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Review Article

Conventionally Reinforced and Post Tensioned Concrete Transfer Beams a Critical Review and Illustrative Decision Framework

Dhammakar Dhammanand Chandrakant[1], Arjun R. Vasatkar[2]

[1,2]*School of Engineering, Ajeenkya D Y Patil University, Lohegaon, Pune, India.*

[1]*Corresponding Author: dhammanand.dhammakar@adypu.edu.in*

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Abstract *- In high-rise buildings, transfer levels are responsible for gravity effects and ensuring structure stiffness and construction connections. The choice of transfer beams between conventional Reinforced Concrete (RCC) and Post-Tensioned (PT) systems needs structural verification and cost, time, environmental and procurement analysis. The purpose of this comprehensive and critical review is to present a summary of fifty research studies related to transfer structures and provide references for theoretical and experimental research on prestressed elements, slabs, frames and performance assessment. The contribution of our work is a distinct separation of published results, assumed scenario inputs and project specific validation requirements. An example considers volumes of 520 m3 and 330 m3 and passive reinforcement quantities of 120 t and 55 t for RCC and PT, respectively. The assumed quantities imply reductions of 36.5% and 54.2% and not equal capacity of structure. Recalculated costs of direct inputs are 187.20 lakh and 168.80 lakh. Initial costs including assumed time preliminaries are 210.70 lakh and 186.30 lakh. The assumptions for sequential activities sum up to 47 and 35 days. In an illustration of discounted cash flow, projections indicate that at 6% discount, the value would be 246.60 lakhs and 200.90 lakhs, respectively, 50 years into the future. It is because of the absence of actual PT inventory and confirmed emission factors, that CO 2 is expressed in an emissions break-even state. The risk levels, along with the weights of decisions taken, are made clear. What about the apprehensions of the specialists regarding price and delay, before the initial-cost advantage evaporates? The system provides clear option filtering, though it in no way claims structural feasibility or universal superiority of the PT method.*

Keywords *- Embodied carbon, Post-Tensioned beams, Reinforced concrete beams, Transfer beams, Whole-Life costs.*

1. Introduction

Transfer beams and girders change concentrated gravity forces at those places where vertical components, such as tower columns or walls, cannot go through the podium, parking, or retail floors. The choice of transfer beams considers shear, flexural forces, anchorage design, functionality, durability, and interaction with the resistance to lateral loads. With fixed floor-to-floor heights, the use of deeper beams leads to lower clear room; a solution with shallower beams will give higher clear headroom.

A large amount of passive reinforcement in a concrete piece will complicate concrete casting and inspection operations. Post-tensioning reduces tensile stresses and allows partially balancing gravity loads but brings additional principles of tendon layout, anchorage, tensioning, grouting, and procurement. Transfer-girder design research [1], RCC/PSC comparison [2] and slab studies [3, 4] address different parts of this decision and must be distinguished by structural scale.

Monitoring studies provide evidence on prestress, strain, crack development and time-dependent response [6-8]. Beyond the volume of materials, the cost and carbon research is performed for PT slabs and floor plates [9-11]. The following studies corroborate the selection of the assessment criteria: the quantity of slabs and the reduction of the response are not directly transferable to a deep transfer girder under concentrated loads in the columns.

Member and building optimization studies involve an economic or environmental goal in addition to structural constraints, with the goal of optimizing the structure [12-15]. Other elements of the life-cycle research are deterioration, intervention and uncertainty [16-19]. These can only be used in a transfer-beam decision once the load path, construction phases, losses of prestress, and serviceability requirements have been determined. A decrease in one of the inventory quantities is therefore not a good argument for a reduced total impact or feasible design. The research gap is related to the linkages between the transfer-member mechanics and project

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delivery. Direct transfer-floor studies focus on discontinuities and seismic response, and much of the optimization research is focused on optimising slabs or whole frames. These models are not a direct indication of anchorage zone bursting, deep-member action, temporary support and/or availability of specialist at transfer levels. There are methods for supporting studies in optimization and floor carbon [20-30], but none provide a common validated RCC/PT transfer-beam benchmark with all design, cost, and schedule and maintenance records.

The question for the review is how to make the published structural evidence useful in making an auditable preliminary RCC/PT decision without simply stating the available numerical evidence. The contribution consists of a transfer-specific evidence classification, explicit evidence inventory and accounting boundary, and proposed framework. The numerical example is kept as a case example and re-calculated at every step. It's not an experimental or new finite-element simulation, optimization or feasibility study of a structure. All fifty bibliographic records and all relevant boundaries are listed in Appendix A.

2. Review Methodology

2.1. Review Design and Evidence Boundary

The article is a critical narrative review, accompanied with illustrative decision framework. A bibliography (provided with the manuscript) contains 50 records. The following data are not available in the original database exports: Search history (date), Duplicates, Screening decisions, and Full-text extraction sheets. Thus, a repeatable systematic search and/or a selection that conforms with the PRISMA checklist is not claimed. The bibliography is not comprehensive or unbiased in its coverage of transfer-beam research nor a complete inventory of all transfer beams.

The results published are distinguished from the inputs assumed in the scenarios. The latter consist of amounts, rates, duration of activity, allowances for maintenance and judgment-based risk score. These inputs are not accompanied by any bill of quantities that has been surveyed, a contractor's quotation, a measured construction programme or a structural model that complies with the code. Any field observations, software outputs, expert-panel judgments or search records that are approved for by the author are inferred. Capacity, loading, serviceability and building construction phase safety must be determined in detail prior to the use of economic rankings.

2.2. Source Collection and Evidence Classification

The collection of sources includes references [1-50], and thus covers the period from 2014 to 2026. Publications on transfer girders and transfer floor provide direct typological data. Papers on beams and monitoring studies provide evidence at the component level. In order for us to point to the indirectly evident approaches, we have to mention the works concerned with slabs, frames, outriggers, as well as the approvals and practical solutions in the field of carbon materials. The titles, DOIs, scope and limits of application of the publications have been listed in Appendix A.

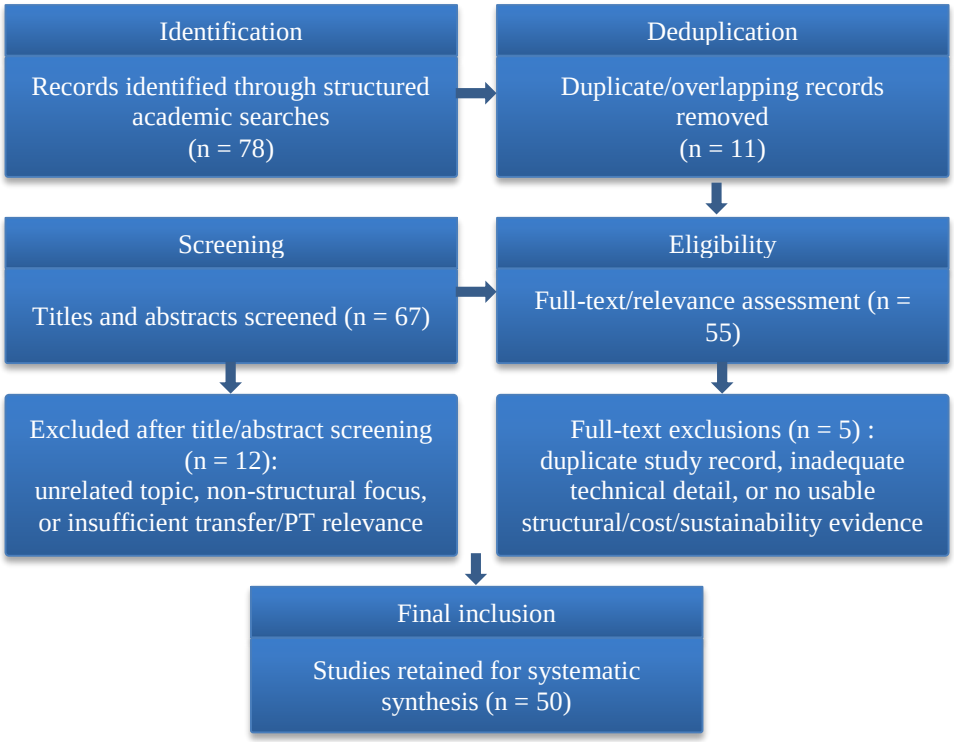


Fig. 1 PRISMA-based literature identification, screening, eligibility, and final inclusion process

