

Forensic Evaluation and Condition-Based Rehabilitation of A High-Rainfall Mountain Highway: Samdrup Jongkhar–Trashigang Road, Bhutan

Deepak Baskandi

Border Roads Organisation

DOI: <https://doi.org/10.51244/IJRSI.2026.1309000065>

Received: 21 September 2026; Accepted: 26 September 2026; Published: 05 October 2026

ABSTRACT

Premature distress on high-rainfall mountain highways is rarely attributable to a single factor. This paper presents a forensic case study of Km 5.0-72.8 of the Samdrup Jongkhar-Trashigang Primary National Highway in eastern Bhutan, where two contrasting distress regimes were observed during July-September 2026: widespread cracking, potholes, and localized slippage in Km 5-40, and recurrent slippage/shoving concentrated in the loaded downhill lane, particularly at curves and gradients, in Km 40-72.8. Pavement history, distress morphology, pavement-condition indexing, falling-weight-deflectometer (FWD) response, core/material properties, interlayer bond indicators, drainage, geometry, and directional axle loading are integrated into a mechanism-based rehabilitation framework. Five homogeneous performance sections are delineated. The evidence indicates that HS-2 (Km 20-40) warrants structural strengthening, whereas HS-3 to HS-5 is governed primarily by interface/shear and moisture risk and should not be treated by uniform deep overlay. The paper proposes a staged response: remove the failed shear plane, correct moisture paths, restore interlayer bond, use dense bituminous reconstruction, and reserve polymer-modified bitumen or stone mastic asphalt for verified high-shear locations. Instrumented trial sections and quality-control hold points are recommended before corridor-wide treatment. The case demonstrates why surface condition, structural capacity, interlayer integrity, and directional traffic demand must be diagnosed separately before rehabilitation is selected.

Keywords: flexible pavement; forensic investigation; slippage; interlayer bond; moisture damage; pavement condition index; FWD; homogeneous section; rehabilitation.

INTRODUCTION

Mountain-road pavements experience loading conditions that differ materially from those on level highways. In addition to vertical wheel loads, steep grades, braking, acceleration, and sharp horizontal curvature generate substantial tangential forces. Where a bituminous overlay is imperfectly bonded to the underlying course, these forces can produce relative movement at the interface and manifest as crescent-shaped slippage cracks, shoving, or local delamination. Interlayer bonding is therefore a structural-performance variable rather than merely a construction detail. Reviews of asphalt interfaces consistently identify surface texture, cleanliness, tack-coat type and rate, temperature, compaction, and moisture as major determinants of bond performance (Yang and Li 2021; Al-Qadi et al. 2023). Field and analytical studies further show that inadequate interlayer bond can reduce fatigue performance and promote slippage under high horizontal loading (Mohammad et al. 2011; Doyle et al. 2022).

The problem is amplified in humid mountain environments. Rainfall and persistent wetness permit water to enter through cracks, pavement edges, joints, and interconnected air voids. Water can then migrate along layer interfaces, reduce adhesion, and accelerate stripping. A visible surface defect may consequently be the terminal expression of several interacting mechanisms such as; traffic-induced shear, moisture susceptibility, deficient bond, pavement age, or structural inadequacy. A rehabilitation strategy based only on resurfacing age or visual distress risks either under-treatment, by leaving the failed plane in place, or over-treatment, by strengthening pavement that remains structurally adequate.

The study corridor is part of the Samdrup Jongkhar-Trashigang Primary National Highway in eastern Bhutan. The investigated length extends from Km 5.0 to Km 72.8. Field inspections during July-September 2026 documented two spatially distinct distress populations. Km 5-40 exhibited network and longitudinal/fatigue-type cracking, potholes, and localized slippage. Km 40-72.8 exhibited recurrent slippage/shoving concentrated in the loaded downhill lane and at curves or grades, while no other major distress types were observed on this zone. Project records indicate a strong rainfall gradient, broadly from about 5,000 mm annually near Samdrup Jongkhar toward about 2,000 mm near Tshelingore (Km 72.8), together with frequent fog and prolonged wetness. Loaded gypsum trucks enter the corridor near Tshelingore and predominantly travel downhill, whereas the reverse movement is mainly empty. These characteristics create a useful natural case for separating structural deterioration from interface/shear failure.

