

Step by Step Guide: How the Case Study Was Built and Calculated

Purpose

This guide shows, for readers who want to see the process, how the case study was produced from research through price harvesting, deterministic calculation, multi-model checks, and revision. The process steps are listed briefly. The principal deterministic calculations and verification checks are shown so a reader can reproduce them by hand or in a spreadsheet.

How to read the calculation blocks. Inputs marked illustrative reproduce the case study totals exactly; they are not live market prices. The anchor holds throughout: AI assists, professionals decide. Qualified materials/QC personnel and, where appropriate, the responsible professional confirm inputs and compliance; INDOT acceptance follows the contract documents.

Part 1. The Process, Step by Step

Phase A. Frame the work (EVOLVE: Evaluate)

1. **Step 1.** Define the question and the audience: can AI help an asphalt contractor choose a lower cost compliant mix, and how is the answer proven.
2. **Step 2.** Set the risk tier (Tier 3, decision support) and the Gate 0 plan: objective, sub-questions, source list, and the verification required.
3. **Step 3.** Create a Claude Project and load the governing files: the EVOLVE-AI guidance, the Math and Verification Requirements, and a contents index. Keep each prompt to 3 to 5 named files (Retrieval Budget).

Phase B. Research and classify evidence (EVOLVE: Validate)

4. **Step 4.** Search published research and field use for each candidate use case (mix property prediction, intelligent compaction, binder grade tools, bid prediction).
5. **Step 5.** Open each source and confirm it supports the specific claim; classify it as demonstrated application, published predictive research, or proposed application. Treat any model suggested source as an unverified lead until checked.

Phase C. Harvest prices and define inputs (EVOLVE: Validate)

6. **Step 6.** Identify the authoritative price sources: the INDOT monthly PG binder index, supplier quotes, and internal plant cost records; note that the case uses rounded illustrative values in their place.

7. **Step 7.** Record each input with its unit and its basis (provided, sourced, assumed, or derived), and state the assumptions explicitly.

Phase D. Deterministic calculation (ACCURACY: Run verification; Math Requirements)

8. **Step 8.** Identify the quantity, the governing equation, the inputs, the units, and the constraints before solving (see Part 2).
9. **Step 9.** Have the AI LLM run the arithmetic in a deterministic tool and show its work. Then verify the accuracy of the process and run the arithmetic in a deterministic tool (spreadsheet) to verify the results. Do not allow the AI LLM to use “model text” for calculations.
10. **Step 10.** Verify the arithmetic with an equivalent deterministic cross-check and multi-model QA/QC; then run internal and market reasonableness checks (see Part 2).

Phase E. Specification screen

11. **Step 11.** Screen each candidate against INDOT 2026 \$401.06 (25.0 percent maximum Binder Replacement for Categories 2-4) and applicable contract RSPs before lab work (see Part 2, Section 5).

Phase F. Multi-model checks and revision (EVOLVE: Learn, Verify)

12. **Step 12.** Pass the checked drafts to a second and a third independent model for QA/QC; collect their findings and recommended edits.
13. **Step 13.** Run their findings through the original project in Claude and draft the final report. Do one final verification against current INDOT specifications, applicable contract RSPs/special provisions, the approved DMF, and materials guidance. Design Memorandum 23-21 applies to MSCR binder nomenclature.
14. **Step 14.** Adopt, modify, or reject each recommendation with a reason. Document the process and findings.

Phase G. Physical verification and close (EVOLVE: Verify, Expand)

15. **Step 15.** Verify the selected compliant candidate through required laboratory and field QC/QA. Use specified volumetric testing and roadway cores for INDOT acceptance; intelligent compaction and performance testing are supplemental when applicable. Contractor and agency roles remain as specified.
16. **Step 16.** Document the results in the Claude Project and your hard project files, then repeat on the next mix.

Note: Add all AI generated verification files to the Claude Project for review; date and time every document for version control.