The bibliographic referencing in the revisions, including the search of the sources according to the database of the publisher of the publications, has been carried out based on the data available for the DOI registration, which differs from bibliographic referencing based on the texts. The original dates, databases and search strings that the collection was created with are not recoverable from the provided files.

A search for a systematic extension could use: For a future systematic extension, a suitable search is ("transfer beam" OR "transfer girder" OR "transfer floor") AND ("reinforced concrete" OR "reinforced concrete construction" OR "post-tension*" OR "prestress*"). A separate search method can include cost, embodied carbon, construction sequence and optimization.

This extension should take the time to search Scopus, Web of Science and Engineering Village, to keep track of the actual dates of inclusion, to export the papers, to remove duplications (by DOI and paper title), and to keep track of all inclusion decisions. These are suggested procedures and are not descriptions of a search already undertaken.

2.3. Comparative Synthesis Framework and Review-Case Inputs

The assumptions that are inherited from the manuscript are recorded in Table 1. The span descriptor of 24–30 m and M50 grade are not representative of a member geometry or provide equivalent structural performance. The concrete volume amounts to 520 m³ and 330 m³, respectively, and the amount of the passive reinforcement are 120 t and 55 t, respectively. The PT entry of 25 equivalent units is only maintained as a commercial pricing quantity with INR 210,000/eu. Not an independently measured strand or anchorage mass, and should not be included in a carbon inventory as 25 physical tonnes. This line is only applicable to the PT supply package, and the INR 10 lakh specialist allowance is applicable to site installation, stressing, grouting and specialist supervision. This division cannot be confirmed by the package quotation. If quoted supply rate already has these services, then the specialist line should be stripped or disaggregated to ensure that the services are not counted twice. Rates are not meant to be precise and do not have an exact quotation date, tax basis or escalation basis and are just illustrative INR values.

Table 1. Scenario inputs for the RCC/PT accounting illustration

Parameter	RCC/Rebar	Prestressed/PT	Evidence boundary
Span descriptor	24–30 m	24–30 m	Assumed transfer-zone descriptor; geometry unverified
Concrete grade	M50	M50	Assumed common grade; no design checks
Concrete volume	520 m³	330 m³	Assumed quantity; no measured bill
Passive reinforcement	120 t	55 t	Assumed mass; no detailing schedule
PT supply pricing quantity	0	25 equivalent units	Commercial allowance; not physical tonnes
Sequential duration	47 d	35 d	Assumed non-overlapping activities
Concrete rate	INR 8,500/m³	INR 8,500/m³	Illustrative; quotation date unavailable
Passive-steel rate	INR 75,000/t	INR 75,000/t	Illustrative; quotation date unavailable
PT supply rate	—	INR 210,000/unit	Supply-only scenario boundary

2.4. Review Synthesis Equations and Decision Criteria

Direct cost excludes time preliminaries and is defined consistently with Table 3:

$$C_{dir}(x) = \sum_{i=1}^{n} q_i(x) \times u_i + C_{fw}(x) + C_{leq}(x) + C_{sp}(x) \quad (1)$$

In this case, x refers to the option available, the letter i represents n different priced materials, q_i is the quantity to be purchased in commercial terms, and u_i refers to the price per unit. C_fw, C_leq and C_sp are the costs of formwork/staging, labour/equipment/general quality control, and specialist services, respectively. The different components mentioned use same units of monetary value. Cost is measured as follows: $C_0(x)$ = C_dir(x) + pT(x), where p = INR 0.50 lakh/day. In this way, the whole-life cost is the sum of initial cost and future cash flows.

$$WLC = C_0 + \sum_{t=1}^{N} \frac{M_t + J_t}{(1+r)^t} - \frac{V_N}{(1+r)^N} \quad (2)$$

Here, N is defined as the assessment time in years; r is referred to as the real yearly discount rate; M_t is denoted as the maintenance cost at the year-end; J_t is known as the intervention cost at t year, and V_N is described as the positive value left after year N. The base case is where the sample has been used with N = 50 and r = 0.06. The cash flow in this equation is expressed in real constant prices; therefore, inflation has not been counted again. The schedule is a sum, but only because these activities form a non-overlapping sequence of events.

$$T = \sum_{a=1}^{m} d_a \quad (3)$$

a indicates the relevant activities on the hypothetical path, and "d_a" represents how long in days. A real program includes precedence relationships, simultaneous processing, and limitations on resource availability. As an example of ordinal risk:

$$R_h = L_h \times I_h \quad (4)$$

h identifies a hazard, L_h is an ordinal likelihood score, and I_h is an ordinal impact score, each from 1 to 5. Their product consists of the screening index, but not the failure probability or expected monetary loss. The weighted decision score is defined as follows:

$$S(x) = \sum_{j=1}^{K} w_j \times s_j(x); \sum_{j=1}^{K} w_j = 1 \qquad (5)$$

j indexes K criteria, s_j is a consistently oriented score with larger values preferred, and w_j is a non-negative normalized weight. Scores require a stated normalization, and weights require a stated preference basis. A proposed multi-objective design framework is:

$$min\, F(x) = [\, C_0(x), T(x), E(x), R(x) \,] \qquad (6)$$

Equation (6) is a proposed framework and has not been solved in this article. The decision vector x may contain beam geometry, concrete grade, passive reinforcement, tendon area/eccentricity and construction variables. C_0 is initial cost, T is duration, E is a defined carbon inventory, and R is a project risk measure.

Feasible solutions fulfill the requirements $g_k(x) \leq 0$ as well as $x_L \leq x \leq x_U$, where the explicit conditions include strength, shear, anchorage, prestress-loss, deflection, cracking, staged-construction, and procurement checks. In order to apply the NSGA-II, NSGA-III, PSO, Bayesian optimization, or any surrogate, the effective response model needs to be defined beforehand.

3. Related Work

3.1. Transfer Structures, Prestressing, and Seismic Response

Direct transfer-girder research [1] concerns preliminary PT member design. RCC/PSC comparison [2] provides member-system evidence, whereas [31] concerns outrigger systems and is used only for global lateral-system context. Studies of irregularity, higher modes and transfer floors [32-37] explain why local member selection must remain compatible with global stiffness and force transfer.

The linear and nonlinear transfer-floor analyses [35] must not all be viewed in the same way. None of the papers provided supporting information for the assumptions from Table 1. The slab [3, 4] output and regular beam optimization [5] involve different load types and detailing.

Direct transfer-floor evidence explains the physical boundary. Abdlebasset et al. [35] study elastic response-spectrum and nonlinear time-history techniques, testing stiffness assumptions, displacements, and internal forces.