The objectives are to (1) develop a reproducible forensic workflow for a high-rainfall hill road; (2) delineate homogeneous performance sections from condition, pavement history, and structural indicators; (3) test a working failure mechanism for recurrent downhill slippage; and (4) translate the diagnosis into section-specific rehabilitation and quality-control requirements. PCI is used as a surface-condition screening tool, not as a surrogate for structural capacity, consistent with ASTM D6433. Structural interpretation follows the principles of IRC:115-2014, in which deflection-bowl response, layer thickness, pavement condition, traffic, and subgrade information are considered jointly.

Corridor Characteristics and Pavement History

The pavement structure is heterogeneous in crust thickness, age, and resurfacing history. Available project records show bituminous macadam (BM) as the legacy binder course and semi-dense bituminous concrete (SDBC) as the wearing course. The recorded total crust is approximately 350 mm in Km 0-20, 475 mm in Km 20-40, 575 mm in Km 40-55, and 475 mm in Km 55-75. The bituminous component varies from 75 mm BM + 25 mm SDBC in the initial length to approximately 50-55 mm BM + 25 mm SDBC elsewhere. Importantly, portions of Km 40-65 were resurfaced earlier than the nominal cycle. Recurrent distress following early intervention is a forensic signal that ageing alone is unlikely to explain performance.

Table 1. Pavement history relevant to forensic interpretation.

Chainage (km)	Legacy bituminous layers (mm)	Completion	Resurfacing history	Forensic significance
0-20	75 BM + 25 SDBC	2014	2019-20; 2022-23	Older pavement; screen fatigue and moisture
20-30	55 BM + 25 SDBC	2014	2019-20; due in 2024-25 but delayed, execution planned in 2026	Delayed renewal; cracking/potholes prominent
30-40	50 BM + 25 SDBC	2014	2019-20; due in 2025-26 but delayed, execution planned in 2026	Condition/structural screening required
40-55	50 BM + 25 SDBC	2018	2021-22 (done prematurely); next due in 2027-28	Recurrent distress suggests interface/shear mechanism
55-65	50 BM + 25 SDBC	2021	2025-26 (done prematurely); next due in 2030-31	Young pavement with slippage requires forensic testing
65-75	50 BM + 25 SDBC	2025	Next cycle indicated 2030-31	Early failure would trigger construction/interface audit

Observed Distress and Forensic Hypotheses

The upper corridor (Km 40-72.8) contains crescent-shaped and longitudinal cracking, local displacement of the wearing course, and repeated shoving in the loaded downhill lane. The morphology is compatible with an interlayer shear mechanism: horizontal traffic demand exceeds the available bond or shear resistance, allowing the upper course to translate relative to the layer below. However, surface appearance cannot establish the depth of the failed plane. Similar-looking distress can arise from interface delamination or instability within the asphalt mixture itself; systematic coring and bond/shear testing are therefore required (Doyle et al. 2022).



Fig. 1. Representative slippage/shoving distress in the loaded downhill lane, Km 40-72.8.



Fig. 2. Field-observed progression from crack initiation to advanced slippage and patch repair.

The lower corridor (Km 5-40) exhibits a different distress family. Network cracking, longitudinal/fatigue-type cracking, potholes, and isolated curve-related slippage are more prevalent. The difference in distress morphology, pavement age, and intervention history supports treating the two zones as separate forensic populations. A single corridor-wide resurfacing prescription would obscure the distinction between a predominantly condition/structural problem in the lower corridor and an interface/shear problem in the upper corridor.



Fig. 3. Representative cracking distress in Km 5-40.

Investigation and Analytical Framework

The investigation is organized as a sequence of converging evidence rather than a single-test diagnosis. First, a chainage- and lane-referenced distress survey records distress type, severity, extent, wheel-path position, curve radius, gradient, drainage condition, and photographic evidence. Second, cores and test pits establish actual layer thickness and identify the physical location of any de-bonded plane. Density, air voids, visible stripping, and moisture-susceptibility testing assess material quality. Third, interlayer bond is evaluated on field cores using an appropriate direct-shear test. Direct shear is widely used because its loading mode resembles slippage/debonding, although test configuration, temperature, confinement, and specimen preparation materially affect measured strength and no universal threshold applies across methods (Haslett et al. 2023; Al-Qadi et al. 2023).

