ESTIMATING CHEMICAL PRE-COMPRESSION IN TUBE-ENCASED EXPANSIVE RAC: DATA-ANCHORED SHORT REVIEW

LiuMin[1]

[1] аспирантура, Brest State Technical University,Brest,Belarus,liumin930406@163.com, +375257602931

Abstract: This paper presents a compact estimation and reporting framework for early chemical precompression in tube-encased recycled aggregate concrete. A single normalized descriptor, the Chemically Precompressed Index, converts measurable inputs into a common lateral-pressure scale using thin walled cylinder relations, with a short reporting note that preserves traceability from measurement to estimate. The mechanics are kept minimal and paired with a first order uncertainty propagation so that modulus choice, laminate thickness scatter, hoop strain readout, and diameter tolerance remain visible as an interval rather than a point value. Two data anchors give practical magnitude: about 5 MPa for concrete filled steel tubes that report core self stress, and about 0.9 to 3.4 MPa for fibre reinforced polymer shells at realistic initial hoop strains. The framework enables cross study comparability, specimen planning, and early selection of tube system and laminate schedule without case specific curve fitting.

Keywords: recycled aggregate concrete; chemical precompression; self stress; fibre reinforced polymer shells; concrete filled steel tubes

INTRODUCTION

The compressive response of recycled aggregate concrete remains highly variable because porous recycled particles and weaker interfacial zones promote microcracking and reduce stiffness and strength. Chemical expansion offers a complementary pathway to regain compressive margin when the matrix is restrained by a tube, since early dilation is redirected into beneficial self-stress that improves load capacity and deformation control. Recent progress on magnesium-oxide expansive systems has clarified reaction kinetics, effective dosage windows, and durability considerations for structural concretes, which supports the deliberate use of chemical precompression in members that must stabilize early age behavior [1]. At the same time, research on FRP-confined RAC has advanced from feasibility to specimen-scale evidence, showing that properly selected shell stiffness and rupture strain can raise strength and stabilize postpeak deformation while improving consistency across replacement levels and casting routes [2]. What is still missing is a compact and transferable way to read and report results from different encasing systems on a common lateral-pressure scale that engineers can apply in early decision making. This paper addresses that gap by introducing a normalized index, CPI, that maps measurable inputs to an equivalent lateral pressure, along with a minimal reporting checklist and an uncertainty treatment suitable for short papers and for planning new tests. A small set of well documented cases serves as data anchors so that the method remains transparent, reproducible, and immediately useful.

MATERIALS AND METHODS

1.Reporting Protocol and Normalized Descriptors

This section sets a compact protocol that makes datasets comparable across tube materials, laminate schedules, and specimen sizes. Reports should state the tube system, the diameter D and thickness t, the hoop modulus E_θ or its derivation route, the measured input in the form of internal pressure, hoop strain, or core self-stress together with the age at reading, the recycled aggregate replacement level, the expansive system and dosage, and the exact conversion and units. The Chemically Precompressed Index is defined so that a single dimensionless quantity captures the intensity of precompression independent of geometry and stiffness, and it reads:

$$CPI \equiv \frac{p_0}{E_\theta t/D} \quad [2] \quad \text{Eq. (1).}$$

Where p_0 is the notional lateral pressure that represents the effect of chemical expansion under restraint. For circular fibre reinforced polymer shells the thin walled cylinder relation links the measured initial hoop strain to the same pressure scale as:

$$p_0 = \frac{2E_\theta t \varepsilon_{\theta,ini}}{D} \quad [1] \quad \text{Eq. (2).}$$

And combining these expressions gives a strain based normalisation that is convenient for quick reconstruction and cross study checks:

$$CPI = 2\varepsilon_{\theta,ini} \quad [3] \quad \text{Eq. (3).}$$

The normalisation removes geometry and stiffness at first order, so CPI can be compared across thin walled steel tubes and composite shells as long as the input variable is traceable. In practice it is recommended to report both the raw input and the derived pair (p_0, CPI) together with the conversion used, which keeps the path from measurement to estimate auditable and allows later model updates without new testing.