In their survey [36], they indicate vulnerabilities that come with sudden changes of stiffness at the transfer level. Elawady et al. [37] compare transfer slabs and girders at different elevations and report damage localization near transfer and first-floor regions. Girder models can reduce seismic weight while being more flexible than slab models. These findings support system-level modelling and elevation sensitivity, but do not establish that the PT scenario in Table 1 has equal or better seismic performance than RCC.

3.2. Material Efficiency, Cost, and Embodied Carbon

Cost-carbon optimization of structural members [12], early-stage strategy reviews [15] and life-cycle research [16-19] support explicit inventory boundaries. Bayesian optimization of a PT bridge girder [38] demonstrates constrained economic-environmental design, but its bridge geometry and loading differ from a building transfer girder.

Slab selection [39] provides a decision-method example. Building-envelope retrofit optimization [40] is indirect methodological context and provides no transfer-beam structural evidence.

Composite-frame environmental optimization [41] and seismic outrigger optimization [42] likewise illustrate methods at different structural scales. RC frame and beam optimization [43, 44] reinforce the need for strength and serviceability constraints.

3.3. Multi-Objective Optimization and Digital Decision Support

The optimization review [45] suggests different strategies for managing the dimensions and conflicting goals. PT fibre-optic monitoring [46, 47] provides a route to measured prestress and strain evidence rather than assumed performance.

Slab optimization [48], material carbon comparison [49] and tall-building wind-layout optimization [50] address supporting design and inventory questions. Their methods can inform a future transfer-beam workflow, but no accuracy, savings or optimality claim for that future workflow is established here.

3.4. Whole-Life, Procurement, Constructability, and Risk

Transfer-level construction makes temporary support, reinforcement access, pour sequencing, concrete strength at stressing and corrosion protection consequential to delivery. A specific design may imply a lesser material demand, but it may also not be compatible if there is an absence of machinery, skilled personnel or the ability to conduct inspections.

Methods of life cycle [16-19, 29, 30] point out the necessity to consider the intervention and uncertainty. The present framework connects these requirements to transfer-specific tasks; it does not claim that this combination has been experimentally validated or that it outperforms existing optimization techniques.

Table 2. Selected studies and limits of transfer-beam applicability

Sr. No.	Author(s) and Year	Method Used	Results	Applicability and limitation
1	Uzel (2020)	Preliminary PT transfer-girder design	Transfer girder-specific design framework	Direct transfer-girder context; not validation of the assumed scenario.
2	Chaturvedi (2025)	RCC vs PSC analytical comparison	RCC/PSC response comparison	Indirect evidence; different structural scale or loading; transfer-beam validation required.
3	Dhamija et al. (2024)	ETABS RCC/PT slab comparison	Lower bending moments, shear forces and drift reported for PT case	Indirect evidence; different structural scale or loading; transfer-beam validation required.
4	Abdelaziz and Abdalla (2021)	ETABS/SAFE/REVIT /Primavera cost-time study	Integrated cost, time and structural comparison	Indirect evidence; different structural scale or loading; transfer-beam validation required.
5	Hernandez-Martinez et al. (2026)	SAP2000 API + Python + PSO	Material-consumption optimization	Indirect evidence; different structural scale or loading; transfer-beam validation required.
6	Fernandez et al. (2025)	Experimental DOFS monitoring	Prestress introduction, long-term response and failure monitored	Monitoring method; does not establish comparative cost or schedule savings.
7	Piątek et al. (2023)	Distributed fibre-optic diagnostics	Strain, crack, stress and shape diagnostics	Monitoring method; does not establish comparative cost or schedule savings.
8	Li et al. (2022)	Neutral-axis identification for prestress	Prestress force quantified from measured strain response	Monitoring method; does not establish comparative cost or schedule savings.
9	Faridmehr et al. (2021)	Hybrid Firefly–ANN	Cost and embodied-carbon prediction for PT slabs	Indirect evidence; different structural scale or loading; transfer-beam validation required.
10	Broyles and Hopper (2023)	Embodied-carbon assessment	PT voided plates assessed as low-carbon floor solution	Indirect evidence; different structural scale or loading; transfer-beam validation required.
11	Zhang and Zhang (2021)	Multi-objective genetic algorithm	Cost and embodied-emission objectives	Indirect evidence; different structural scale or loading; transfer-beam validation required.
12	Tanhadoust et al. (2023)	Two-stage NSGA-III	Cost and water-footprint optimization of RC buildings	Indirect evidence; different structural scale or loading; transfer-beam validation required.
13	Fang et al. (2023)	Review of early-stage strategies	Network of embodied-carbon design strategies	Indirect evidence; different structural scale or loading; transfer-beam validation required.
14	Malami et al. (2024)	Probabilistic LCCA + LCA	Costs and CO_2 considered over RC service life	Indirect evidence; different structural scale or loading; transfer-beam validation required.
15	Ruiz-Vélez et al. (2024)	NSGA-II/III/RVEA + MCDM	Multi-algorithm sustainability comparison	Indirect evidence; different structural scale or loading; transfer-beam validation required.

16	Bojórquez et al. (2024)	Genetic algorithm seismic optimization	Failure probability embedded in optimal design	Indirect evidence; different structural scale or loading; transfer-beam validation required.
17	Gindy et al. (2025)	FE topology optimization + deep learning	Mass minimization under strength/serviceability constraints	Indirect evidence; different structural scale or loading; transfer-beam validation required.
18	Haryanto et al. (2025)	FE seismic strengthening study	Prestressed T-beam response with NSM-CFRP	Indirect evidence; different structural scale or loading; transfer-beam validation required.
19	Paknahad et al. (2025)	Nonlinear FE RC floor comparison	Embodied carbon and cost optimized across slab systems	Indirect evidence; different structural scale or loading; transfer-beam validation required.
20	Alanani et al. (2024)	ETABS + ANN + NSGA-II	Multiobjective tall-building layout study	Indirect evidence; different structural scale or loading; transfer-beam validation required.
21	Abdlebasset et al. (2016) [35]	3D response-spectrum and nonlinear time-history analysis	Examines drift, internal forces and stiffness assumptions around transfer levels	Direct transfer-floor evidence; not an RCC/PT equal-capacity cost comparison.
22	Abdlebasset et al. (2016) [36]	Review of transfer-floor seismic behaviour	Identifies stiffness discontinuity and damage near transfer levels	Review evidence; no common PT/RCC numerical benchmark.
23	Elawady et al. (2014) [37]	3D linear and nonlinear comparison of transfer slabs and girders	Transfer-level position affects response; girder models reduce seismic weight with greater flexibility	Compares transfer typologies; does not isolate post-tensioning effect.

Table 2 separates study methods and reported subject matter from transferability. Transfer-girder studies are capable of providing member design information, while transfer floor studies can be used to evaluate global response. Slab studies and frame analyses provide indirect evidence of methodology. Both the numerical series presented for span, load case, or structural system do not allow for comparison similar to controlled trials. Since no pooled effect size can be calculated, any comparisons made focus on what has been corroborated and what additional corroborations remain necessary.4. Review-Derived Research Gaps

The principal gap is a shared, independently reproducible RCC/PT transfer-beam comparison that combines code-compliant equal-performance designs with documented quantities, construction logic, current rates and life-cycle assumptions. Research on transfer floors [35-37] indicates the significance of the discontinuity response, whereas the transfer girders' design concept [1] deals with the requirements of specific elements. Studies on the optimization of support and carbon content [12-15, 38, 41] provide few generic methodologies instead of necessary reference benchmarks. Other relevant gaps are related to transparency of PT material bounds, maintenance and corrosion frameworks, specific procurement evidence, and preferences identification. This article organizes these requirements and demonstrates their accounting consequences; it does not claim to close the empirical or structural-validation gaps.

