



Organic-Tainted Mineral Soils, Part II: Operationalising Neutralisation-First Stabilisation from Laboratory to Field

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ABSTRACT

Organic-tainted mineral soils (OTMS) represent an intermediate geotechnical condition in which the soil remains predominantly mineral and physically compactable, yet reactive organic matter can interfere with conventional lime- and cement-based stabilisation. Part I established the mechanistic basis of OTMS treatability and introduced neutralisation demand (ND) as the chemical requirement that must be satisfied before effective structural cementation can develop. This Part II operationalises that framework through a laboratory-to-field verification protocol. The proposed procedure separates chemical conditioning from structural binder contribution, defines candidate approaches for determining ND, and establishes controlled treatment comparisons based on equivalent structural-binder dosage. Laboratory qualification integrates soil characterisation, conditioning response, compaction behaviour, strength, soaked bearing capacity, stiffness, volumetric stability and durability. Treatments progressing beyond laboratory qualification are then subjected to field verification of constructability, treatment uniformity, moisture control and retained performance. Particular emphasis is placed on distinguishing the chemical input consumed in controlling organic interference from that subsequently contributing to cementitious strengthening. The resulting framework links ND determination, JKR-aligned engineering performance and variability-based field acceptance to support decisions on conventional treatment, neutralisation-first treatment, further optimisation or rejection of shallow stabilisation. The contribution is therefore an operational and experimentally testable protocol rather than a report of completed laboratory or field validation.

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1. INTRODUCTION

Part I of this twin-paper study defined organic-tainted mineral soil (OTMS) as a distinct geotechnical treatability category: A predominantly mineral, workable soil in which reactive organic matter can impair conventional chemical stabilisation. It introduced neutralisation demand as the governing treatability variable, arguing that neither organic content nor immediate pH adequately represents interference with binder response. The central premise was therefore that organic chemical demand must first be sufficiently satisfied before reliable cementitious strengthening can develop.

Part II addresses the operational question arising from that premise. Neutralisation demand is useful only if it can be

measured reproducibly, incorporated into treatment design and verified against engineering performance. Qiao et al. [1] showed that humic-matter behaviour is governed by its functional characteristics and interactions with soil minerals, reinforcing the limitations of organic content as a stand-alone indicator. Luo and Zhang [2] similarly reported differing effects of humic and fulvic acids on strength and durability, while Sindete et al. [3] demonstrated that elevated pH does not necessarily correspond to meaningful strength development. These findings reinforce the need to distinguish chemical compatibility from structural performance.

For road applications, treatment must extend beyond dry strength to compactability, achievable density, soaked bearing

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capacity, stiffness, durability and field uniformity. Such combined assessment is increasingly adopted for stabilised subgrades [4]. OTMS adds a further challenge because part of the added chemical capacity may be consumed by organic interference before contributing to cementation. Binder dosage alone may therefore overstate structural effectiveness and conceal vulnerability under wetting or field variability.

This paper consequently develops a staged procedure for determining neutralisation demand, separating conditioning from structural binder contribution, establishing road-specific performance criteria, translating laboratory findings to field verification, and defining a performance-based treatment framework. It does not prescribe a universal neutraliser or binder dosage; rather, it establishes how OTMS treatment should be designed, compared, verified and, where adequate performance cannot be demonstrated, rejected. The two parts therefore address complementary but distinct questions. Part I establishes the conceptual and mechanistic basis of OTMS, organic interference and the ND treatability boundary; Part II addresses how those concepts can be translated into measurable laboratory procedures, controlled treatment comparisons, road-relevant performance verification and field acceptance logic. Part II is accordingly an operational protocol and framework paper rather than a critical review or a report of completed experimental validation. No experimental dataset is divided between the two manuscripts.

2. OPERATIONAL FRAMEWORK AND RESEARCH PROPOSITIONS

Building on Part I, this section translates neutralisation demand into an operational framework for OTMS treatment. It defines how chemical interference is conditioned, distinguished from structural cementation, and evaluated against binder efficiency and road-relevant performance within the OTMS treatability boundary. In the sections that follow, indicative wording is used for findings established in the cited literature, whereas conditional and prescriptive wording denotes proposed OTMS procedures and hypotheses requiring experimental verification.

2.1 From Neutralisation Demand to Treatment Design

Section 1 established the need to convert Part I's treatability concept into a reproducible engineering procedure. OTMS stabilisation is therefore treated through six functional stages: Delineation of the treatable layer, characterisation of its mineral-organic-moisture condition, neutralisation of interfering chemical demand, activation of binder-compatible reactions, cementation of the soil skeleton and verification of retained performance. Although one material may ultimately fulfil several functions, these roles should first be isolated experimentally.