Fourth, FWD testing evaluates structural response independently of the surface-condition score. Deflection bowls are normalized to the target load and corrected for bituminous temperature and seasonal effects before back-calculation. Surface Curvature Index, $SCI = D0 - D300$, is used as a near-surface response indicator and, together with layer thickness, subgrade strength, traffic, distress, and pavement history, supports homogeneous-section delineation under IRC:115-2014. Fifth, classified traffic and axle-load surveys quantify directional heavy-vehicle demand. For this corridor, the directionality of loaded trucks is particularly important because braking and cornering generate horizontal stresses that are not represented by standard equivalent-axle calculations alone. Drainage, shoulder-edge ingress, surface texture, and geometry are audited in parallel.

Condition Profile and Homogeneous Sections

For each 5-km condition interval, PCI-equivalent values consistent with the recorded distress descriptions were assigned based on ASTM D6433 sample-unit survey. The lowest condition occurs in Km 20-35, where cracking and potholes are most extensive. Condition improves progressively beyond Km 40 even though localized slippage remains important, illustrating why an aerial surface index can understate severe but spatially concentrated interface failure.

Table 2. PCI-equivalent profile drawn for each 5 km stretch.

Chainage (km)	PCI-equivalent	Field constraint
5-10	61	Moderate cracking/local potholes
10-15	59	Moderate cracking

15-20	56	Cracking increases
20-25	40	20-30% cracking + potholes
25-30	35	Worst cracked/potholed interval
30-35	37	Widespread cracking
35-40	44	Cracking + local slippage
40-45	48	Recurrent slippage; limited general cracking
45-50	51	Slippage at curves/grades
50-55	54	Slippage; premature resurfacing history
55-60	58	Localized slippage
60-65	61	Localized slippage
65-70	64	Recent surfacing with high-shear risk
70-72.8	63	High-shear approach to Tshelingore

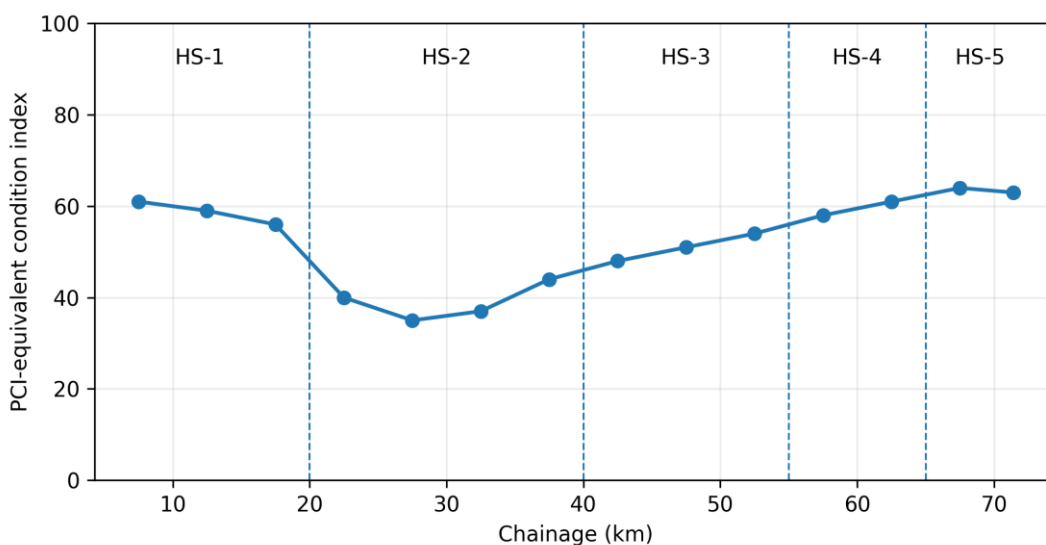


Fig. 4. PCI-equivalent profile and preliminary homogeneous performance sections.

Five preliminary homogeneous sections result: HS-1, Km 5-20; HS-2, Km 20-40; HS-3, Km 40-55; HS-4, Km 55-65; and HS-5, Km 65-72.8. The boundaries coincide with changes in distress morphology, pavement history, and age. They remain preliminary until verified against corrected FWD bowl parameters, actual layer thickness, traffic, and subgrade data. This distinction is important: PCI describes surface condition but does not directly measure structural capacity, roughness, or skid resistance (ASTM 2024).

1. Structural, Material, and Traffic Evidence

Table 3 summarizes the recorded FWD results as per the identified homogenous sections. HS-2 has the highest D0 (0.92 mm) and SCI (0.34 mm) and the lowest back-calculated bituminous, granular, and subgrade moduli, making it the principal structural concern. HS-4 and HS-5 show lower deflection and higher inferred moduli. The contrast demonstrates the practical value of homogeneous sectioning: applying the HS-2 strengthening

response uniformly to the upper corridor would likely over-treat sections whose principal deficiency is interlayer integrity rather than global structural capacity.