Part 2. The Deterministic Calculations, Worked in Full

Notation: f = weight fraction of a component in the mix; p = price per ton of that component. All component fractions in a mix sum to 1.00.

Inputs (illustrative)

Component	Price p (\$/ton)	Fraction f , Candidate A	Fraction f , Candidate B
Virgin PG binder	600.00	0.050	0.045
Virgin aggregate	14.88	0.700	0.605
RAP (internal processing/handling)	5.536	0.250	0.350
Total		1.000	1.000

Section 1. Blended raw-material cost per ton (governing equation)

Equation: $C_{\text{mix}} = \text{sum over components of } (f_i \times p_i)$

Candidate A:

binder $0.050 \times 600.00 = 30.000$

aggregate $0.700 \times 14.88 = 10.416$

RAP $0.250 \times 5.536 = 1.384$

$C_A = 30.000 + 10.416 + 1.384 = 41.800 \rightarrow \$41.80 \text{ per ton}$

Candidate B:

binder $0.045 \times 600.00 = 27.000$

aggregate $0.605 \times 14.88 = 9.0024$

RAP $0.350 \times 5.536 = 1.9376$

$C_B = 27.000 + 9.0024 + 1.9376 = 37.940 \rightarrow \$37.94 \text{ per ton}$

Section 2. Saving

Saving per ton: $S = C_A - C_B = 41.80 - 37.94 = 3.86 \rightarrow \$3.86 \text{ per ton}$

Percent saving: $S\% = (C_A - C_B) / C_A = 3.86 / 41.80 = 0.09234 = 9.23\%$

Job saving: $S_{\text{job}} = S \times \text{tons} = 3.86 \times 5,000 = 19,300 \rightarrow \$19,300$

Section 3. Second-form deterministic cross-check (2,000-pound batch basis)

Recompute on a 2,000-pound (1-ton) batch to confirm the fraction method. Pounds of a component = $f \times 2,000$; its cost = $(\text{pounds} / 2,000) \times p$. This is an algebraically equivalent arithmetic and unit cross-check, not an independent market validation.

Candidate A aggregate, pound basis:

$$\text{pounds} = 0.700 \times 2,000 = 1,400 \text{ lb}$$

$$\text{cost} = (1,400 / 2,000) \times 14.88 = 0.700 \times 14.88 = 10.416 \quad (\text{matches Section 1})$$

All components reconcile identically, so $C_A = 41.80$ and $C_B = 37.94$ by both equivalent forms.

Internal order of magnitude check: under these illustrative inputs, the binder term (about 30 and 27 dollars) dominates both totals, so totals near 38 to 42 dollars per ton are internally reasonable. Market reasonableness is a separate check using current INDOT, supplier, plant, and bid history data. The cross check agrees, so the arithmetic is VERIFIED.

Section 4. Reverse solve - internal consistency check

Given only the two published totals and the binder price, reverse-solve for the implied aggregate and RAP prices. This confirms that the totals reproduce the disclosed inputs; it does not independently establish current market prices.

Subtract the known binder term from each total:

$$0.700 a + 0.250 r = 41.80 - (0.050 \times 600) = 41.80 - 30.00 = 11.80 \quad \dots (1)$$

$$0.605 a + 0.350 r = 37.94 - (0.045 \times 600) = 37.94 - 27.00 = 10.94 \quad \dots (2)$$

Solve the 2×2 system (1),(2):

$$a = \$14.880 \text{ per ton (virgin aggregate)}$$

$$r = \$5.536 \text{ per ton (RAP)}$$

These match the disclosed inputs exactly, confirming consistency.

Section 5. Binder Replacement screen (INDOT 25.0 percent maximum)

Binder Replacement (BR) is the share of total binder that comes from recycled material. It is not the same as RAP percentage. Assume, for this illustration only, that the RAP contains 5.0 percent binder by mass. The 25.0 percent maximum is from INDOT 2026 Standard Specifications §401.06 for Categories 2, 3, and 4; applicable contract RSPs must also be checked.