5. Review Findings and Comparative Synthesis

5.1. Material Demand and Structural-System Implications

Figure 2 plots assumed scenario quantities separately by physical unit. Concrete decreases from 520 to 330 m³, a difference of 190 m³ or 36.54%. The use of passive reinforcement diminishes from 120 to 55, amounting to a divergence of 65 and a percentage change of 54.17.

Since the PT commercial allowance has no equivalent price unit, it is eliminated from the physical mass chart. These reductions are sources of input comparison rather than results of equal capacity design.

Possible contributors, mentioned in literature, are less congested and less intense service demand, but their extent needs analysis of tendon, anchorage, shear, loss and serviceability.

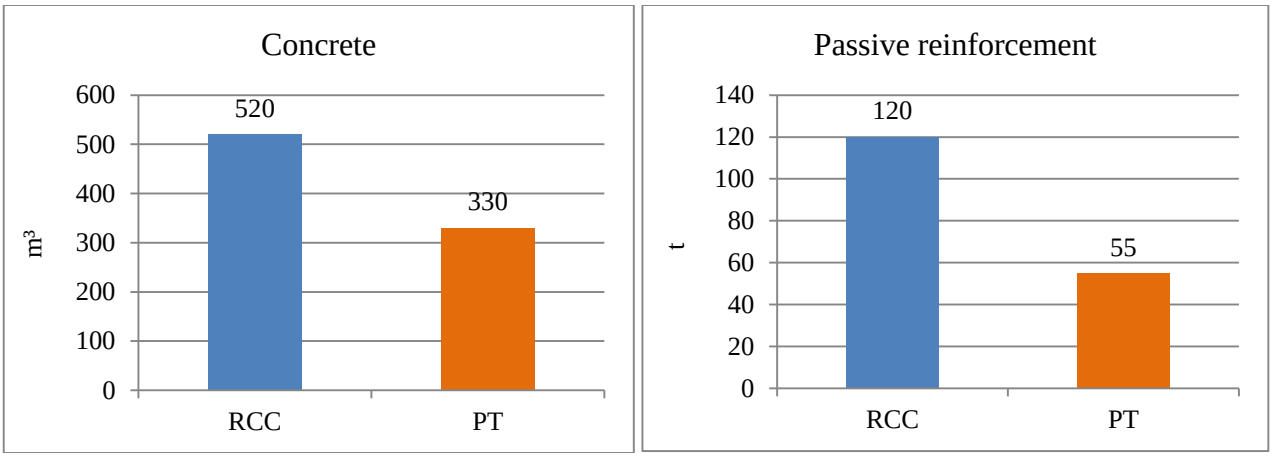


Fig. 2 Review-case material quantities used in the RCC/PT comparative synthesis

Table 3. Review-case direct-cost synthesis for RCC and PT alternatives (INR lakh)

Cost component	RCC/Rebar	Prestressed/PT	PT minus RCC
Concrete	44.20	28.05	−16.15
Passive reinforcement	90.00	41.25	−48.75
PT supply package	0.00	52.50	+52.50
Formwork/staging	33.00	22.00	−11.00
Labour/equipment/general QC	20.00	15.00	−5.00
Specialist site services	0.00	10.00	+10.00
Direct cost subtotal	187.20	168.80	−18.40
Time preliminaries	23.50	17.50	−6.00
Initial cost	210.70	186.30	−24.40

Table 3 is calculated without rounding intermediate products. RCC concrete and rebar cost 520 × 8,500/100,000 = INR 44.20 lakh and 120 × 75,000/100,000 = INR 90.00 lakh. PT concrete and rebar cost INR 28.05 and 41.25 lakh. Its commercial supply package costs 25 × 210,000/100,000 = INR 52.50 lakh. The inclusion of the previously mentioned lump-sum allowances leads to direct costs of INR 187.20 and 168.80 lakh. The preliminaries expected to incur costs of INR 0.50 lakh/day will be INR 23.50 and 17.50 lakh. Thus, the total initial costs would be INR 210.70 and 186.30 lakh difference between which would therefore amount to INR 24.40 lakh or 11.58% of the total.

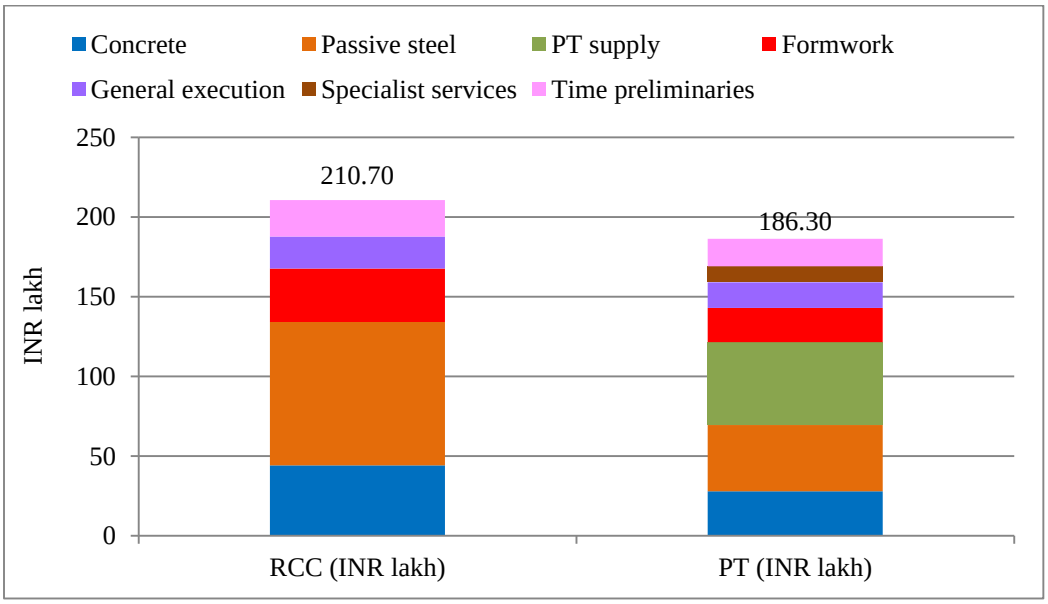


Fig. 3 Review-case direct-cost breakdown showing material, specialist, and time-related trade-offs

In Figure 3, we can see the distinction made between direct costs and time timing so that the commercial limits of the PT supply composition are retained. An assumption of less high price for materials of concrete, for passive steel, and for costs for temporary works and standard construction works covers the costs for material delivery, including payment for specialists and contractors. The supply rate will rise to INR 97,600 per unit before the initial cost becomes equal to the cost of the RCC: the break-even point is at INR 307,600 per unit.