This separation is essential for dosage interpretation. Conventional stabilisation often increases binder content until a target response is achieved, but for OTMS this can obscure whether additional binder is overcoming organic interference or contributing to structural bonding. Joy et al. [5] reported that optimised chemical addition improved lime treatment of organic-rich clay, whereas excessive dosage reduced the benefit. Mohammed et al. [6] likewise found that cement response depended on the balance between organic content and binder dosage, while Mostafa et al. [7] observed distinct compaction, CBR, UCS and resilient-modulus responses among stabiliser combinations. Neutralisation-first design therefore conditions chemical interference before defining the structural binder requirement.

2.2 Operational Definition of Neutralisation Demand

For Part II, neutralisation demand is operationally defined as the minimum conditioning input required to overcome the dominant acidity and buffering imposed by reactive organic matter, satisfy the initial chemical demand for available alkalinity and calcium, and establish a sustained binder-compatible pore-fluid condition after controlled equilibration. ND is therefore defined from chemical response independently of subsequent engineering strength. For solid conditioning agents, it may be reported as conditioning-agent dosage expressed as percentage of dry-soil mass; where an alkali-titration approach is used, the corresponding demand may additionally be expressed as equivalent alkalinity demand ($\text{mmol OH}^-/\text{kg dry soil}$). Meng et al. [8] showed that organic matter continued to affect hydration and strength development in activated slag-treated sediment, while Long et al. [9] recorded non-linear modifier responses as organic contamination increased. These findings support a response-based rather than content-based threshold.

Persistence is equally important. A conditioning response should remain compatible after the prescribed equilibration and water-exposure stages rather than merely producing a transient increase in pH. Johnney et al. [10] showed that initial improvement in treated organic marine clay does not necessarily imply sustained longer-term response. Engineering performance is therefore used as a subsequent verification of the geotechnical relevance of ND, not as part of its chemical definition. At an equivalent structural-binder dosage, improved soaked CBR, retained strength, stiffness or durability would indicate that prior conditioning has increased the fraction of binder contributing productively to cementation.

2.3 Parametric Evaluation of Treatment Response

The experimental programme is structured around five parameter-response relationships that test whether neutralisation-first treatment improves binder efficiency, retained strength and moisture resistance within the OTMS treatability boundary. Table 1 summarises the principal comparisons and their geotechnical significance.

Table 1. Parametric propositions for evaluating OTMS treatment response

Proposition	Principal comparison	Expected response	Geotechnical significance
P1	Neutralisation-first vs. cement-only at equal structural-binder dosage	Higher soaked CBR and retained strength	Tests improved binder efficiency
P2	Neutralisation demand and equilibrated alkalinity vs. TOC and immediate pH	Stronger association with performance	Tests predictive value of response-based indicators

Proposition	Principal comparison	Expected response	Geotechnical significance
P3	Increasing reactive organic interference within OTMS	Greater conditioning benefit up to the treatability boundary	Defines viable treatment range
P4	Neutralisation-first blended binder vs. cement-dominant treatment	Comparable soaked performance at lower cement demand	Tests binder optimisation potential
P5	Dry strength vs. post-wetting response	Rejection where moisture sensitivity persists	Prevents acceptance based on dry UCS alone

The propositions deliberately prioritise retained road performance rather than peak dry strength. Soaked CBR and durability remain essential indicators of service suitability in stabilised pavement soils [11], while properly activated blended systems can maintain favourable bearing and durability performance at reduced cement contents [12]. P3 and P5 establish the principal decision boundaries: Treatment remains viable only while mineral-soil behaviour dominates, and satisfactory dry strength cannot compensate for persistent moisture sensitivity. This is particularly important because wetting-drying can progressively weaken stabilised soil structure [13]. The parametric programme therefore tests whether OTMS treatment is structurally efficient, moisture-resistant and geotechnically acceptable.

3. LABORATORY VERIFICATION PROGRAMME AND JKR PERFORMANCE ALIGNMENT

The laboratory programme translates the operational framework into controlled comparisons aligned with Malaysian road practice. For the present JKR-linked investigation, the purpose is not merely to optimise a binder mixture, but to determine whether neutralisation demand can distinguish OTMS that can be treated reliably from material that should remain unsuitable for shallow stabilisation.

3.1 Material Selection and Baseline Characterisation

Representative OTMS should be sampled across the affected layer to capture variations in depth, natural moisture, drainage, mineral grading and organic occurrence, since spatial heterogeneity may govern both neutralisation demand and treatment response. Baseline testing should include particle-size distribution, Atterberg limits, moisture content, specific gravity, LOI, pH, electrical conductivity, compaction characteristics, untreated UCS and four-day soaked CBR. Selected specimens should additionally be assessed for buffering capacity, reactive organic fractions, calcium interaction, mineralogy and compressibility.

