Wall Insulation & Vapour Control in South African Climatic Zones

A quantitative study of the Technical Wall Insulation & VCL Guide's four assemblies, computed with the THERMA 2-D finite-element engine (v2.2). Rev B: EPS external insulation, gypsum sheathing boards, and cavity-wall masonry.

Technopol · 5 June 2026 (rev B — EPS, gypsum sheathing, cavity masonry)

Contents

Executive summary

- Four wall assemblies from the guide — LSF and masonry, in cold/wet and hot/humid configurations — were modelled in 2-D FEM and screened for interstitial condensation in the three SANS climatic regimes that bracket South Africa (zones 1/2, 4 and 5).
- Continuous external insulation is confirmed as the most robust strategy: it limits the steel-stud penalty to +21 % (R 3.22 m^{2}K/W bridged, U 0.31) and keeps f_Rsi ≥ 0.88 for the insulated walls, and moves the dew point outboard of moisture-sensitive layers.
- The vapour control layer must follow the dominant vapour drive. The interior VCL that protects the wall in a Johannesburg winter (57 % saturation vs a marginal 98 % without it) fails when used in Durban: 107 % — condensation on the VCL under inward summer drive.
- Masonry with external insulation passes every climate tested (≤ 86 %) without a dedicated VCL.
- Hot/humid assemblies (exterior vapour control) pass zone 5 comfortably but FAIL the winter zones outright (107–119 % at the cold retarder) — one wall does not serve all zones.
- Uninsulated baselines make the case for insulating at all: the bare cavity-brick wall achieves only R = 0.68 m^{2}K/W (vs 1.99 insulated) and the empty LSF wall R = 0.51 (vs 3.22 insulated, and far below the SANS 10400-XA non-masonry minima of R 2.2 / 1.9). The bare LSF wall fails the surface-mould criterion (f_Rsi 0.70 < 0.75); the cavity gives bare masonry a pass (0.81) — but at three times the heat loss.

The verdict at a glance

Everything this study finds, in one table — the rest of the report is the evidence. Each wall keeps its short name and code throughout (Figure 2 shows the build-ups):

Wall	R (m^{2}K/W)	SANS min R (2.2 / 1.9)	Surface mould	Cond. JHB z1	Cond. CPT z4	Cond. DBN z5
LSF-Full (A1)	3.22	PASS	low · f 0.88	OK 57 %	OK 83 %	FAIL 107 %
LSF-Coastal (A3)	3.22	PASS	low · f 0.97	FAIL 119 %	FAIL 107 %	OK 76 %
Brick-EWI (A2)	1.99	n/a *	low · f 0.93	OK 61 %	OK 84 %	OK 76 %
Brick-EWI-Coastal (A4)	1.99	n/a *	low · f 0.93	OK 65 %	OK 86 %	OK 76 %
LSF-NoEPS (X1)	1.75	FAIL	FAILS · f 0.74	—	—	—
Brick-Bare (B1)	0.68	n/a *	marginal · f 0.81	OK 77 %	OK 82 %	OK 77 %
LSF-Bare (B2)	0.51	FAIL	HIGH · f 0.70	OK † 62 %	OK † 73 %	OK † 83 %

** Masonry walls comply via the SANS masonry route (clause 4.4.3.2 / CR values), not the non-masonry R rule — which is R 2.2 in zones 1 & 6 and R 1.9 in zones 2–5 (SANS 10400-XA prescriptive route). † Passes inside the build-up, but the room-side surface fails — mould, not interstitial condensation (§6.2). X1 is a thermal reference case and was not condensation-screened.*

1. Introduction & objectives

The guide gives qualitative layer sequences and the principle that vapour control belongs on the side of the dominant vapour drive: the warm interior side in heating climates, and toward the exterior in hot-humid climates with air-conditioned interiors. This study quantifies that guidance for South African conditions: solved temperature fields and U-values including steel-stud thermal bridging, inner-surface mould risk (f_Rsi), and dew-point (Glaser) condensation screens for each assembly in each climatic regime, with and without the VCL.