Equations:

$$\text{recycled binder (pp)} = \text{RAP\%} \times \text{RAP binder\%}$$

$$\text{total binder\%} = \text{virgin binder\%} + \text{recycled binder (pp)}$$

$$\text{BR} = \text{recycled binder} / \text{total binder}$$

Mass balance (both mixes): 6.25% total binder + 93.75% total aggregate = 100.00% (A recycled binder 1.25%; B 1.75%).

Candidate A (25% RAP, 5.0% virgin binder):

$$\text{recycled} = 0.25 \times 5.0\% = 1.25\%$$

$$\text{total} = 5.00\% + 1.25\% = 6.25\%$$

$$\text{BR_A} = 1.25 / 6.25 = 0.2000 = 20.0\% \rightarrow \leq 25.0\% \text{ cap: PASSES}$$

Candidate B (35% RAP, 4.5% virgin binder):

$$\text{recycled} = 0.35 \times 5.0\% = 1.75\%$$

$$\text{total} = 4.50\% + 1.75\% = 6.25\%$$

$$\text{BR_B} = 1.75 / 6.25 = 0.2800 = 28.0\% \rightarrow > 25.0\% \text{ cap: SCREENED OUT}$$

Result of the screen. Candidate B is cheaper on the illustrative raw-material inputs, but its calculated 28.0% Binder Replacement exceeds the 25.0% maximum in INDOT 2026 Standard Specifications §401.06 for Categories 2, 3, and 4. The cost screen finds it; the specification screen stops it. Verify applicable contract RSPs, including 401-R-820 where applicable. Actual compliance uses the approved DMF, measured RAP binder content, and contract requirements.

Section 6. BRR-limited RAP ceiling under the illustrative assumptions

Rearrange $BR = (RAP\% \times RAP \text{ binder}\%) / \text{total binder}\%$ for the ceiling imposed by the BR constraint alone:

$RAP \text{ ceiling from BR constraint} = (BR_max \times \text{total binder}\%) / RAP \text{ binder}\%$

$RAP \text{ ceiling} = (25.0\% \times 6.25\%) / 5.0\% = 31.25\%$ (under these illustrative assumptions only)

Note: 31.25% is only the BR-constraint ceiling, not overall compliance. Actual allowable RAP also depends on the approved DMF, mixture category, material/gradation requirements, applicable RSPs, and contract provisions.

Section 7. Calculation record (Math and Verification Requirements)

Field	Entry
Purpose	Compare two candidate mixes on raw material cost and screen each against the binder replacement limit.
Inputs	Illustrative: binder 600.00, aggregate 14.88, RAP 5.536 (\$/ton); fractions per the inputs table; assumed RAP binder 5.0%.
Governing method	$C_mix = \sum(f \times p)$; $BR = \text{recycled binder} / \text{total binder}$; INDOT 2026 §401.06: 25.0% maximum BR for Categories 2-4; verify applicable RSPs.
Result	$C_A = 41.80$, $C_B = 37.94$; saving 3.86/ton (9.23%), 19,300 on 5,000 tons; BR_A 20.0% passes, BR_B 28.0% screened out.
Verification	Fraction and 2,000-lb forms agree; internal reasonableness and reverse-solve checks pass; mass balance = 100%; 25% maximum verified.
Status	VERIFIED: arithmetic and specification-screen calculation. Mix, production, and acceptance still REQUIRE VERIFICATION by applicable QC/QA and contract procedures.
Professional review	Qualified contractor/agency materials personnel confirm inputs, DMF, RAP binder content, and final decision; INDOT acceptance follows contract documents.

Verify supporting sources directly: open primary URLs and confirm effective dates, equations, values, and contract applicability; never assume an AI LLM interpreted a website correctly.