Table 4. Review-case 50-year whole-life cost NPV synthesis (INR lakh; 6% real discount rate)

WLC component	RCC/Rebar	Prestressed/PT	PT minus RCC
Initial cost	210.70	186.30	−24.40
Annual maintenance PV	26.60	14.70	−11.90
Year-25 intervention PV	10.60	3.30	−7.30
Year-50 residual PV	−0.30	−0.40	−0.10
50-year WLC NPV	247.60	203.90	−43.70

Table 4 is essentially cash-flow reconstruction, and it is not a maintenance forecast. The annuity factor at 6 percent over a period of 50 years is 15.76186. Hence, it results in constant annuity, which corresponds to maintenance allowances of INR 1.68762 lakh/year for RCC and INR 0.93263 lakh/year for PT (i.e., 26.6/15.76186 and 14.7/15.76186, respectively). The single-year-25 intervention in terms of expenses is represented as 10.6(1.06) ^ 25, which is equal to INR 45.49 lakh for RCC, while it is represented as 3.3(1.06) ^ 25, namely INR 14.16 lakh for PT. The positive year-50 residual values can be calculated as 0.3(1.06) ^ 50, which comes to INR 5.53 lakh, and 0.4(1.06) ^ 50 that is equal to INR 7.37 lakh. These definitions refer to the concept of the inherited allowances on present values, while the timing and different profiles of maintenance should be taken as analytical assumptions and should not be confused with the results of condition assessments. In the recalculated values of the initial cost, the WLC will be INR 247.60 lakh and INR 203.90 lakh, which makes the conditional difference equal to INR 43.70 lakh or 17.65%.

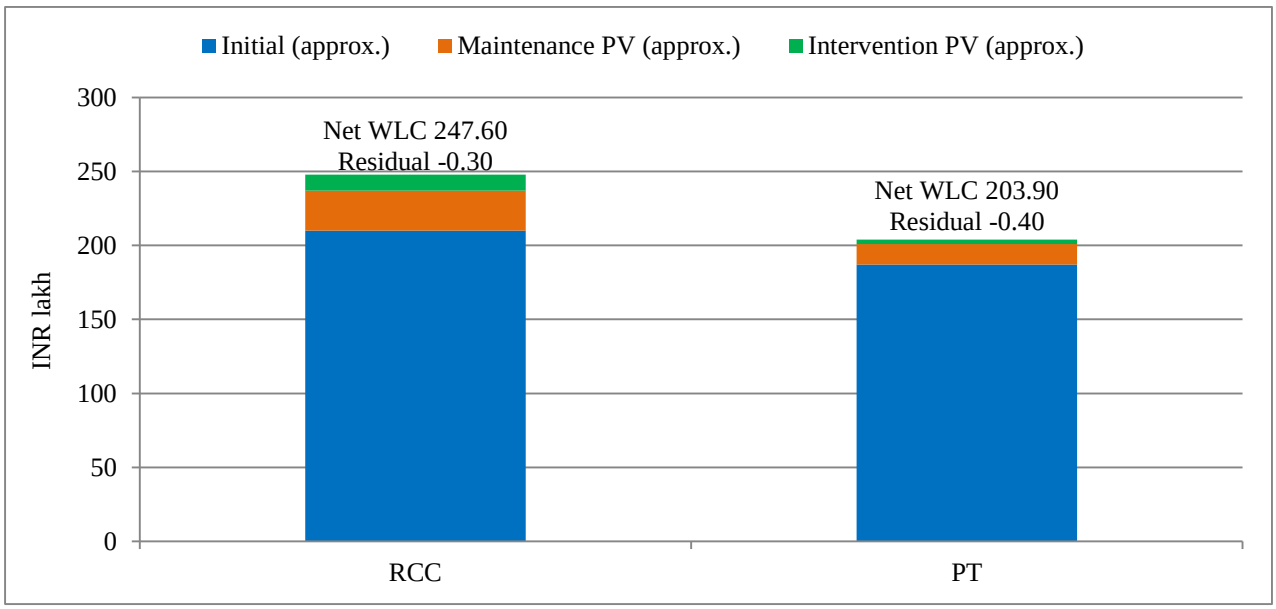


Fig. 4 Review-case fifty-year whole-life cost NPV comparison for RCC and PT alternatives

Figure 4 displays the reconstructed base cash flows. Lower PT maintenance is an imposed scenario assumption and cannot be attributed to demonstrated crack-control performance. The costs of PT intervention may increase as a result of tendon inspection, grouting faults, corrosion exposure, and access. In the event of beating both alternatives, resulting in identical future cash flows, the WLC will turn into an initial cost difference amounting to INR 24.40 lakh. An additional PT future-cost present value of INR 43.70 lakh would eliminate the base WLC advantage. In Table 9, the same actual cash-flow schedule is analyzed at various rates of discount, without the need to recalculate the annual values of the amounts for each year or that of the amount for year 25.

Table 5. Carbon inventory boundary and break-even sensitivity

Sensitivity case	e_c (tCO_2e/m^3)	e_s (tCO_2e/t)	Budget B (tCO_2e)
Hypothetical low	0.25	0.50	80.0
Hypothetical middle	0.35	1.00	131.5
Hypothetical high	0.50	2.00	225.0
Decision rule	Same concrete and steel factors for both	Full incremental PT inventory required	PT lower only if E_add < B

A numerical 0.74–0.88 carbon index cannot be reproduced without documented factors and a physical PT inventory, so it is not retained. Let us assume that e_c is the emissions that arise at the concrete stage in terms of tCO_2e/m^3 and e_s is the emissions at the steel stage in tCO_2e/t. Emission budgets created with concrete and reinforced steel thus results in a budget of B = 190e_c + 65e_s. Let E_add include actual strands, anchorages, ducts and grout plus the PT-minus-RCC difference in transport, site processes and temporary works. PT makes a lesser impact in terms of total impact within the defined boundary, only if E_add is lower than B. In Table 5 B is calculated from an explicitly theoretical mix of factors; these are inputs for sensitivity testing purposes, not actual EPDs or measured carbon figures. It is important to note that embodied carbon of the product stage is different from whole life carbon that also includes maintenance cost, replacement cost and end-of-life inventory. No whole life carbon reductions are claimed. According to Table 6, the period of time accounted for is 47 days for RCC and 35 days for PT, with total being 12 days or 25.53% of the total period of time.

These durations are just planning assumptions and do not include any productivity measurements and programme records. The sequences assume that no activities are performed at the same time. They do not justify concrete release or stressing at a particular age: those decisions depend on verified in-situ strength, engineer-approved temporary works and the stressing specification. Procurement and approval time are outside the base activity sequence and must be added where they affect the critical path.

Table 6. Review-case construction activities used for transfer-level schedule synthesis

Activity	Duration (days)	System
Staging/formwork	8	RCC/Rebar
Rebar fixing	14	RCC/Rebar
Embed/inspection	3	RCC/Rebar
Concrete pour	6	RCC/Rebar
Curing/back-propping	14	RCC/Rebar
QA/QC release	2	RCC/Rebar
Formwork/soffit	7	Prestressed/PT
Tendon profile	6	Prestressed/PT
Mild rebar fixing	8	Prestressed/PT
Concrete pour	2	Prestressed/PT
Early curing	7	Prestressed/PT
Stressing/grouting	4	Prestressed/PT
QA/QC release	1	Prestressed/PT