2. Minimal Mechanics with Uncertainty Bands

The mechanics needed to place early chemical action on a comparable pressure scale are intentionally simple and rest on a thin walled cylinder view of the jacket. For a circular shell carrying hoop tension, the notional lateral pressure corresponding to a measured circumferential strain follows:

$$p_0 \approx \frac{E_\theta t}{r} \varepsilon_\theta \quad \text{Eq. (4).}$$

Where E_θ is the hoop modulus of the encasing tube, t is wall thickness, r is the mid-surface radius, and ε_θ is the circumferential strain at the readout of interest. When the input is the initial hoop strain of an FRP shell, the index defined in Section 2 is obtained directly as:

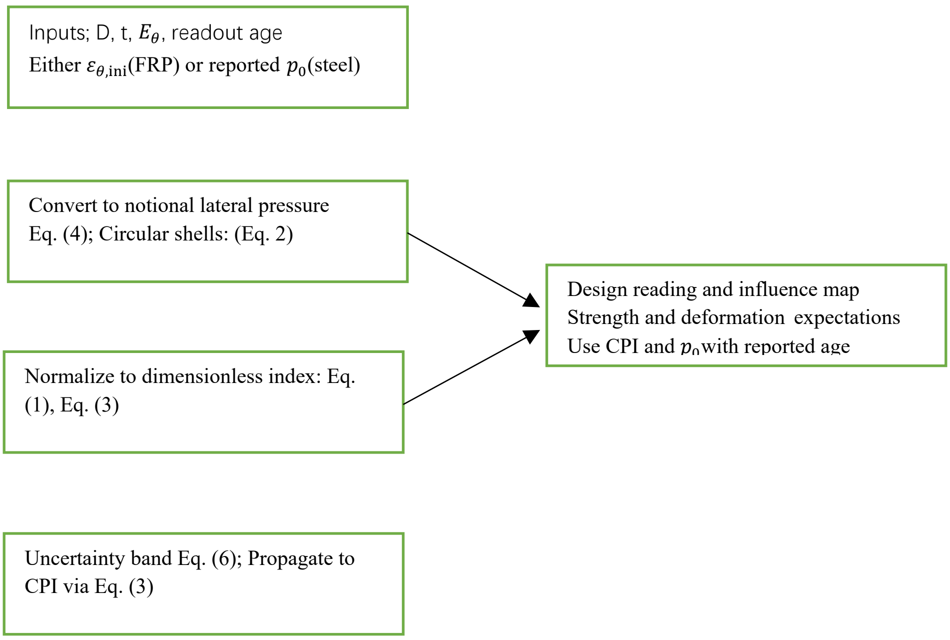
$$CPI = \frac{p_0}{E_\theta t/D} = 2\varepsilon_{\theta,ini} \quad \text{Eq. (5).}$$

So that a single strain measurement provides a geometry free descriptor. This linear mapping is adequate for the low strain window used to characterise chemical precompression before significant dilation of the core, and it mirrors the analysis oriented treatments that translate jacket stiffness into an equivalent pressure scale for confinement models [4]. Applicability requires a thin wall so that membrane action governs, a circular planform or an equivalent diameter defined from perimeter for mildly noncircular cases, and a consistent choice of E_θ. For laminated FRP tubes, E_θ should follow classical laminate theory using the fibre angle with respect to the hoop direction or be taken from coupon tests in the circumferential direction when a unidirectional wrap is used. Small deviations of the fibre angle from the hoop direction reduce the effective hoop modulus and can be treated as a source of model uncertainty, which justifies reporting both the nominal angle and a tolerance range for E_θ [5].

Uncertainty bands follow from first order propagation applied to equation (4). With $p_0 = 2E_\theta t\ \varepsilon_\theta / D$ and independent errors, the relative uncertainty reads:

$$\frac{\delta p_0}{p_0} \approx \sqrt{\left(\frac{\delta E_\theta}{E_\theta}\right)^2 + \left(\frac{\delta t}{t}\right)^2 + \left(\frac{\delta \varepsilon_\theta}{\varepsilon_\theta}\right)^2 + \left(\frac{\delta D}{D}\right)^2} \quad \text{Eq. (6) [6,7].}$$

Which converts directly into a band for CPI through equation (5). In practice, δE_θ reflects fibre-angle tolerance and laminate variability, δt captures ply count and resin content scatter, $\delta \varepsilon_\theta$ combines gauge resolution with early age relaxation during the readout window, and δD is usually small but nonzero when liners or wraps change the effective diameter. When reported alongside the readout age, these components produce a transparent interval that can be propagated into any strength or deformability estimate that uses p_0 as an input. Probabilistic views of model error for FRP confinement further support this interval approach, since database calibrations show nontrivial distributional spreads for both strength and ultimate strain enhancement ratios, typically well fitted by Gumbel or Lognormal laws [1]. Figure 1 in the full paper summarises the flow from inputs to p_0, to CPI, and then to the target response so that uncertainty components remain visible at each stage.