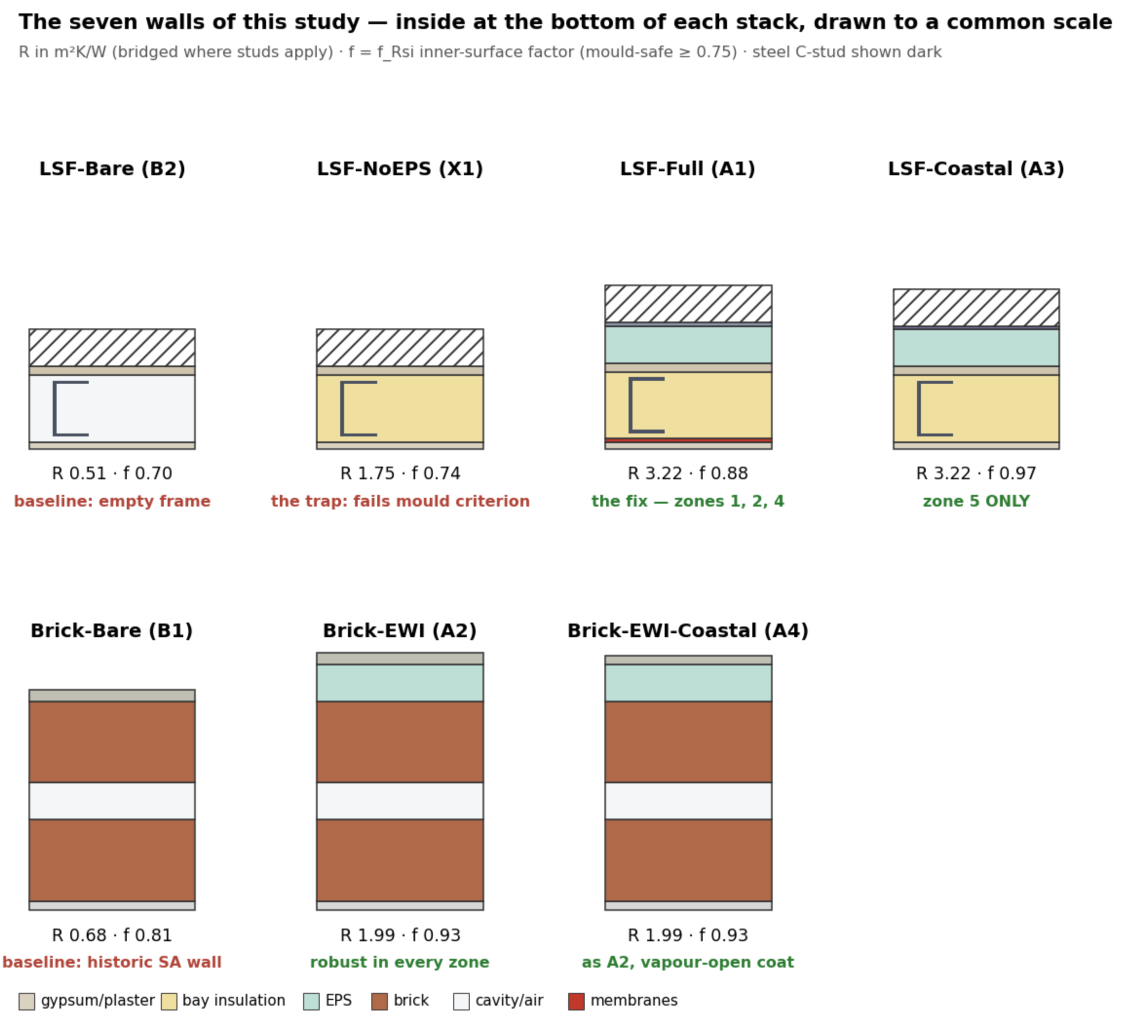


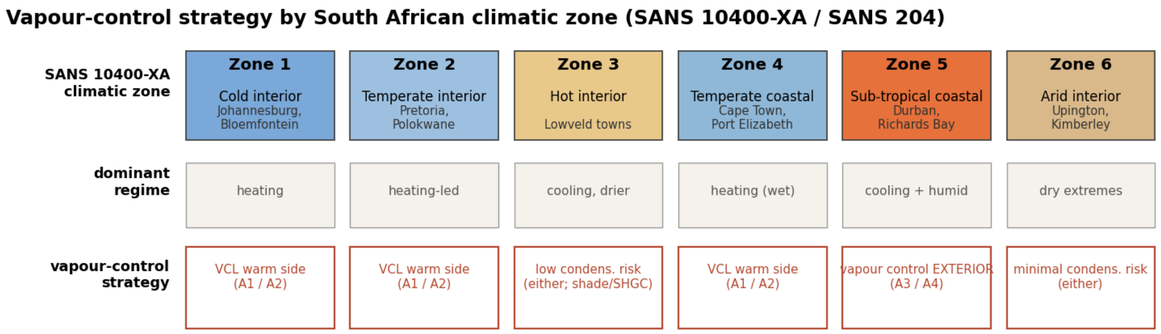
Figure 2 — The seven walls at a glance: build-ups to a common scale, with the names, bridged R-values, surface factors and verdicts used throughout this study.

2. Method

- Heat transfer: 2-D steady-state finite-element conduction (EN ISO 10211 numerical method; the engine reproduces the ISO 10211 A.1 and A.2 reference cases). Surface films per ISO 6946; ventilated cladding cavities excluded per ISO 6946 with Rse = 0.13.
- LSF walls are solved twice — clear field, and with the lipped C-stud (C 90×40×12, 0.8 mm steel) at 600 mm centres — so the bridging penalty is explicit.
- Interstitial condensation: dew-point (Glaser) method per EN ISO 13788 — temperature, saturation pressure p_sat and vapour pressure p_v profiles through the layers, using the vapour permeabilities of §A.1.
- f_Rsi: inner-surface temperature factor; ≥ 0.75 indicates low mould risk.

3. South African climatic zones

SANS 10400-XA / SANS 204 divide South Africa into six climatic zones. The guide's two regimes map onto them directly: the cold/wet principles govern the heating-dominated zones (1, 2 and 4), and the hot/humid principles govern the sub-tropical coastal zone 5 (Durban, Richards Bay), where HVAC reverses the vapour drive. Zones 3 and 6 are lower-risk for interstitial condensation owing to drier air.



Vapour-control strategy by South African climatic zone (SANS 10400-XA / SANS 204)

SANS 10400-XA climatic zone	**Zone 1** Cold interior Johannesburg, Bloemfontein	**Zone 2** Temperate interior Pretoria, Polokwane	**Zone 3** Hot interior Lowveld towns	**Zone 4** Temperate coastal Cape Town, Port Elizabeth	**Zone 5** Sub-tropical coastal Durban, Richards Bay	**Zone 6** Arid interior Upington, Kimberley
dominant regime	heating	heating-led	cooling, drier	heating (wet)	cooling + humid	dry extremes
vapour-control strategy	VCL warm side (A1 / A2)	VCL warm side (A1 / A2)	low condens. risk (either; shade/SHGC)	VCL warm side (A1 / A2)	vapour control EXTERIOR (A3 / A4)	minimal condens. risk (either)

Figure 1 — Vapour-control strategy mapped to the SANS climatic zones.

3.1 Design conditions used

Condition set	Zone	Interior	Exterior
Johannesburg winter	1 (cold interior)	20 °C · 45 % RH	0 °C · 60 % RH
Cape Town winter	4 (temperate coastal)	20 °C · 55 % RH	7 °C · 85 % RH
Durban summer + HVAC	5 (sub-tropical coastal)	23 °C · 55 % RH	30 °C · 75 % RH

4. The assemblies

Layer sequences are taken from the guide; thicknesses and properties are typical South African specifications (Appendix A). The VCL position — the study's central variable — is highlighted in red. Results are reported as total thermal resistance R (m²K/W), the convention of SANS 204 / 10400-XA, with U given alongside.

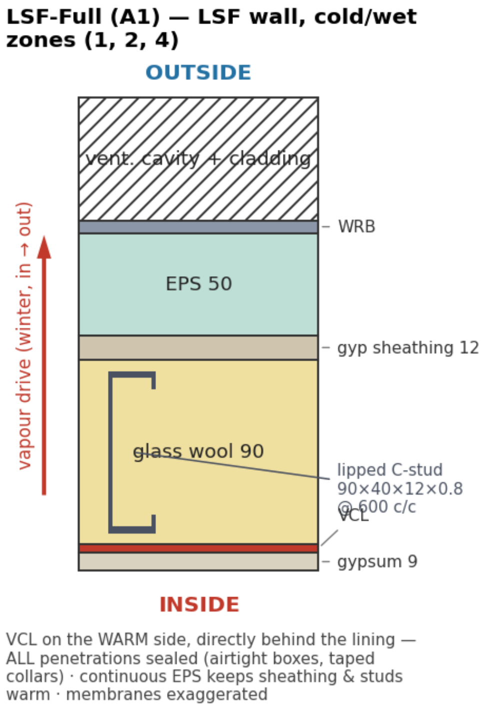


Figure 3 — LSF-Full (A1): LSF wall for cold/wet zones. VCL on the warm side; lipped C-stud indicated.

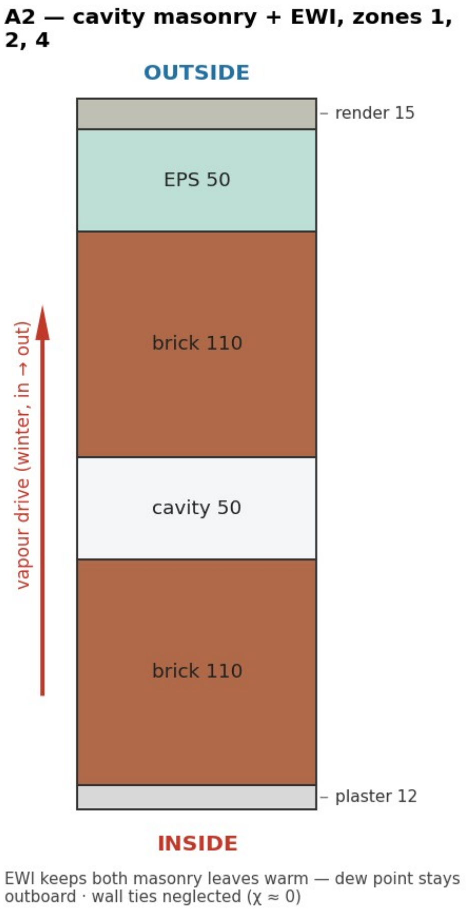
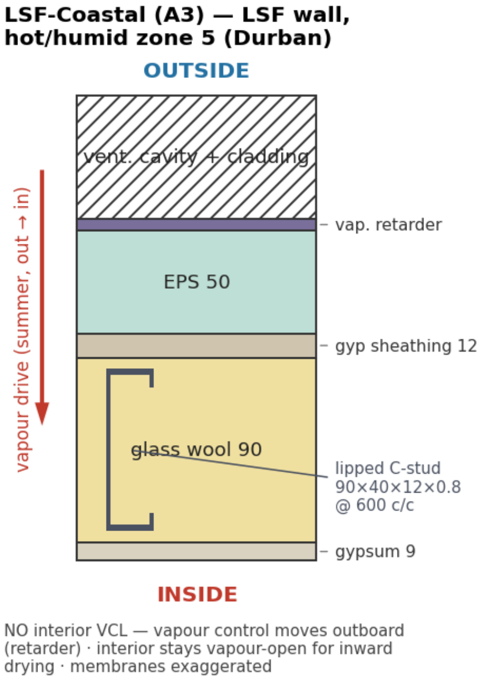


