preservation of compressive performance rather than a substantial strength enhancement.

C. Flexural Strength

Flexural strength followed a similar trend. TS5 produced the lowest values, after which strength progressively recovered with increasing Turritella content. At 28 days, TS20 achieved 4.88 MPa compared with 4.87 MPa for the control. The difference of 0.01 MPa, or 0.21%, indicates practical equivalence.

D. Split-Tensile Strength

The split-tensile response differed from the other strength properties. TS10 provided the maximum 28-day value of 5.96 MPa, corresponding to a 5.86% increase over TS0. TS15 remained 2.66% above the control, whereas TS20 returned to the control value.

The split-tensile results exhibited non-monotonic early-age variation; therefore, the 28-day results were used as the principal basis for identifying the optimum tensile-performance level.

E. Overall Performance

Table VII compares the principal 28-day outcomes. TS20 demonstrated the strongest combined fresh, compressive, and flexural response, while TS10 produced the highest split-tensile strength. The optimum proportion is therefore property dependent. The recovery observed at 20% may be consistent with physical filling and packing effects, but microstructural testing would be required to establish the controlling mechanism.

Table III: Fresh properties of SCC mixtures

Mixture	Turritella (%)	Slump flow (mm)	(T_{50}) (s)	V-funnel (s)	L-box ratio
TS0	0	650	2.1	8.5	0.86
TS5	5	660	2.2	9.2	0.88
TS10	10	670	2.3	9.8	0.90
TS15	15	680	2.4	10.5	0.92

TS20	20	690	2.5	11.0	0.94

Table IV: Compressive Strength of SCC Mixtures (MPa)

Mixture	7 days	14 days	28 days
TS0	32.33	40.415	48.50
TS5	29.80	37.30	44.80
TS10	30.36	37.95	45.55
TS15	30.83	38.54	46.25
TS20	32.32	40.50	48.80

Table V: Flexural Strength of SCC Mixtures (MPa)

Mixture	7 days	14 days	28 days
TS0	3.98	4.45	4.87
TS5	3.82	4.27	4.68
TS10	3.85	4.31	4.72
TS15	3.88	4.34	4.76
TS20	3.97	4.45	4.88

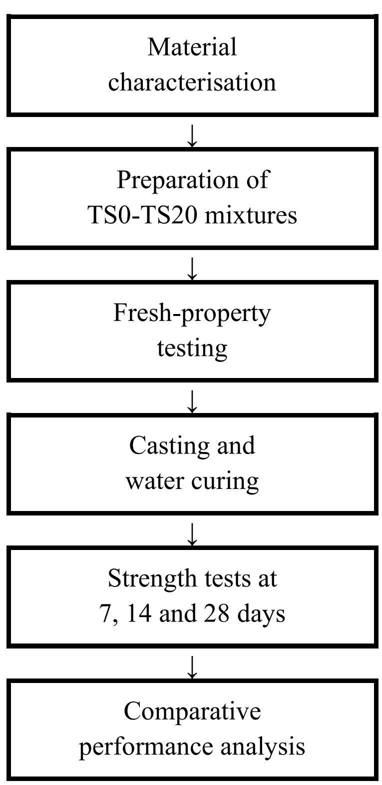

Figure 1: Experimental workflow for preparation, testing, and comparative evaluation of the SCC mixtures.

Table VI: Split-Tensile Strength of SCC Mixtures (MPa)

Mixture	7 days	14 days	28 days
TS0	3.97	4.80	5.63
TS5	4.35	4.48	5.85
TS10	4.92	4.11	5.96
TS15	4.75	4.06	5.78
TS20	3.49	4.94	5.63

Table VII: Performance relative to the control mixture

Mixture	Slump-flow change	Compressive change	Flexural change	Split-tensile change
TS5	+1.54%	−7.63%	−3.90%	+3.91%
TS10	+3.08%	−6.08%	−3.08%	+5.86%
TS15	+4.62%	−4.64%	−2.26%	+2.66%
TS20	+6.15%	+0.62%	+0.21%	0.00%

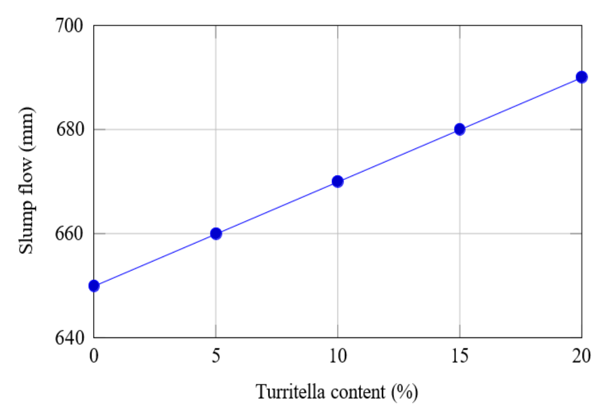

Figure 2: Variation of slump flow with Turritella content.