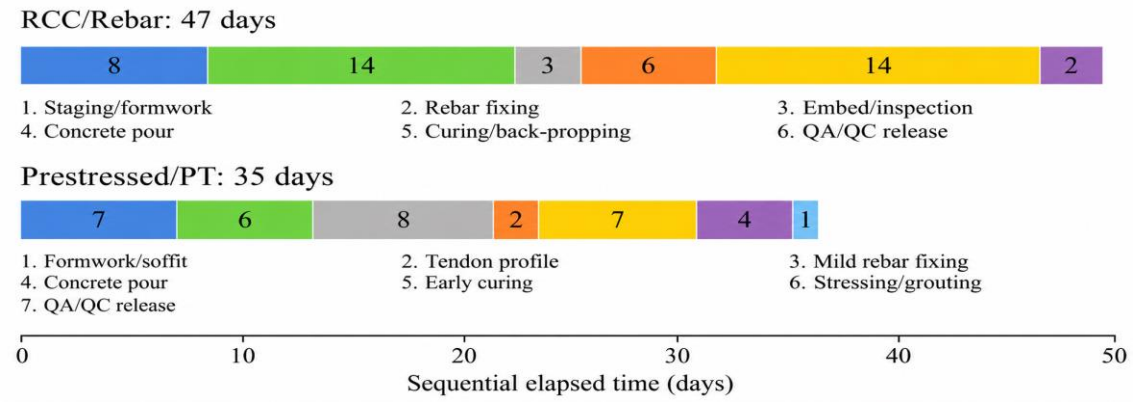


Fig. 5 Review-case construction-sequence comparison between RCC and PT transfer alternatives

Figure 5 shows the assumed sequential paths rather than tower-floor cycle savings. A 12-day PT delay makes the durations equal; with the same daily preliminaries and no other cost change, PT still retains its INR 18.40 lakh direct-cost advantage. A 48.8-day additional critical-path delay eliminates the INR 24.40 lakh initial-cost advantage at INR 0.50 lakh/day. The threshold assumes that there is no outside disruption or expenses regarding finance and subcontractors. In reality, the planning for the real applications includes scheduling deliveries of tendons, obtaining necessary approvals, calibrating equipment, determining the condition of concrete, and releasing back propping.

Table 7. Illustrative likelihood and impact products for risk screening

No.	Risk item	RCC L×I=R	PT L×I=R	Rating basis
1	Excessive depth	4×4=16	2×3=6	Illustrative assumption
2	Rebar congestion	4×5=20	3×3=9	Illustrative assumption
3	Crack/serviceability	4×4=16	2×3=6	Illustrative assumption
4	Mass-concrete thermal control	3×5=15	2×3=6	Illustrative assumption
5	Tendon profile/stressing error	N/A	3×5=15	Illustrative assumption
6	Specialist availability	1×2=2	4×4=16	Illustrative assumption
7	Long-term deflection/creep	4×4=16	3×3=9	Illustrative assumption
8	Column/wall interface coordination	3×5=15	3×4=12	Illustrative assumption
9	Special-material delay	2×3=6	3×4=12	Illustrative assumption
10	Grouting/corrosion protection	N/A	3×5=15	Illustrative assumption

The values shown in Table 7 indicate the chances of occurrence and severity of effects for each inherited product. Specifically, they are the hypothetical assumptions that were recreated for purposes of transparency and do not represent actual expert evaluation or already known risk figures. A numerical probability is not assigned. RCC congestion is illustrated by 4 × 5 = 20; PT specialist availability by 4 × 4 = 16. The tendon-specific hazards are reported as not applicable to the RCC instead of creating a false tendon risk. It is impossible to include the ordinal products into the total safety of the project or reason the score for technical risks.

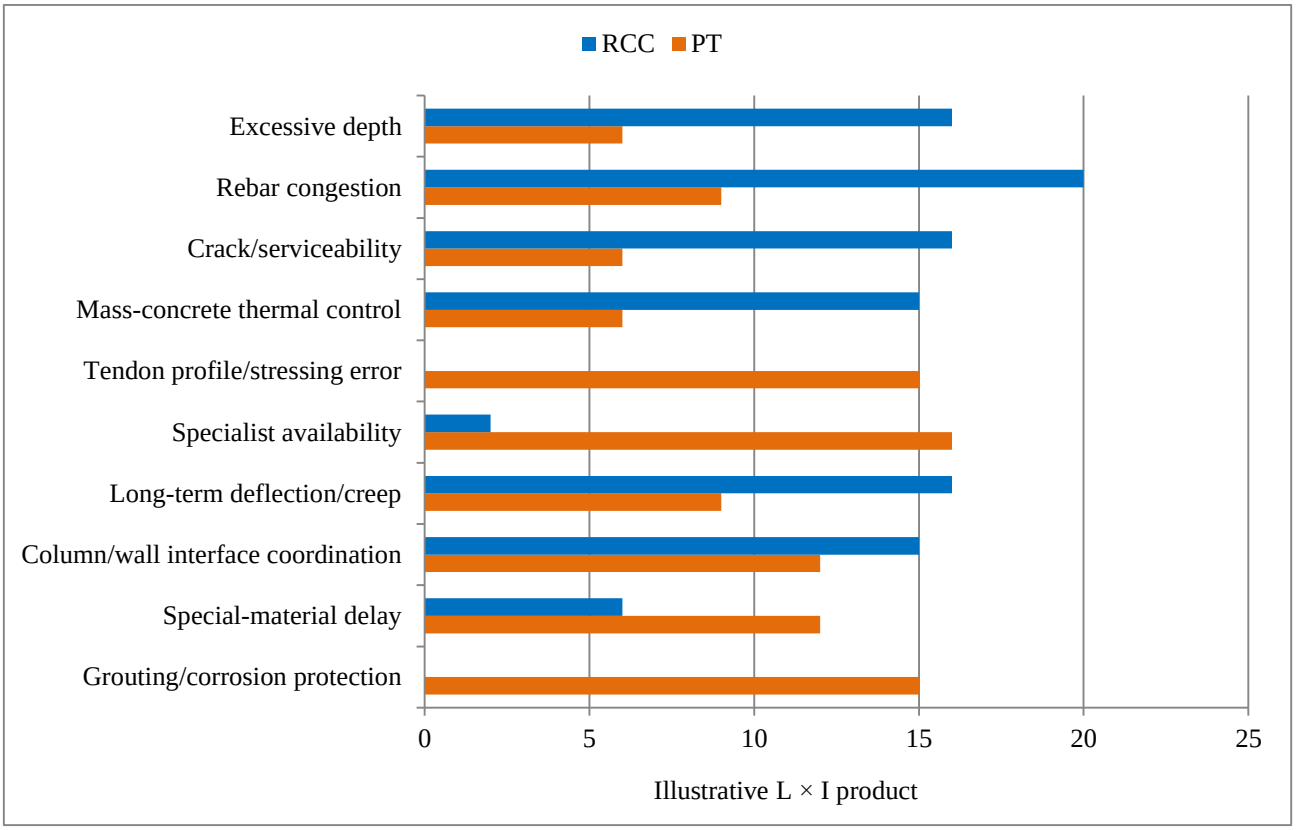


Fig. 6 Literature-Informed risk-priority comparison for major RCC and PT transfer-beam risks

In Figure 6, you can see the likelihood-impact products for illustrative purposes. The illustration describes exposure categories and excludes the irrelevant RCC tendon threats. Project assessment shall specify the owners of risk, assessment for likelihood, impact bands of time/cost/safety, controls that exist and risk ratings after mitigation. RCC controls include simultaneous bar detailing, pouring and thermal control strategies. PT controls can be independent tendon profile examination, calibrated stressing, elongation acceptance and documented grouting. No validated overall risk ranking between RCC and PT is established.