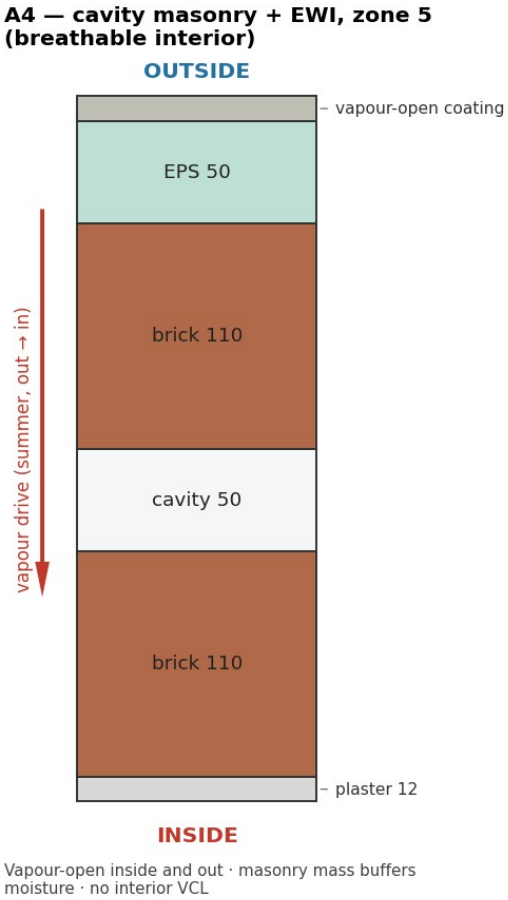
Figure 4 — Brick-EWI (A2): cavity masonry (110/50/110), external insulation, cold/wet zones.



LSF-Coastal (A3) — LSF wall, hot/humid zone 5 (Durban)

NO interior VCL — vapour control moves outboard (retarder) · interior stays vapour-open for inward drying · membranes exaggerated

Figure 5 — LSF-Coastal (A3): LSF wall for zone 5. No interior VCL; vapour control moves outboard.



A4 — cavity masonry + EWI, zone 5 (breathable interior)

Vapour-open inside and out · masonry mass buffers moisture · no interior VCL

Figure 6 — Brick-EWI-Coastal (A4): cavity masonry EWI for zone 5 with breathable interior finish.

A note on services (A1): the VCL sits directly behind the lining, so every socket box, switch and conduit penetrates it. Each penetration must be sealed — airtight boxes, grommets and taped collars — and the condensation pass of Section 7 assumes this is done; an unsealed box row behaves like a perforated VCL. Where site QA cannot guarantee sealing, adding a 25 mm battened service cavity inboard of the VCL restores continuity by geometry (and adds R 0.18). A3 has no interior membrane, so services run in the stud bay as usual.

A note on the masonry cavity: once the insulation and its weather coating sit OUTSIDE the masonry, the cavity's traditional function — stopping rain penetration by drainage — is taken over by the EWI system, so the wall may equally be built solid. Solved solid (220 mm brick + 50 EPS + render): R = 1.81 m²K/W, f_Rsi = 0.93, worst Glaser 84 % — essentially the cavity wall minus the air gap's R 0.18. The cavity remains worthwhile as rain-control redundancy where the EWI system is not a certified weather barrier; thermally and hygrothermally it is optional under EWI.

For comparison, the two baselines — the same wall types with the insulation layer (and VCL) removed:

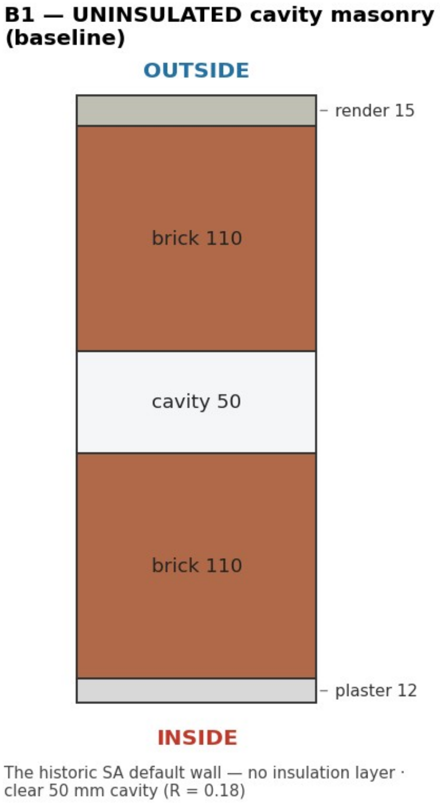


Figure 7 — Brick-Bare (B1): uninsulated plastered cavity masonry — the historic SA default wall.

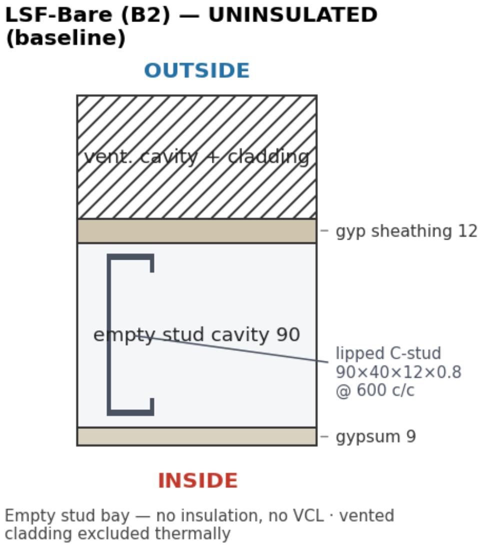


Figure 8 — LSF-Bare (B2): uninsulated LSF — empty stud bay (C-stud indicated) behind the gypsum lining.

5. Thermal performance & steel bridging

Assembly	R clear (m²K/W)	R bridged (m²K/W)	Stud penalty	U (W/m²K)	f_Rsi
Brick-Bare (B1) — uninsulated	0.68	—	—	1.48	0.81
LSF-Bare (B2) — empty bay	0.52	0.51	+3 %	1.96	0.70
LSF-NoEPS (X1) — insulated bay, no continuous EPS	2.59	1.75	+48 %	0.57	0.74
LSF-Full (A1) — cold/wet	3.91	**3.22**	+21 %	0.31	0.88
LSF-Coastal (A3) — hot/humid	3.91	**3.22**	+21 %	0.31	0.97
Brick-EWI (A2)	1.99	—	—	0.50	0.93
Brick-EWI-Coastal (A4)	1.99	—	—	0.50	0.93