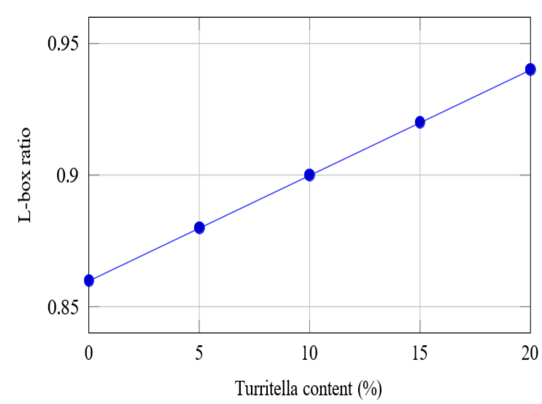

Figure 3: Variation of L-box ratio with Turritella content

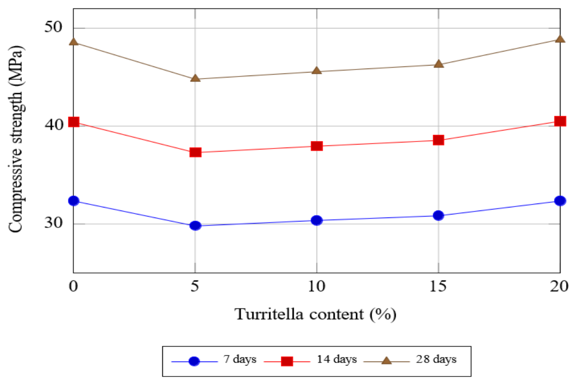

Figure 4: Compressive-strength development at different curing ages

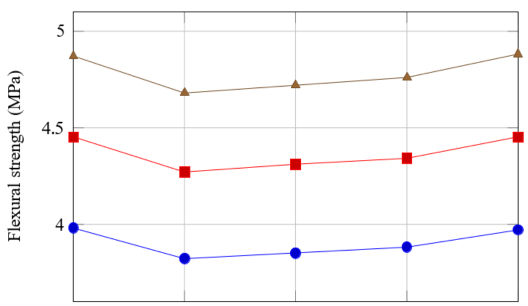

Figure 5: Flexural-strength development at different curing ages.

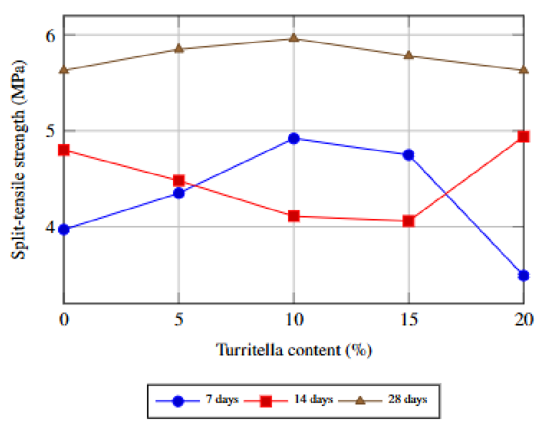

Figure 6: Split-Tensile-Strength Development at Different Curing Ages

V. CONCLUSION

The experimental investigation supports the following conclusions:

1. Increasing Turritella content from 0 to 20% increased slump flow from 650 to 690 mm and the L-box ratio from 0.86 to 0.94.
2. T50-time and V-funnel time increased moderately, showing that improved final spread occurred together with a slower rate of flow.
3. TS20 achieved the highest 28-day compressive strength of 48.80 MPa and flexural strength of 4.88 MPa. The gains over the control were marginal and indicate per-formance preservation rather than major enhancement.
4. TS10 produced the highest 28-day split-tensile strength of 5.96 MPa, representing a 5.86% improvement over the control.
5. Among the tested mixtures, 20% Turritella provided the best overall fresh, compressive, and flexural response, whereas 10% was preferable when split-tensile strength was prioritised.
6. The unusual 14-day split-tensile values for TS10 and TS15 require verification against original laboratory records.