Table 3. Homogeneous section-wise FWD results.

Section	D0 (mm)	D300 (mm)	SCI (mm)	Ebit (MPa)	Egran (MPa)	Esg (MPa)	Interpretation
HS-1	0.62	0.40	0.22	1500	240	85	Moderate; renewal if cores sound
HS-2	0.92	0.58	0.34	1050	190	65	Highest structural concern
HS-3	0.71	0.43	0.28	1350	225	78	Moderate bowl; high interface concern
HS-4	0.64	0.39	0.25	1550	245	82	Generally adequate; local interface repair
HS-5	0.56	0.35	0.21	1750	260	90	Better response; localized high-shear treatment

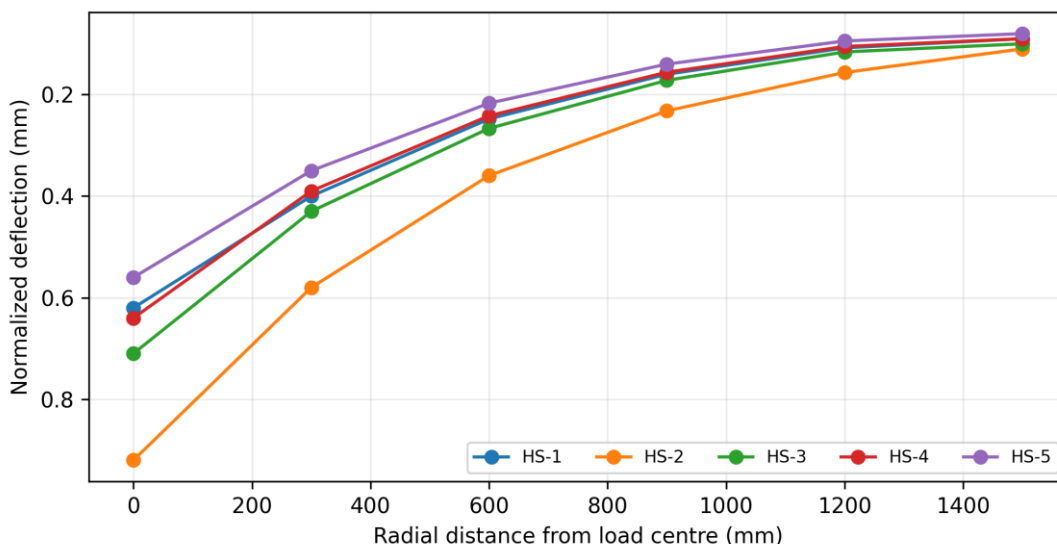


Fig. 5. Normalized FWD bowls illustrating section-specific structural response.

Core/material indicators tell a different but complementary story. HS-3 has the lowest recorded interlayer bond range (0.35-0.55 MPa) despite only moderate FWD response, matching the observed concentration of slippage. HS-2 combines relatively high air voids, visible stripping, low bond, and adverse structural response. HS-5 has the best density and bond range, so recurrent distress there would more strongly imply localized construction variability, braking geometry, or unobserved moisture paths. Literature shows that field-core bond testing is preferable for forensic work because it captures the combined effects of surface preparation, tack application, compaction, contamination, and construction variability (Doyle et al. 2022; Haslett et al. 2023).

Table 4. Homogeneous section-wise core/material scenario.

Section	Recovered layers (mm)	Density (% Gmm)	Air voids (%)	Visible stripping (%)	Bond/shear (MPa)	Interpretation
HS-1	25 SDBC / 70-75 BM	94-95	5-6	5-10	0.65-0.80	Ageing; locally reduced bond

HS-2	25 SDBC / 50-55 BM	92-94	6-8	10-20	0.45-0.65	Higher voids/moisture damage
HS-3	25 SDBC / 50 BM	93-95	5-7	10-15	0.35-0.55	Interface weakness consistent with slippage
HS-4	25 SDBC / 50 BM	94-96	4-6	5-12	0.45-0.65	Localized interface weakness
HS-5	25 SDBC / 50 BM	95-96	4-5	<10	0.60-0.80	Generally sound; audit high-shear sites