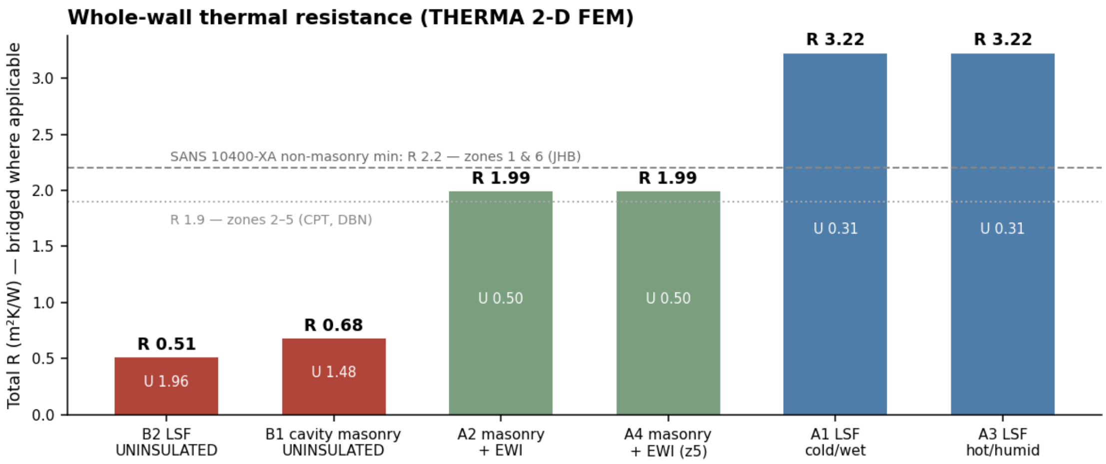


Figure 9 — Total R per assembly (U inside the bars); the steel stud costs only 19–21 % of R thanks to the continuous external insulation. Dashed lines: SANS 10400-XA non-masonry minima — R 2.2 (zones 1 & 6) and R 1.9 (zones 2–5).

5.1 The uninsulated baselines

The same wall types without any insulation layer put the guide in context. The bare plastered cavity-brick wall achieves only R = 0.68 m²K/W (U 1.48) and the empty-bay LSF wall R = 0.51 (U 1.96) — a third to a seventh of the insulated assemblies' resistance, and far below the SANS 10400-XA non-masonry minima (R 2.2 in zones 1 & 6; R 1.9 in zones 2–5). The bare LSF wall sits at f_Rsi = 0.70, below the 0.75 criterion, i.e. surface condensation and mould become plausible at the coldest interior spots in winter design conditions; the masonry cavity wall scrapes a surface pass at 0.81 thanks to its 50 mm air cavity. Two further observations: the steel stud penalty almost disappears (+3 %) in the uninsulated LSF wall — not because the stud improves, but because the whole wall is already so conductive; and the interstitial (Glaser) screens of the uninsulated walls pass (≤ 83 %), confirming that their failure mode is energy and surface mould, not interstitial condensation. Insulation multiplies R by 2.9 (masonry) to 6.3 (LSF) and lifts f_Rsi to ≥ 0.88.

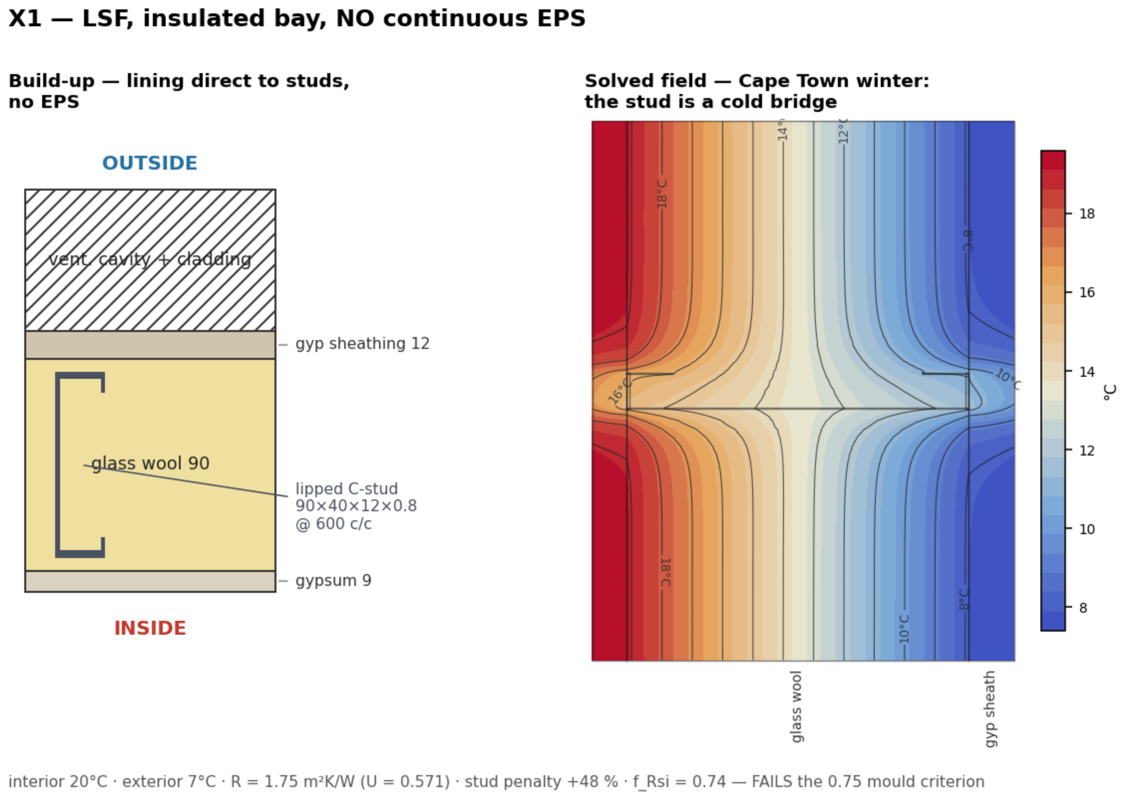
Two stud penalties need careful reading. In the EMPTY bay (B2) the stud costs only 3 % — not because steel is harmless, but because the bay it bridges holds just R 0.18 of cavity resistance; there is almost nothing to short-circuit. Fill that bay with glass wool, fix the lining directly to the studs and omit the continuous EPS (row X1) and the same stud destroys 48 % of the wall's resistance (R 2.59 → 1.75) and drags f_Rsi down to 0.74 — below the 0.75 mould criterion: this is the classic LSF bridging problem. Adding the 50 mm continuous EPS (A1) restores the bay's insulation to effectiveness — the penalty falls back to 21 % and the wall lands at R 3.22. The continuous layer is what makes steel framing thermally viable.

5.2 What insulating the bay does to the stud penalty

Solving the same 90 mm bay with progressively better fill (lining fixed directly to the studs, as bay-only LSF walls are built) isolates the steel-frame effect. The stud penalty is not a property of the steel — it is a property of the CONTRAST between the steel and what surrounds it:

90 mm bay fill	R clear	R bridged	Stud penalty	R lost to studs	f_Rsi
Empty (B2)	0.52	0.51	+3 %	0.01	0.70
Glass wool λ 0.040	2.59	1.75	+48 %	0.84	0.74
Rock wool λ 0.035	2.92	1.88	+55 %	1.04	0.74
Glass wool + 50 EPS outside (A1)	3.91	**3.22**	+21 %	0.69	0.88

Three readings. First, the empty bay loses almost nothing to the stud (+3 %) because the steel bypasses only R 0.18 of cavity — there is nothing to short-circuit. Fill the bay with mineral wool and the same stud now bypasses R 2.25 of insulation: the penalty jumps to +48 % and 0.84 m²K/W of the installed product is lost. Second, upgrading to a better bay product is largely futile through steel framing: rock wool at λ 0.035 raises the clear-field R by 0.33 but delivers only 0.13 of it once bridged (+55 % penalty) — the better the bay insulation, the larger the fraction the steel steals, with the bay product delivering only ~60–65 % of its nominal value. Third, f_Rsi falls to 0.74 for the bay-only options — BELOW the 0.75 criterion: the stud line is no longer a cosmetic stripe but a mould-risk plane. The continuous EPS layer is what breaks the pattern — it cuts the relative penalty from +48 % to +21 % and lifts f_Rsi to 0.88 because it is unbroken across the stud line.