Future investigations should document the complete mixture proportions, test replicate specimens for statistical analysis, Future investigations should document the complete mixture proportions, test replicate specimens for statistical analysis, evaluate strength at 56 and 90 days, and measure durability properties such as water absorption, sorptivity, permeability, chloride penetration, acid resistance, and sulphate resistance. behaviour. X-ray fluorescence, X-ray diffraction, particle-size analysis, scanning electron microscopy, and life-cycle assessment would improve understanding of the material mechanism and environmental benefit.

REFERENCES

[1] H. Okamura and M. Ouchi, "Self-compacting concrete," J. Adv. Concr. Technol., vol. 1, no. 1, pp. 5–15, 2003, doi: 10.3151/jact.1.5.

[2] The European Project Group, The European Guide-lines for Self-Compacting Concrete: Specification, Pro-duction and Use. EFNARC, BIBM, CEMBUREAU, EFCA, and ERMCO, 2005.

[3] Bureau of Indian Standards, IS 10262:2019 Concrete Mix Proportioning—Guidelines. New Delhi, India: BIS, 2019.

[4] Bureau of Indian Standards, IS 456:2000 Plain and Reinforced Concrete—Code of Practice. New Delhi, India: BIS, 2000.

[5] Bureau of Indian Standards, IS 516 (Part 1/Sec 1):2021—Hardened Concrete: Methods of Test—Testing of Strength of Hardened Concrete: Compressive, Flexural and Split Tensile Strength. New Delhi, India: BIS, 2021.
[6] K. H. Mo, U. J. Alengaram, M. Z. Jumaat, S. C. Lee, W. I. Goh, and C. W. Yuen, "Recycling of seashell waste in concrete: A review," Constr. Build. Mater., vol. 162, pp. 751–764, 2018, doi: 10.1016/j.conbuildmat.2017.12.009.
[7] B. A. Tayeh, M. W. Hasaniyah, A. M. Zeyad, and M. O. Yusuf, "Properties of concrete containing recycled seashells as cement partial replacement: A review," J. Clean. Prod., vol. 237, Art. no. 117723, 2019, doi: 10.1016/j.jclepro.2019.117723.
[8] B. A. Tayeh, M. W. Hasaniyah, A. M. Zeyad, M. M. Awad, A. Alaskar, A. M. Mohamed, and R. Alyousef, "Durability and mechanical properties of seashell partially-replaced cement," Journal of Building Engineering, vol. 31, Art. no. 101328, 2020, doi: 10.1016/j.jobe.2020.101328.
[9] H. M. Hamada, F. Abed, B. Tayeh, M. S. Al Jawahery, A. Majdi, and S. T. Yousif, "Effect of recycled seashells on concrete properties: A comprehensive review of the recent studies," Construction and Building Materials, vol. 376, Art. no. 131036, 2023, doi: 10.1016/j.conbuildmat.2023.131036.
[10] F. Soltanzadeh, M. Emam-Jomeh, A. Edalat-Behbahani, and Z. Soltan-Zadeh, "Development and characterization of blended cements containing seashell powder," Construction and Building Materials, vol. 161, pp. 292–304, 2018.
[11] J. Wang, E. Liu, and L. Li, "Characterization of the recycling of waste seashells with Portland cement towards sustainable cementitious materials," Journal of Cleaner Production, vol. 220, pp. 235–252, 2019.
[12] J. Wang and E. Liu, "Upcycling waste seashells with cement: Rheology and early-age properties of Portland cement paste," Resources, Conservation and Recycling, vol. 155, Art. no. 104680, 2020, doi: 10.1016/j.resconrec.2019.104680.
[13] S. Liu, Y. Zhang, B. Liu, Z. Zou, Q. Liu, Y. Teng, and L. V. Zhang, "Sustainable use of waste oyster shell powders in a ternary supplementary cementitious material system for green concrete," Materials, vol. 15, no. 14, Art. no. 4886, 2022, doi: 10.3390/ma15144886.
[14] S. A. Stel'makh, E. M. Shcherban', A. N. Beskopylny, L. R. Mailyan, B. Meskhi, S. S. Tashpulatov, A. Chernil'nik, N. Shcherban', and A. Tyutina, "Composition, technological, and microstructural aspects of concrete modified with finely ground mussel shell powder," Materials, vol. 16, no. 1, Art. no. 82, 2023, doi: 10.3390/ma16010082.