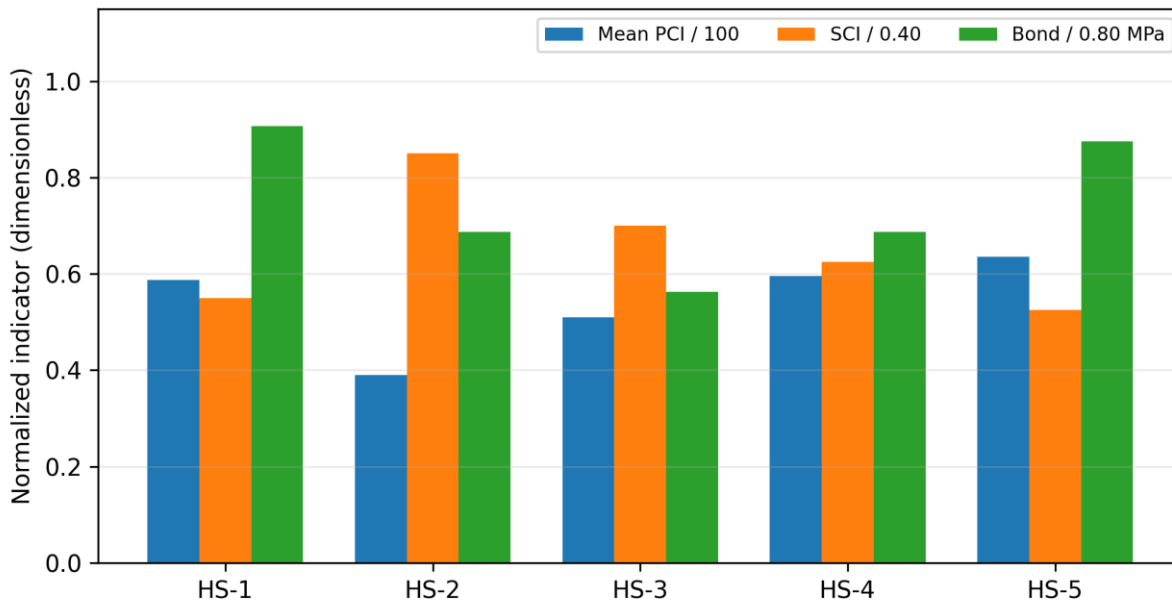


Fig. 6. Normalized comparison of surface condition, SCI, and midpoint interlayer-bond indicators by homogeneous section.

The axle-load scenario in this study places most loaded single-axle groups in the 80-110 kN range and tandem groups in the 140-190 kN range, with approximately 15% of vehicles surveyed above the stated operational/legal threshold. Their forensic role is twofold: they inform cumulative structural loading and, more importantly for the slippage hypothesis, identify the loaded downhill traffic stream that generates braking and cornering demand. Spatial coincidence between loaded direction and distress is strong circumstantial evidence, but not proof of causation; it must be tested against measured bond, gradient, curvature, pavement age, and moisture condition.

Failure Mechanism

The integrated evidence supports a working mechanism in which loaded downhill trucks generate elevated longitudinal and tangential stresses at curves and braking zones. If tack coat is inadequate, the receiving surface is dusty or wet, or moisture has degraded the interface, available shear capacity is reduced. Repeated loading then produces relative movement of the upper course, followed by crescent cracking, shoving, local delamination, and breakup. Rainfall and fog accelerate deterioration by sustaining wet conditions and transporting water through cracks and edges toward the interface. The mechanism is consistent with published evidence that slippage is associated with high horizontal force zones and that interlayer performance depends on surface condition, tack application, temperature, and moisture (Mohammad et al. 2011; Al-Qadi et al. 2023).