X1 — LSF, insulated bay, NO continuous EPS

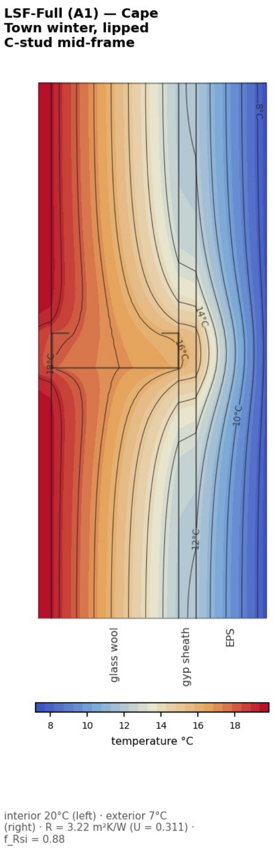
Build-up — lining direct to studs, no EPS

Solved field — Cape Town winter: the stud is a cold bridge

interior 20°C · exterior 7°C · R = 1.75 m²K/W (U = 0.571) · stud penalty +48 % · f_Rsi = 0.74 — FAILS the 0.75 mould criterion

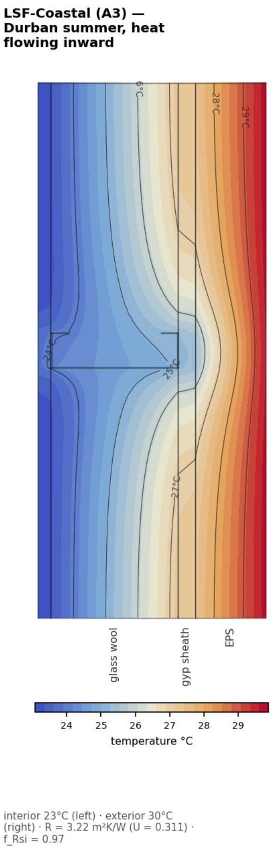
Figure 10 — LSF-NoEPS (X1), the wall the table above describes: build-up (left) and solved isotherm field (right). The stud line runs ≈ 4 °C colder than mid-bay — the cold stripe behind ghost-marking. Compare Figure 11 (A1, with EPS): same stud, barely visible.

The solved temperature fields make the mechanism visible: the steel stud pulls heat through the frame zone, but the continuous EPS holds the sheathing and stud warm, so the disturbance stays mild and the inner surface stays above mould-risk temperatures (f_Rsi ≥ 0.88):



LSF-Full (A1) — Cape Town winter, lipped C-stud mid-frame

interior 20°C (left) · exterior 7°C (right) · R = 3.22 m²K/W (U = 0.311) · f_Rsi = 0.88

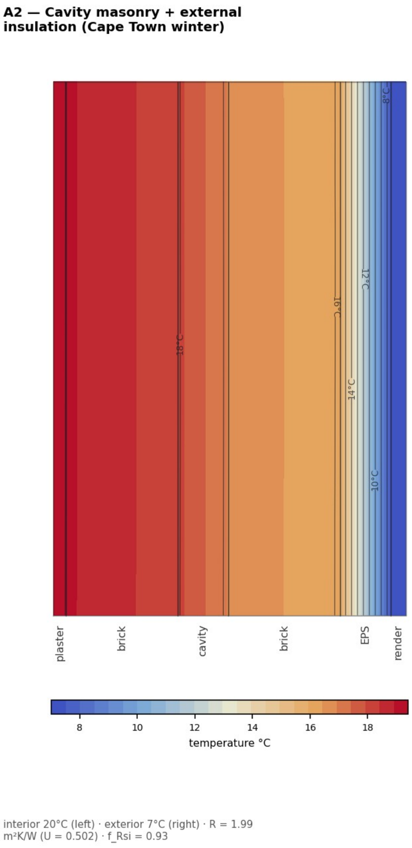


LSF-Coastal (A3) — Durban summer, heat flowing inward

interior 23°C (left) · exterior 30°C (right) · R = 3.22 m²K/W (U = 0.311) · f_Rsi = 0.97

Figure 11 — LSF-Full (A1) in a Cape Town winter: isotherm field with the lipped C-stud mid-frame; interior (left) stays warm. R = 3.22, f_Rsi = 0.88.

Figure 12 — LSF-Coastal (A3) in a Durban summer: heat flows inward (exterior 30 °C right, HVAC interior 23 °C left).



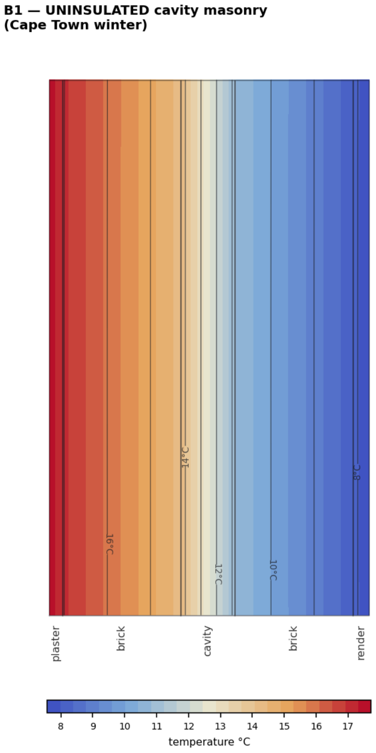
A2 — Cavity masonry + external insulation (Cape Town winter)

interior 20°C (left) · exterior 7°C (right) · R = 1.99 m²K/W (U = 0.502) · f_Rsi = 0.93

Figure 13 — Brick-EWI (A2) in a Cape Town winter: the EPS takes most of the temperature drop (tightly packed isotherms) and both brick leaves stay warm — the basis of its condensation robustness.

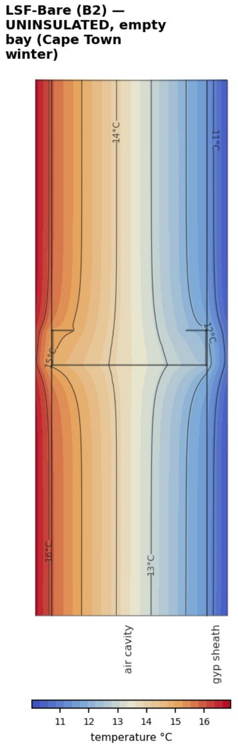
6. Insulated vs uninsulated — side by side

Solving the bare walls with the identical engine and boundary conditions makes the comparison direct. The contour fields tell the story at a glance: in the insulated walls (Figures 11–13) almost every isotherm is packed inside the insulation layers, holding the structure and the inner surface warm; in the bare walls below, the isotherms spread evenly through brick or empty cavity and the inner surface (left edge) is dragged down toward the outdoor temperature.



interior 20°C (left) · exterior 7°C (right) · R = 0.68 m²K/W (U = 1.478) · f_Rsi = 0.81

Figure 14 — Brick-Bare (B1), Cape Town winter: isotherms spread through both leaves, a visible jump across the 50 mm cavity; inner surface ≈ 17.5 °C (f_Rsi 0.81).



interior 20°C (left) · exterior 7°C (right) · R = 0.51 m²K/W (U = 1.958) · f_Rsi = 0.70

Figure 15 — LSF-Bare (B2): the stud barely perturbs the field — the wall is already so conductive (R 0.51) that the steel costs only 3 % of R. Coldest of the set: f_Rsi 0.70.