Note. p_0, normalization to CPI using Eqs. (1)–(3), and propagation of measurement and model scatter to an uncertainty band using Eq. (6) [1,2,3,6,7].

Figure 1. Workflow from measurement input to conceptual side pressure

RESULTS

3. Data-Anchored Conversions and Design Reading

Each dataset is first converted to the notional lateral pressure p_0 using the thin wall relation and then normalized to CPI using Eqs. (1) to (3). Concrete filled steel tubes that report core self stress provide a repeatable anchor near 5 MPa on the pressure axis, which sets the upper practical magnitude of chemical precompression observed in early age tests. Fibre reinforced polymer shells use the initial hoop strain in Eq. (2) to obtain p_0 and Eq. (1) to obtain CPI, which places realistic laminate schedules in a working window of about 0.9 to 3.3 MPa. Design reading reduces to a single placement on this common axis: locate a specimen by its CPI, compare it with the thin wall recycled aggregate baseline, and check whether the target recovery margin is met. The uncertainty from Eq. (6) should be carried as a band, since readout age, relaxation within the window, fibre angle tolerance, and ply thickness scatter can shift the point. Figure 1 shows the workflow from input to p_0, to CPI, and then to design reading.

Table 1. Minimal data anchors and worked conversions to p_0 and CPI

System	D (mm)	t (mm)	E_θ (MPa)	Measured input	Value	Conversion	p_0 (MPa)	CPI (dimensionless)	Note
CFST anchor	—	—	—	core self stress	5.00	direct p_0 from test	5.00	not reported	Early age self stress anchor on pressure axis
CFRP jacket example	150	1.00	165000	initial hoop strain $\varepsilon_{\theta,\mathrm{ini}}$	0.00150	Eq. (2)	3.30	0.00300	Realistic two ply carbon wrap
GFRP jacket example	200	1.00	40000	initial hoop strain $\varepsilon_{\theta,\mathrm{ini}}$	0.00225	Eq. (2)	0.90	0.00450	Glass wrap with lower hoop modulus

Notes: Row 2 maps its geometry, modulus, and initial hoop strain to a notional lateral pressure of 3.30 MPa with a CPI of 0.00300. Row 3, processed the same way, yields 0.90 MPa and a CPI of 0.00450.

CONCLUSION

This paper turns early chemical action in tube-encased recycled aggregate concrete into a usable design quantity. By defining the Chemically Precompressed Index and pairing it with a compact reporting note, measurable inputs such as initial hoop strain or directly reported core self-stress are mapped to a notional lateral pressure through a thin walled cylinder relation and then normalized for geometry and stiffness. The framework is anchored by two practical magnitudes, about five megapascals for concrete filled steel tubes and about zero point nine to three point four megapascals for fibre reinforced polymer shells, which allows quick placement of any new specimen on a common axis and a direct reading of the expected recovery relative to a thin wall recycled aggregate baseline. Uncertainty is treated explicitly with a first order propagation so that age at reading, relaxation, fibre angle tolerance, and ply thickness scatter remain visible in the final estimate. The combined result is a transparent path from measurement to pressure, to CPI, and then to design reading that supports early selection of tube system and laminate schedule without case specific curve fitting.

REFERENCES

[1] Lin G., Teng J. G. Advanced stress–strain model for FRP-confined concrete in square columns // Composites Part B: Engineering. 2020. Vol. 197. Article 108149.

[2] Li Z., Feng P., Yang J. Q. Analysis-oriented model for FRP tube-confined concrete: 3D interpretation of biaxial tube behaviour // Engineering Structures. 2022. Vol. 272. Article 114987.

[3] Wu M., Fan X., Qian H. Research on stress–strain model of FRP-confined concrete based on compressive fracture energy // Buildings. 2025. Vol. 15, No. 15. Article 2716.

[4] Keshtegar B., Gholampour A., Ozbakkaloglu T., et al. Reliability analysis of FRP-confined concrete at ultimate using conjugate search direction method // Polymers. 2020. Vol. 12, No. 3. Article 707.

[5] Banaeipour A., Tavakkolizadeh M., Akbar M., et al. Effects of small deviations in fiber orientation on compressive characteristics of plain concrete cylinders confined with FRP laminates // Materials. 2022. Vol. 16, No. 1. Article 261

[6] JCGM 100:2008. Evaluation of measurement data — Guide to the expression of uncertainty in measurement (GUM). Joint Committee for Guides in Metrology, 2008.

[7] Taylor J. R. An Introduction to Error Analysis. 2nd ed. Sausalito: University Science Books, 1997.