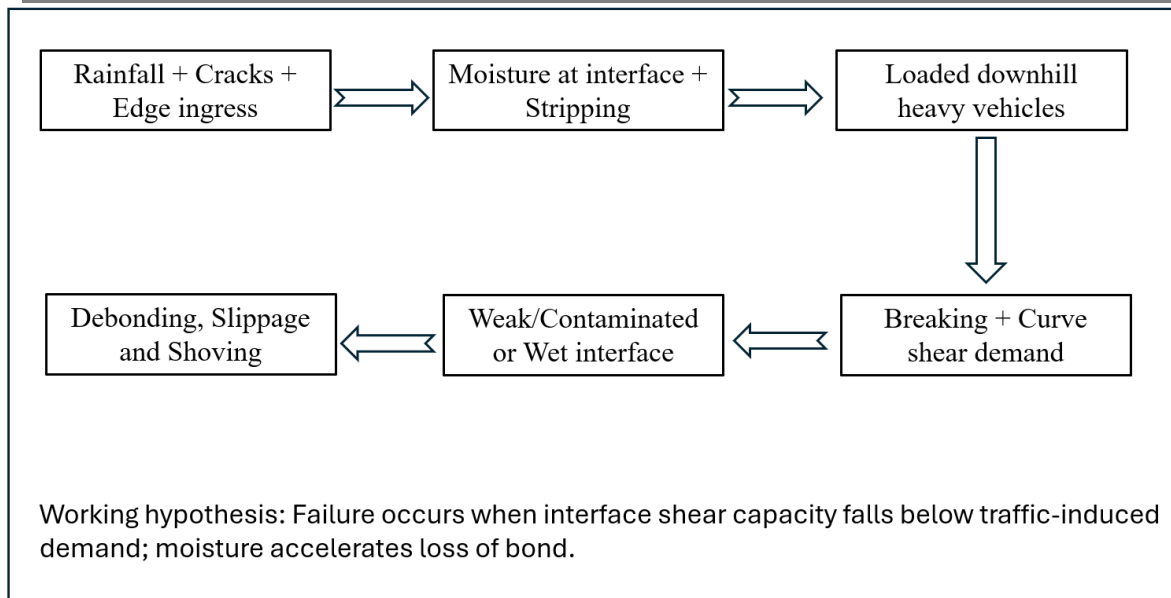


Fig. 7. Mechanism-based hypothesis for recurrent downhill slippage.

Tack coat should therefore be treated as a performance-critical interface. IRC:16-2008 specifies tack-coat practice for bonding an existing bituminous surface to a new course. The receiving surface must be clean, uniformly treated, and protected from contamination before paving. Published research also cautions against assuming that “more tack” always produces higher bond: optimum residual rate depends on surface texture, material, and test condition, and excessive binder can itself create a weak plane (Yang and Li 2021; Al-Qadi et al. 2023). Consequently, recurrent sites should be evaluated using field-core bond/shear testing rather than material type or nominal spray rate alone.

Moisture is the second principal accelerator. High air voids increase connectivity for water ingress; cracks and unsealed edges provide direct pathways; and water can migrate laterally along an interface even where the side drain appears serviceable. Density/air voids, stripping, moisture susceptibility, drainage condition, and interlayer bond should therefore be interpreted together. Dense rehabilitation mixtures can reduce future permeability, but they cannot restore a wet or stripped underlying layer that remains in place.

Distress-Cause-Investigation-Treatment Matrix

Distress	Probable cause	Investigation	Treatment
Crescent/slippage cracks; displaced wearing course	Weak/contaminated interface; braking shear; moisture	Cores at distress/control; bond/shear; tack/QC records; geometry; axle loads	Mill beyond failed plane; repair lower layer; calibrated tack; dense BC; DBM+BC if depth/structure requires
Network/fatigue cracking	Ageing; repeated load; possible structural deficiency	Formal condition survey; FWD; cores; layer moduli; drainage	Pre-treat cracks/local failures; BC if structurally sound; designed DBM+BC if deficient
Potholes/local breakup	Water ingress; stripping; local weak layer	Core/test pit; moisture/stripping; drainage outlet and edge audit	Excavate to sound material; correct water path; rebuild and seal
Recurrent failure at curves/hairpins	High tangential shear; insufficient bond or mix stability	Curve/grade/braking zone; bond test; axle loads; texture/skid review	Correct interface first; evaluate PMB-SBS BC or SMA at verified severe sites

Premature distress after resurfacing	Construction/QC deficiency or untreated underlying failure	JMF; tack rate; temperature; density; thickness; cores; bond tests	Instrumented trial section; QC hold points; rectify failed plane
Edge wetness/moss/algae	Persistent moisture; shoulder/edge ingress; shaded drainage	Drainage audit; edge cores; outlet survey	Restore drainage/shoulder seal; remove moisture-damaged material

Rehabilitation Strategy by Homogeneous Section

HS-1 (Km 5-20) should receive detailed crack and pothole pre-treatment, correction of drainage defects, and wearing-course renewal where structural verification is satisfactory. HS-2 (Km 20-40) is the priority structural section because the lowest condition profile coincides with the most adverse FWD response and material indicators. Subject to verified design inputs, a DBM + BC strengthening treatment is appropriate rather than a surface-only renewal. HS-3 (Km 40-55) is principally an interface/shear investigation zone: recurrent slippage and premature prior resurfacing make another surface patch technically weak unless the failed plane is removed and bond restored.