Table 8. Reproducible cost and schedule scoring illustration

Criterion	Weight (%)	RCC/Rebar score	Prestressed/PT score
Direct cost	50	4.5085	5.0000
Sequential duration	50	3.7234	5.0000
Weighted total	100	4.1160	5.0000
Risk/carbon/procurement	Separate gates	Not quantitatively ranked	Not quantitatively ranked

Only direct cost and schedule have numerical inputs suitable for a reproducible score in this scenario. For either criterion, s = 5v_min/v, where v is the alternative value and v_min the smaller value across the alternatives.

This ratio mapping gives the preferred alternative 5 and uses a larger-is-better scale. Weights are evenly distributed at 0.50 value and are representative of the preference, not the priorities derived from stakeholder input. Factors such as carbon, risk, and purchasing have been excluded from the aggregate result due to lack of necessary inventories, calibrated measurement scales, and preference evidence. Their exclusion does not mean that they are unimportant; they just represent independent decision points.

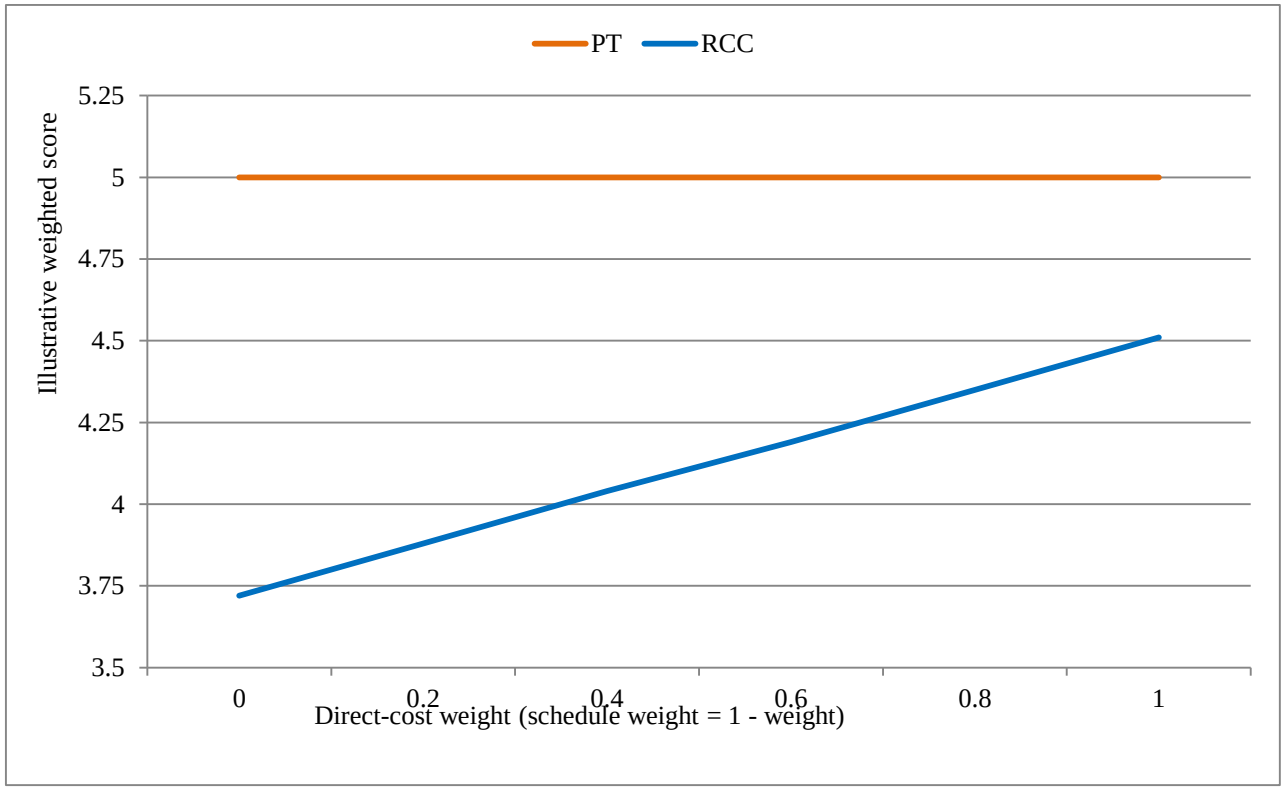


Fig. 7 Cost–Schedule score sensitivity to the direct-cost weight

RCC scored a direct-cost score of 4.5085, while PT acquired a total score of 5.0000. The schedule scores were 3.7234 and 5.0000, respectively. Overall scores equaled 4.1160 and 5.0000 with equal weights. When the direct-cost weight can vary from 0 to 1, RCC scores vary from 3.7234 to 4.5085, while PT scores 5, due to its overall superiority. It should be noted that this domination is valid with varying input quantities and pricing, low marks, and timing of inputs. No domination has been established in structural fitness, carbon and safety and procurement. The total price-delay boundary is $25\Delta u/100{,}000 + 0.50\Delta h = 24.40$ lakh.

Table 9. Sensitivity of the assumed cost and cash-flow scenario

Case	RCC (lakh)	PT (lakh)	Basis
WLC at 3%	274.59	215.38	Same real cash-flow amounts and timing
WLC at 6%	247.60	203.90	Same real cash-flow amounts and timing
WLC at 9%	234.40	198.07	Same real cash-flow amounts and timing
PT supply rate +25%	210.70	199.43	PT initial cost; all else fixed
PT delay +12 d	210.70	192.30	Equal durations; PT still lower cost
PT delay +48.8 d	210.70	210.70	Initial-cost break-even
Identical future cash flows	—	—	WLC margin equals 24.40 lakh initial margin

6. Critical Discussion and Review Implications

The scenario discussed demonstrates that it is possible to offset a professional package, in terms of available accounting models, through the desired reduction of passive materials. There are no wins compared to that of a conventional technique because a corresponding baseline structural design, optimization run and validation set were not available.

Beams and slabs studies [2-5] correspond to different geometries, loadings and structural functions, thus percentages indicated cannot be interpreted as benefits compared to the mentioned studies. The methodological contribution is traced accounting and clear evidence borders instead of any efficient algorithm or proven optimum realization. The execution at the transfer level can disrupt the tower schedule, but the lag of 12 days is a result of presumed sequential time periods. This cannot be generalized to repetitive cycles. In support of this assertion, monitoring studies [6-8, 46, 47] prove that it is better to check the installed prestress and strain response than to measure the execution level of design intent. There are different controls applied in RCC and PT works, and availability of specialists can lead to revoking the delivery decision even in case PT ballots with two criterions. The major constraints are the limited source collection of a bounded narrative, lack of historical search and full-text extraction records, lack of validation of quantities/rates of scenarios, and lack of equal structural performance designs. We don't guarantee that the original screening count can be verified, and it is not offered as completed research. The commercial PT quantity is too small to make it possible to perform a physical carbon inventory. Reconstructed future cash flows and illustrative risk assumptions are used to be transparent, rather than being calibrated. Such constraints do not allow for claims of structural feasibility, verified carbon savings or even general risk superiority. The framework should begin by defining the functional requirements of each project, and then finding alternatives that are both code compliant and match the project requirements. The quantities should be taken from auditable drawings and bills, rates from dated quotations with non-overlapping scope, schedules from a precedence-linked programme and carbon from exposure and inspection scenarios, and maintenance from exposure and inspection scenarios. Weights and scales for the decisions and risks should be established prior to considering alternatives. The uncertainty checks in Table 9 identify assumptions that may affect the results of the scenario and the additional information that would be required for a defensible selection.