6.1 R-values

	R total (m²K/W)	U (W/m²K)	f_Rsi
Brick-Bare (B1) — uninsulated	0.68	1.48	0.81
Brick-EWI (A2) — + 50 mm EPS	1.99	0.50	0.93
masonry gain	**× 2.9**	**−66 %**	
LSF-Bare (B2) — empty bay	0.51	1.96	0.70
LSF-Full (A1) — bridged	3.22	0.31	0.88
LSF gain	**× 6.3**	**−84 %**	

6.2 Surface condensation potential

The bare walls differ: the empty LSF wall sits at f_Rsi = 0.70, the cavity-brick wall at 0.81. In a Johannesburg winter (20 °C inside, 0 °C design night) the coldest inner-surface points are 14.0 °C (B2), 16.2 °C (B1) and 17.7 °C (insulated A1). Translating to surface relative humidity (mould threshold 80 %, condensation 100 %):

Indoor air 20 °C at …	LSF-Bare B2 (14.0 °C)	Brick-Bare B1 (16.2 °C)	LSF-Full A1 (17.7 °C)
50 % RH	73 % — OK	64 % — OK	58 % — OK
60 % RH	88 % — MOULD	76 % — OK	69 % — OK
70 % RH	102 % — CONDENSATION	89 % — MOULD	81 % — at the mould line
Condensation onset	≈ 68 % indoor RH	≈ 79 % indoor RH	≈ 87 % indoor RH

A kitchen, bathroom or crowded room easily holds 60–70 % RH in winter: on the bare LSF wall that means mould-active surface humidity every cold night and outright condensation at 70 %; the bare cavity-brick wall crosses the mould line at ≈ 65 % indoor RH; the insulated wall holds 10–19 points of margin. In Cape Town’s milder winter the surfaces sit at 16.1 / 17.5 / 18.4 °C (B2 / B1 / A1) — same ranking, smaller gap. Note the failure mode: the bare walls pass the interstitial Glaser screen (Section 7) — their problem is surface mould and energy, precisely what the insulation layer fixes.

7. Condensation study (Glaser)

Worst saturation ratio p_v/p_sat through each assembly in each climate (100 % = condensation):

Assembly / variant	Joh'burg winter (z1)	Cape Town winter (z4)	Durban summer (z5)
LSF-Full (A1) with its VCL	57 % — OK	83 % — OK	107 % — CONDENSATION
LSF-Full (A1) without VCL	98 % — marginal	91 % — OK	76 % — OK
LSF-Coastal (A3) as designed	119 % — CONDENSATION	107 % — CONDENSATION	76 % — OK
LSF-Coastal (A3) + wrong-side VCL	66 % — OK	86 % — OK	103 % — CONDENSATION
Brick-EWI (A2)	61 % — OK	84 % — OK	76 % — OK
Brick-EWI-Coastal (A4)	65 % — OK	86 % — OK	76 % — OK
Brick-Bare (B1)	77 % — OK	82 % — OK	77 % — OK
LSF-Bare (B2)	62 % — OK*	73 % — OK*	83 % — OK*

* B2 passes the interstitial screen but fails the SURFACE criterion (f_Rsi 0.70 < 0.75) — condensation/mould risk appears on the inner face, not inside the build-up. B1 passes both screens, but at three times the heat loss of A2.

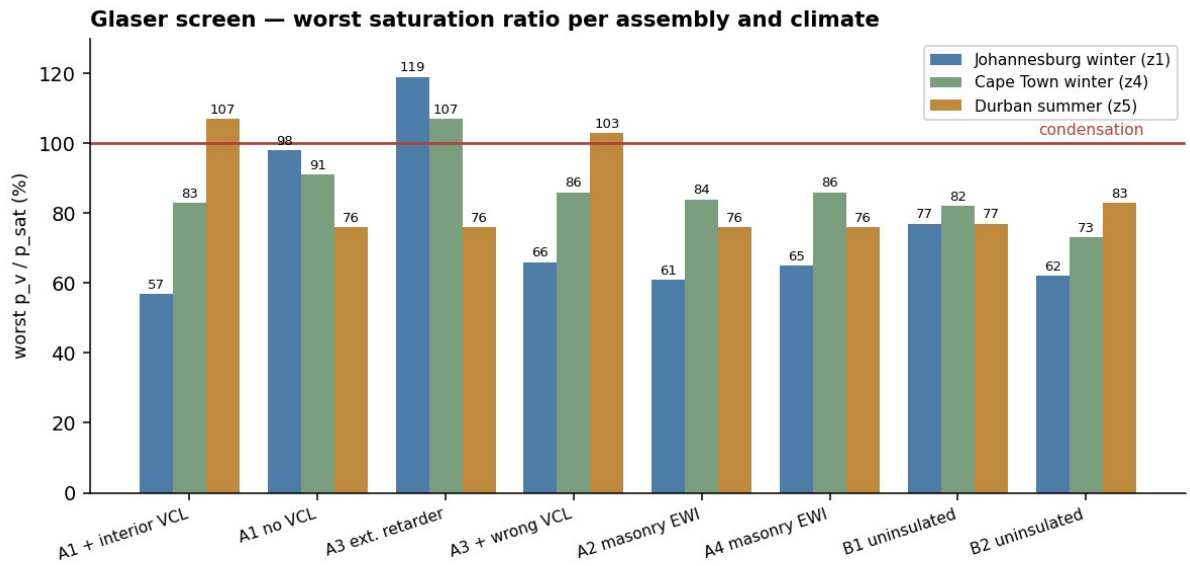


Figure 16 — The condensation screen at a glance. Three configurations cross the line: the interior VCL in Durban, and the exterior-retarder wall (A3) in both winter zones.

The two decisive profiles:

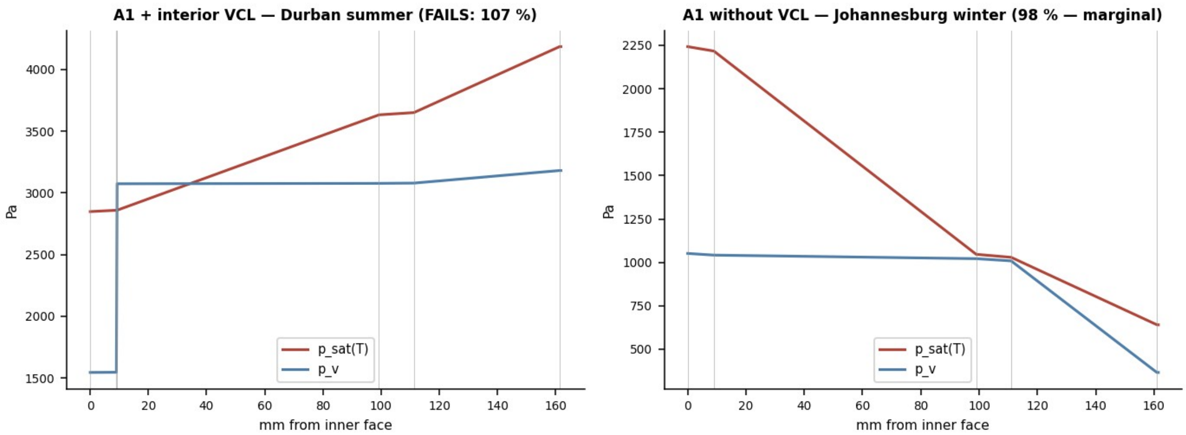


Figure 17 — Left: in Durban, inward vapour drive meets the cool interior-side VCL and p_v reaches p_sat — condensation on the VCL (shaded). Right: in a Johannesburg winter the same wall WITHOUT its VCL peaks at 98 % at the gypsum sheathing — the VCL is what protects it in heating zones.