HS-4 (Km 55-65) is a younger pavement with localized slippage. Treatment should be driven by core bond, moisture, and high-shear geometry rather than automatic structural strengthening. HS-5 (Km 65-72.8) is the most recently surfaced section and should be treated as a construction-control sentinel: early slippage warrants immediate audit of receiving-surface preparation, tack application, compaction, drainage, and loaded-traffic braking locations. This hierarchy avoids the common error of using one overlay thickness to solve fundamentally different failure mechanisms.

For localized slippage, milling or saw-cutting should extend beyond visible distress until sound, stable material is exposed. The lower layer should be examined for stripping, deformation, trapped moisture, and delamination. Only after the substrate is dry or appropriately conditioned and free of loose material should tack coat be uniformly applied with a calibrated distributor. Dense BC is suitable where the defect is shallow; DBM + BC is required where removal extends deeper or structural design indicates strengthening. A routine seal coat over dense BC is not inherently required. Traffic opening should follow cooling, joint finishing, and acceptance checks.

At verified high-shear curves, hairpins, or braking zones, polymer-modified bitumen conforming to the applicable project specification and IS 15462 may improve deformation and shear resistance. Stone mastic asphalt under IRC:SP:79 may also be considered where severe shear/rutting demand justifies its material and construction controls. Neither treatment should be presented as a remedy for a contaminated interface, moisture-damaged substrate, or structurally inadequate pavement; the root mechanism must be corrected first.

Trial Section, Quality Control, and Monitoring

A representative downhill high-shear curve should be repaired as an instrumented trial before corridor-wide adoption. The trial record should include milling depth; condition of the exposed plane; moisture observations; layer thickness; core density and air voids; tack material, residual application rate, and distributor calibration; mix temperature; JMF compliance; rolling pattern; achieved density; joint details; and traffic-opening time. Where practicable, interface shear/bond should be measured on control and repaired cores. The trial should then be inspected after meaningful heavy-vehicle loading and at least one substantial rainfall period.

Five quality-control hold points are recommended. (1) Milling stops only after the failed plane and moisture-damaged material have been removed. (2) Tack application is prohibited until the interface is clean and suitably dry/conditioned. (3) Tack is accepted only after binder documentation, calibration, rate, and uniformity are verified. (4) Paving and compaction proceed only under approved JMF, temperature, thickness, rolling, and density controls. (5) Traffic is released only after cooling, joint finishing, surface inspection, and documentation. Project sampling and statistical acceptance should follow the applicable quality-control specification, including IRC:SP:112 where adopted.

Post-rehabilitation monitoring should be chainage- and lane-specific. A practical minimum program is pre-monsoon baseline mapping, immediate post-monsoon inspection, and annual repeat surveys of distress recurrence, patching, drainage, and representative bond/structural indicators. The key performance measure is not merely absence of visible cracking but whether the original mechanism interface movement under loaded downhill traffic has been suppressed.

Lessons Drawn

The case illustrates why fixed resurfacing cycles are insufficient for heterogeneous mountain corridors. Portions of Km 40-65 had already received premature resurfacing, yet distress recurred. If the governing mechanism is interlayer shear or moisture-induced debonding, replacing only the displaced wearing course leaves the causal plane in place. Conversely, low PCI in HS-2 may indicate widespread surface deterioration but still requires FWD and material evidence before strengthening thickness is finalized. Surface condition and structural capacity answer different engineering questions.

The analytical dataset is internally consistent with this interpretation. HS-2 combines the lowest mean PCI-equivalent condition, highest SCI, lowest back-calculated moduli, elevated air voids, and visible stripping, supporting a strengthening hypothesis. HS-3, by contrast, has only moderate deflection response but the lowest interlayer-bond range and repeated slippage, supporting interface-focused rehabilitation. HS-4 and HS-5 would therefore be over-treated by a uniform deep overlay.

The strongest field relationship is directional: loaded gypsum trucks travel downhill from Tshelingore, and recurrent slippage is concentrated in the same lane, particularly at curves and grades. A stronger causal analysis would geo-reference every distress occurrence and test distress frequency or severity against gradient, curve radius, braking location, axle group/load, measured bond strength, pavement age, and moisture condition. A generalized linear or logistic model could then quantify whether geometry and bond remain significant after controlling for age and pavement structure. Such analysis would convert the present forensic association into a statistically testable mechanism.