7. Conclusion

This important and in-depth bibliographic review classifies 50 records relating to the selection of RCC/PT transfer-beams and separates direct evidence of transfer from supporting methods for the slab, frame and monitoring and optimization. Its contribution is a proposed framework which breaks down structural verification from prelim cost and schedule, carbon and risk assessment. In the assumed scenario Concrete and passive reinforcement are decreased by 36.54% and 54.17%, respectively, for PT, without establishing equal capacity. The initial cost was recalculated as INR 210.70 lakh and 186.30 lakh, with the assumed sequential durations as 47 and 35 days. The reconstructed 50-year WLC at 6% is INR 247.60 and 203.90 lakh. Carbon remains a zero-inventory and risk item, while the original cost boundary is eliminated when the PT delivery rate rises by either INR 97600 per equivalent or by 48.8 extra important dates in the supply chain or in between the two. The conclusion highlights the sensitivity of the situation and helps make it clear during the selection process. In order for the RCC/PT option to be chosen, all verified designs, physical inventories, current quotations and programme logic and stakeholder assessments should be available.

Conflicts of Interest

The authors declare that they have no conflicts of interest that could have influenced the research, authorship, or publication of this paper.

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Appendix a Source Register

This register documents the fifty bibliographic records retained in the bounded source collection. Grouping records their subject and intended use, not a claim that full-text screening or a systematic quality appraisal has been completed. The reference list supplies publication metadata and DOI identifiers. Quantitative findings from different structural systems are not pooled.

Transfer Structures

Direct typological and system-response context; no validation of the assumed cost scenario.

[1] Preliminary Design of Post-Tensioned Transfer Girders.

[35] High-Rise Buildings with Transfer Floors: Linear Versus Nonlinear Seismic Analysis.

[36] Seismic Analysis of High-Rise Buildings with Transfer Slabs: State-ofthe- Art-Review.

[37] Seismic Behaviour of High-Rise Buildings with Transfer Floors.

Prestressed Members and Monitoring

Member and sensing evidence; concentrated transfer loading and construction stages need separate verification.

[2] Analysis of RCC and PSC Beam: A Comparative Research with Post-Tensioning Performance in Multistory Building under Seismic Zone III.

[5] Optimization of Material Consumption in Reinforced Concrete Beams Using Post-Tensioning and Particle Swarm Optimization.

[6] Evaluation of post-tensioned reinforced and fiber reinforced concrete beams by using DOFS.

[7] Strain, crack, stress and shape diagnostics of new and existing post-tensioned structures through distributed fibre optic sensors.

[8] Prestress Force Monitoring and Quantification of Precast Segmental Beams through Neutral Axis Location Identification.

[25] Simulation-based Study on the Performance of NSM-CFRP Strengthening in Prestressed Concrete T-Beams Under Seismic Loading.

[46] Structural performance assessment of post-tensioned concrete beams by embedded continuous fibre optics.

[47] Post-tensioning Force Measurement Using Optical Fiber Sensor-Embedded Strand for Prestressed Concrete Structures.

Slabs and Floor Systems

Indirect evidence; distributed floor loading differs from concentrated transfer actions.

[3] Comparative analysis of RCC and PT Slabs underneath Lateral Loading: A Structural study using ETABS.

[4] Cost Evaluation of Post-tensioned Slabs in Multi-storey Buildings Considering Seismic Effect.

[9] Predicting Embodied Carbon and Cost Effectiveness of Post-Tensioned Slabs Using Novel Hybrid Firefly ANN.

[10] Assessment of the embodied carbon performance of post-tensioned voided concrete plates as a sustainable floor solution in multi-story buildings.

[11] A Comparative Study of Optimised Embodied Carbon and Cost in RC Slab Structures.

[26] Finite Element Based Optimization of Two-Way Concrete Slabs: A Comparative Study on Embodied Carbon and Cost Efficiency.

[28] Evaluation of reductions in carbon emissions from building construction due to innovative approaches to floor construction.

[39] Optimizing Structural Slab Selection for High-Rise Construction: Applied Value Engineering for Cost-Performance Balance.

[48] Parametric Optimisation of Two-Way Slabs on Beams for Early-Stage Low-Carbon Design.

Carbon Life Cycle and Materials

Inventory and assessment methods; use project-specific factors and consistent boundaries.

[12] Sustainable design of reinforced concrete structural members using embodied carbon emission and cost optimization.

[13] Low-carbon design optimization of reinforced concrete building structures using genetic algorithm.

[15] Reducing embodied carbon in structural systems: A review of early-stage design strategies.

[16] Sustainability in life-cycle structural engineering: Review.

[17] Life cycle cost analysis of sustainable reinforced concrete buildings with treated wastewater, recycled concrete aggregates, and fly ash.

[18] Probabilistic approach to the sustainability assessment of reinforced concrete structures in conditions of climate change.

[19] Performance assessment of LC3 concrete structures considering life-cycle cost and environmental impacts.

[27] Parametric analysis on embodied carbon (CO2-e) in reinforced concrete-based buildings.

[29] Life Cycle Assessment and Sustainable Construction: A Comprehensive Review from Theoretical Foundations to Practical Strategies and Innovative Methods.

[30] Life cycle sustainability assessment and optimization of seismic retrofit solutions for RC frame structures.

[41] Life-cycle environmental impact optimization of an RC-THVS composite frame for sustainable construction.

[49] Construction Carbon Footprint Reduction: A Comparative Analysis of Traditional and Innovative Materials.

Structural Optimization and Global Response

Supporting methods and global-response evidence; not transfer-beam algorithm validation. Reference [40] concerns envelope retrofits only.

[14] Two-stage multi-objective optimization of reinforced concrete buildings based on non-dominated sorting genetic algorithm (NSGA-III).

[20] Enhancing Robustness in Precast Modular Frame Optimization: Integrating NSGA-II, NSGA-III, and RVEA for Sustainable Infrastructure.

[21] Failure Probability-Based Optimal Seismic Design of Reinforced Concrete Structures Using Genetic Algorithms.

[22] Improved Non-dominated Sorting Genetic Algorithm III: An innovative multi-objective optimization framework for sustainable building design.

[23] Robust multi-objective building design optimization approach using NSGA-II algorithm considering weather and occupant uncertainties.

[24] Hybrid Topology Optimization of a Concrete Structure via Finite Element Analysis and Deep Learning Surrogates.

[31] Optimizing Seismic Resilience in High-Rise Structures through Comprehensive Evaluation and Enhancement of Outrigger Systems: A Comparative and Multifaceted Study.

[32] Impact of Vertical Irregularities on High-Rise Buildings and Their Effect on Internal Forces and Horizontal Displacement.

[33] Dynamic Analysis of High-Rise Buildings for Various Irregularities with and without Floating Column.

[34] Towards understanding, estimating and mitigating higher-mode effects for more resilient tall buildings.

[38] Efficient multi-objective constrained Bayesian optimization of bridge girder.

[40] Multi-Objective Optimization of Building Envelope Retrofits Considering Future Climate Scenarios: An Integrated Approach Using Machine Learning and Climate Models.

[42] Multi-objective optimization of high-rise buildings with outrigger systems subject to seismic loads.

[43] Optimal configuration of RC frames considering ultimate and serviceability limit state constraints.

[44] Otimização de Custos com Consideração de Probabilidade de Falha em Vigas de Concreto Armado Sob Flexão.

[45] Topology, Size, and Shape Optimization in Civil Engineering Structures: A Review.

[50] Multiobjective Structural Layout Optimization of Tall Buildings Subjected to Dynamic Wind Loads.