7.1 Findings

- The VCL is climate-dependent protection: essential on the warm side in zones 1/2/4 (57 % vs 98 % without it), a liability in zone 5 where it traps inward-driven moisture (107 %).
- The zone-5 assembly (exterior vapour control, vapour-open interior) passes Durban at 76 % but FAILS the winter zones (107–119 %): with the vapour-open gypsum sheathing and EPS, the exterior retarder carries most of the vapour resistance at its coldest plane. It is strictly a zone-5 wall — assemblies must be specified per zone.
- Cavity masonry + EWI is the most forgiving wall everywhere (≤ 86 %): external insulation keeps both leaves warm so the dew point never enters the structure.
- Glaser is a conservative steady-state screen: results at ≈ 100 % call for a monthly ISO 13788 or hygrothermal (WUFI-type) check or a variable-permeance membrane — not necessarily a redesign. The 103–119 % results are genuine fails.

8. Zone-by-zone recommendations

Zone	Character	Recommended approach

1 · 2	Cold/temperate interior (Johannesburg, Pretoria) — heating, dry-to-moderate air	A1 or A2 with warm-side VCL. Without the VCL the LSF wall runs to 98 % — keep it. Continuous external insulation mandatory for LSF.
3	Hot interior — cooling-led but drier air	Condensation risk low; either assembly. Prioritise shading/SHGC and the U-value; VCL position not critical.
4	Temperate coastal (Cape Town) — wet winters, heating	As zones 1/2: warm-side VCL (A1/A2). The no-VCL case runs to 91 % — the VCL keeps margin.
5	Sub-tropical coastal (Durban, Richards Bay) — humid, HVAC interiors	A3 or A4 only: vapour control on the EXTERIOR, vapour-open interior for inward drying. Never an interior PE film — it fails at 107 %.
6	Arid interior — dry extremes	Condensation risk minimal; either assembly. Thermal performance and airtightness govern.

9. Conclusions

- The guide's central claims are quantitatively confirmed: continuous external insulation is the most robust strategy for both construction types, and VCL position must follow the dominant vapour drive of the climatic zone.
- The steel-stud penalty with 50 mm continuous EPS is 21 % of total R (3.22 m^2K/W bridged) — versus the 48–55 % the same engine finds when insulation sits only between the studs (§5.2) — and f_Rsi stays ≥ 0.88 in all insulated assemblies.
- Two genuine failure modes were found: an interior VCL in zone 5 (107 % — condensation on the film), and the zone-5 exterior-retarder wall used in winter zones (107–119 % at the cold retarder). Specification control on vapour-layer position is the highest-value QA intervention this study identifies.
- For projects spanning zones (national rollouts), a variable-permeance (smart) membrane or zone-specific wall types are the two defensible options; a single fixed-VCL wall is not.

Appendix A — Assumptions

A.1 Materials

Material	d (mm)	λ (W/m·K)	vp ng/(Pa·s·m)
Gypsum board	9	0.25	36
VCL — PE sheet	0.25	—	0.001
Glass wool between studs	90	0.040	170
Lipped C-stud 90×40×12, 0.8 mm steel @600	90 deep	50	0
Gypsum sheathing board	12	0.25	36
EPS continuous external insulation	50	0.038	3
WRB (vapour-open)	0.5	—	1000
Vapour retarder (zone 5, ext. side)	0.5	—	0.02
Internal plaster	12	0.50	25
Brick leaf (×2)	110 each	0.77	20
Wall cavity (unventilated, R 0.18)	50	0.278 eq.	200
Render / weather coating	15 / 10	0.87	18 / 5

A.2 Geometry & framing

- Steel framing modelled as a lipped C-stud, C 90×40×12 (web 90 across the cavity, 40 mm flanges on both faces, 12 mm lips), 0.8 mm steel ($\lambda = 50$ W/m·K), at 600 mm centres. One repeating 600 mm cell is solved with adiabatic symmetry cuts top and bottom.
- The thin steel is explicitly resolved by the engine's metal-refined mesh (fine-element zone hugging $\lambda \geq 5$ materials).
- 2-D analysis: stud (linear) bridging is captured. Point bridges — screws, fasteners, noggins/crossing members, purlin-rafter type contacts — are excluded; a separate 3-D node assessment applies where these occur (see ISO 10211 χ).

A.3 Films, cavities & exclusions

- Surface films per ISO 6946: Rsi 0.13 (walls); Rse 0.04 on exposed render; Rse 0.13 behind ventilated cladding, with the cladding and vented cavity excluded per ISO 6946 §6.9.
- The 50 mm masonry wall cavity is treated as an unventilated still-air layer (R = 0.18 m²K/W, ISO 6946); masonry wall ties neglected ($\chi \approx 0$).
- Membranes (VCL, WRB, vapour retarder) are thermally negligible and enter only the vapour calculation.

A.4 Analysis assumptions

- Steady-state conduction: no thermal mass, solar gain, night-sky radiation, rain absorption, wind washing or air leakage.
- Condensation screen per the simplified (Glaser) method of EN ISO 13788: vapour resistance proportional to d/vp; saturation by the Magnus relation; no liquid transport, capillarity, built-in moisture or hygroscopic storage; condensation flagged where p_v ≥ p_sat. Marginal (95–100 %) outcomes warrant the monthly method or transient hygrothermal (WUFI-type) analysis.
- Material properties are typical design values (ISO 10456 ranges / common SA product data); they are assumptions, not certified product values — substitute project-specific declarations for compliance work.
- Design climates are steady design-day conditions chosen to represent each zone's governing season, not annual or monthly means.
- Climatic-zone mapping per the common SANS 204 six-zone classification (Johannesburg z1, Cape Town z4, Durban z5); verify against the SANS 10400-XA:2021 map for a specific site.

Appendix B — Worked calculations

B.1 Clear-field U by sum of resistances (ISO 6946)

Each layer contributes R = d/λ; the clear-field U is the reciprocal of the total including surface films. Worked example, assembly A1:

Layer	d (mm)	λ (W/m·K)	R = d/λ (m²K/W)
Interior film Rsi	—	—	0.130
Gypsum board	9	0.25	0.036
Glass wool	90	0.040	2.250
Gypsum sheathing	12	0.25	0.048
EPS	50	0.038	1.316
Exterior film Rse (vented)	—	—	0.130
Total R			**3.910**

U = 1/R			**0.256 W/m²K**

The same summation for every assembly, against the FEM result (identical for 1-D builds — the check that engine and hand-calc agree):

Assembly	Σ layer R	+ films	R total → U	U (FEM)
LSF-Full (A1) — cold/wet	3.650	0.260	3.910 → 0.256	0.256
LSF-Coastal (A3) — hot/humid	3.650	0.260	3.910 → 0.256	0.256
Brick-EWI (A2)	1.823	0.170	1.993 → 0.502	0.502
Brick-EWI-Coastal (A4)	1.817	0.170	1.987 → 0.503	0.503
Brick-Bare (B1)	0.507	0.170	0.677 → 1.477	1.478
LSF-Bare (B2)	0.264	0.260	0.524 → 1.908	1.909