The broader implication is transferable. Mountain-road rehabilitation should proceed from mechanism to treatment, not from distress label to standard overlay. Surface-condition indices are useful for network screening; FWD establishes structural response; cores identify the failed plane and material condition; bond testing assesses interlayer integrity; and traffic/geometry explain the applied shear demand. Agreement among these independent evidence streams provides a more defensible basis for treatment selection than any single indicator.

CONCLUSIONS

The investigated corridor contains at least two distinct distress regimes and should not receive a single uniform rehabilitation treatment.

- Km 5-40 is dominated by cracking, potholes, and age/structural concerns; HS-2 is the priority for verified FWD-based strengthening design.
- Km 40-72.8 is most consistent with an interface/shear–moisture mechanism amplified by loaded downhill traffic at curves and gradients. The hypothesis is further verified with core, bond, moisture, geometry, and axle-load records.
- PCI/PCR is suitable for surface-condition screening and preliminary homogeneous sectioning but cannot replace structural evaluation.
- Durable slippage repair requires removal of the failed shear plane, correction of moisture paths, a clean and adequately bonded interface, and dense, properly compacted reconstruction.
- PMB-SBS and SMA are selective performance enhancements for verified high-shear sites, not substitutes for correcting failed bond, wet substrate, or structural deficiency.

- Instrumented trial sections, explicit QC hold points, and post-monsoon monitoring should precede corridor-wide treatment.

Disclaimer

The interpretations are presented for technical study and do not constitute an official specification or approval of a particular rehabilitation treatment. Final design and execution shall follow current contract specifications, organizational requirements, and the controlled editions of IRC, MoRTH, BIS, ASTM, and project standards adopted for the work.

REFERENCES

1. Al-Qadi, I. L., et al. 2023. "Shear properties and various mechanical tests in the interface zone of asphalt layers: A review." *Infrastructures* 8 (3): 48. <https://doi.org/10.3390/infrastructures8030048>.
2. ASTM International. 2024. Standard practice for roads and parking lots pavement condition index surveys. ASTM D6433-24. West Conshohocken, PA: ASTM International. <https://doi.org/10.1520/D6433-24>.
3. BIS (Bureau of Indian Standards). 2019. Polymer modified bitumen (PMB)—Specification. IS 15462:2019. New Delhi: BIS.
4. Doyle, J. D., Z. P. Robinson, S. A. Stache, and B. C. Cox. 2022. "Consideration of a tack coat bond strength test to minimize the potential for slippage failures on flexible airfield pavements." In *Transportation Research Board 101st Annual Meeting*. Washington, DC.
5. Haslett, K. E., Z. Robinson, and J. Wielinski. 2023. "Comparison of bond strength evaluation methods between pavement layers." *Transportation Research Record* 2677 (5): 399–414. <https://doi.org/10.1177/03611981221141434>.
6. IRC (Indian Roads Congress). 2008. Standard specifications and code of practice for prime and tack coat. IRC:16-2008. New Delhi: IRC.
7. IRC (Indian Roads Congress). 2009. Specifications for dense graded bituminous mixes. IRC:111-2009. New Delhi: IRC.
8. IRC (Indian Roads Congress). 2014. Guidelines for structural evaluation and strengthening of flexible road pavements using falling weight deflectometer (FWD) technique. IRC:115-2014. New Delhi: IRC.
9. IRC (Indian Roads Congress). 2017. Manual for quality control in road and bridge works. IRC:SP:112-2017. New Delhi: IRC.
10. IRC (Indian Roads Congress). 2023a. Code of practice for maintenance of bituminous road surfaces. IRC:82-2023. New Delhi: IRC.
11. IRC (Indian Roads Congress). 2023b. Specifications for stone matrix asphalt. 1st Rev. IRC:SP:79-2023. New Delhi: IRC.
12. MoRTH (Ministry of Road Transport and Highways). 2013. Specifications for road and bridge works. 5th Rev. New Delhi: Indian Roads Congress.
13. Mohammad, L. N., M. M. Hassan, and N. Patel. 2011. "Effects of shear bond characteristics of tack coats on pavement performance at the interface." *Transportation Research Record* 2209 (1): 1–8. <https://doi.org/10.3141/2209-01>.
14. Yang, K., and R. Li. 2021. "Characterization of bonding property in asphalt pavement interlayer: A review." *Journal of Traffic and Transportation Engineering (English Edition)* 8 (3): 374–387.