B.2 Bridged U and the stud's linear transmittance

The bridged U cannot be hand-summed — it is read from the 2-D field as U = L^{2D}/H (EN ISO 10211), where L^{2D} is the solved thermal coupling coefficient and H the 600 mm repeat. The stud's effect can be expressed as a linear transmittance per stud, Ψ = (U_bridged − U_clear) × spacing:

Assembly	U clear	U bridged (FEM)	ΔU stud	Ψ per stud (W/m·K)
LSF-Full (A1) — cold/wet	0.256	0.311	0.055	0.055 × 0.6 = 0.033
LSF-Coastal (A3) — hot/humid	0.256	0.311	0.055	0.055 × 0.6 = 0.033

B.3 Surface temperature factor

f_Rsi = (T_si,min − T_e)/(T_i − T_e). Example, A1 in Cape Town winter: f_Rsi = 0.88 → coldest inner-surface temperature T_si,min = 7 + 0.88 × (20 − 7) = 18.4 °C, far above dew point for 20 °C/55 % air (≈ 10.7 °C). The uninsulated LSF wall at f_Rsi = 0.70 gives T_si,min = 7 + 0.70 × 13 = 16.1 °C — below the ≈ 0.75 criterion that keeps surface RH under 80 %; the bare cavity-brick wall reaches 17.5 °C (f_Rsi 0.81), a pass with little margin.

B.4 Glaser worked example — the failing case

A1 with its interior VCL in Durban summer (interior 23 °C/55 %, exterior 30 °C/75 %). Saturation by Magnus: p_sat(T) = 610.5·exp(17.269·T/(237.3+T)). Vapour pressure varies linearly with cumulative vapour resistance Z = d/vp (Z_tot = 267.8, dominated by the VCL at 250); temperature linearly with cumulative R (R_tot = 3.912). Boundary vapour pressures: p_i = 1 544 Pa, p_e = 3 180 Pa (drive is inward):

Interface	ΣR	T (°C)	p_sat (Pa)	p_v (Pa)	p/p_sat
inner surface	0.130	23.2	2848	1544	54 %
after gypsum	0.166	23.3	2859	1546	54 %
after VCL (PE)	0.167	23.3	2859	3073	107 %
after glass wool	2.417	27.3	3632	3077	84 %
after gyp sheathing	2.465	27.3	3650	3079	84 %

after EPS	3.781	29.8	4184	3180	76 %
after WRB (open)	3.782	29.8	4184	3180	76 %

The vapour pressure jumps across the high-resistance VCL and exceeds saturation on its outer face: 3 073 Pa ≥ 2 859 Pa → 107 % — condensation forms on the VCL. Removing the VCL (or moving vapour control outboard, assembly A3) drops the worst ratio to 76 %.

Appendix C — Reading the results: method and theory in brief

A plain-language companion to the numbers, for readers presenting or reviewing this study.

C.1 Clear-field R (sum of resistances, ISO 6946)

Heat through a layered wall behaves like current through series resistors: each layer contributes R = thickness ÷ conductivity (glass wool: 0.090/0.040 = 2.25 m^{2}K/W), plus two surface films (Rsi 0.13, Rse 0.13 or 0.04) for the still-air boundary layers. Air cavities do not follow d/λ because the air circulates: any unventilated cavity ≥ 25 mm is capped at R 0.18 — why B1's 50 mm cavity and B2's 90 mm bay contribute the same 0.18. The B.1 table shows the FEM reproducing these sums exactly for 1-D build-ups — the verification that engine and theory agree.

C.2 Bridged R (2-D FEM, EN ISO 10211)

Once steel crosses the insulation, heat flows in two dimensions — sideways into the stud, along it, and out — and no resistance sum can capture it. The engine meshes the actual geometry (the 0.8 mm steel resolved explicitly), solves steady-state conduction $\nabla\cdot(\lambda\nabla T) = 0$ over one repeating 600 mm cell, and integrates the boundary heat flux; U is flow ÷ (area × ΔT). The penalty is the difference from the clear field; per stud it is the linear transmittance Ψ = ΔU × 0.6 (B.2).

C.3 Why the stud penalty depends on the bay (§5.2)

The penalty is not a property of the steel but of the CONTRAST between the steel path and its surroundings. In the empty bay the stud bypasses only R 0.18 → 3 %. Filled with mineral wool it bypasses R 2.25 → 48 %, and a better wool raises the contrast further → 55 %. The continuous EPS is the one layer the stud cannot cross, cutting the relative penalty to 21 %. In one sentence: steel does not punish insulation; it punishes insulation it can short-circuit.

C.4 f_Rsi and surface condensation (§6.2)

f_Rsi = (T_si,min − T_e)/(T_i − T_e), read off the FEM field at the coldest interior point (the stud line). It is a property of the wall, independent of climate — one number serves all zones. The 0.75 criterion is calibrated to keep surface RH below 80 %, the mould-germination threshold. The §6.2 table is psychrometrics applied to it: at f 0.70 and 0 °C outside, the coldest spot is 14.0 °C; air at 20 °C/60 % RH carries 1 402 Pa against a saturation of 1 598 Pa there → 88 % surface RH. Saturation follows the Magnus relation p_sat = 610.5·e^(17.269T/(237.3+T)).

C.5 The Glaser screen (§7, EN ISO 13788)

Vapour diffuses like heat: each layer has vapour resistance Z = d/permeability; temperature varies linearly with cumulative R, vapour pressure with cumulative Z. Wherever p_v would exceed p_sat(T), vapour condenses. Both failures follow one theorem — vapour condenses where high vapour resistance coincides with low temperature. In Durban the inward drive piles vapour against the cool interior-side PE film (107 %); in a Johannesburg winter A3's exterior retarder carries most of the wall's vapour resistance at its coldest plane (119 %). Hence the study's thesis: the control layer must sit on the warm side of the dominant drive, and the dominant drive is set by the climatic zone.

C.6 The narrative arc

Resistance sums say what the wall promises (B.1) → the FEM says what the steel takes back (§5) → f_Rsi and the surface table say whether occupants get mould (§6) → Glaser says whether the structure wets from inside (§7) → the zones say which answer applies where you build (§3, §8).

References

- EN ISO 10211:2017 — Thermal bridges in building construction: heat flows and surface temperatures, detailed calculations (numerical method; validation cases Annex A — the THERMA engine reproduces cases A.1 and A.2).
- ISO 6946:2017 — Building components and elements: thermal resistance and transmittance; surface resistances, air spaces and ventilated layer rules.
- EN ISO 13788:2012 — Hygrothermal performance: internal surface temperature to avoid critical surface humidity, and interstitial condensation (Glaser method; f_Rsi criterion).
- ISO 14683 — Thermal bridges: linear thermal transmittance, simplified methods and default values.
- ISO 10456:2007 — Building materials: declared and design thermal values.
- ASHRAE Handbook — Fundamentals 2021 (SI), chapters 25–27: heat, air and moisture control; material property data; calculation examples.
- SANS 10400-XA (Energy usage in buildings; clause 4.4.3: non-masonry walls min total R 2.2 in zones 1 & 6, 1.9 in zones 2–5; masonry deemed-to-satisfy types) and SANS 204 — climatic zone classification and envelope requirements. The 2021 edition redraws the six climatic zones as eight energy zones; verify zone and limits per site.
- Technical Wall Insulation & VCL Guide (client document) — source of the four assembly sequences and the vapour-control principles tested here.
- THERMA v2.2 — Technopol 2-D finite-element thermal engine used for all temperature fields, U-values and f_Rsi in this study.

All thermal fields and U-values computed with the THERMA v2.2 engine. Substitute project-specific products and conditions and the study can be re-run directly.