For operational screening, the assessment should proceed sequentially. First, deposits dominated by peat fabric, excessive natural moisture, deep compressibility or settlement-controlled behaviour should be excluded from the shallow-OTMS framework. Second, the remaining material should be confirmed as mineral-dominated and physically workable using grading, plasticity, moisture-density and compaction characteristics. Third, LOI or TOC and initial pH should be used as screening indicators of possible organic interference rather than definitive treatability limits. Fourth, soils showing suspected interference should undergo assessment of buffering behaviour, equilibrated chemistry and, where practicable, calcium interaction. Finally, only materials retaining credible shallow-treatment potential should progress to ND

determination, the controlled treatment matrix and JKR-aligned engineering verification.

This characterisation is particularly relevant to the JKR context. JKR/SPJ/2020-S2 [14] classifies organic clay, organic silt and material exceeding 2.5% LOI as unsuitable, yet permits deficient material within the upper 300 mm of subgrade to be stabilised where it is suitable to do so; otherwise removal and replacement are required. The present study addresses this decision boundary rather than assuming that all organic-tainted material is either treatable or unsuitable. Stabilisation response is known to depend jointly on soil properties, binder dosage, curing and loading condition [15]. The objective is therefore to establish a minimum practical characterisation set capable of distinguishing chemically disruptive OTMS from mineral soil that retains credible treatment potential.

3.2 Determination of Neutralisation Demand

Neutralisation demand should be determined through an incremental conditioning series using the selected alkaline or calcium-bearing agent. A common dry-soil basis should be used for all mixtures, with increasing conditioner dosages applied at predefined increments. For every dosage, the immediate chemical response should first be recorded, followed by measurement after a fixed equilibration period and a prescribed water-exposure stage. The same liquid-to-solid ratio, mixing procedure, temperature and equilibration duration should be maintained throughout a test series. The principal response variables should include pH and, where analytically available, buffering response and exchangeable or soluble calcium. Plasticity, moisture demand, workability and volumetric response should be monitored concurrently because a chemically effective dosage that impairs handling, compaction or dimensional stability remains unsuitable for road application.

The critical dosage is not that producing the highest initial pH, but the lowest dosage that establishes a persistent binder-compatible condition. Jiang et al. [16] showed that pH, exchangeable calcium and related chemical states continue to evolve during lime treatment, demonstrating the limitations of instantaneous measurements. As demonstrated by Regasa et al. [17], stabiliser dosage should be verified through compaction, soaked CBR, swelling and workability rather than pH alone. Neutralisation demand should therefore be established from sustained chemical response coupled with measurable geotechnical improvement, converting stabiliser screening from simple dosage selection into a treatment-efficiency criterion.

For a given soil-conditioner system, the candidate ND is taken as the lowest conditioning dosage that satisfies the predefined binder-compatible chemical criterion and retains that condition after equilibration and water exposure. It should be reported as conditioner dosage (% dry-soil mass) together with the test-specific target criterion, dosage increment, liquid-

to-solid ratio, equilibration period and number of replicates; where titration is used, equivalent alkalinity demand may additionally be reported in mmol OH⁻/kg dry soil. These protocol variables must be stated explicitly because ND is material- and treatment-specific rather than a universal pH or dosage threshold. Engineering verification is subsequently undertaken at equal structural-binder dosage to determine whether satisfying ND translates into improved binder efficiency and retained geotechnical performance.

3.3 Treatment Matrix and Mixing Protocol

The experimental matrix separates chemical conditioning from structural cementation by changing one treatment function

at a time (Table 2). Series A provides the untreated OTMS baseline, while Series B represents conventional cement treatment. Series C is the key conditioning-only control, showing whether neutralisation alters pH stability, workability, plasticity, compaction behaviour or early mechanical response before cement is added. Series D then combines the same conditioning stage with cement. Holding the structural cement dosage constant in Series B and D allows any improvement in Series D to be attributed more confidently to enhanced binder efficiency rather than greater cement addition.

Table 2. Proposed laboratory treatment matrix for OTMS

Series	Conditioning	Structural binder	Primary purpose
A	None	None	Establish untreated baseline
B	None	Cement	Represent conventional treatment
C	Neutraliser	None	Isolate conditioning response
D	Neutraliser	Cement	Test neutralisation-first treatment
E	Neutraliser	Cement-GGBFS/blended binder	Assess cement-reduction potential
F	Alternative neutraliser	Selected binder	Compare chemical compatibility
G	Advanced conditioning	Selected binder	Examine severe-interference cases

The B-C-D comparison forms the core experimental test. Series C identifies the contribution of conditioning alone; C-D quantifies the additional benefit of cementation after conditioning; and B-D determines whether prior neutralisation improves performance at an equivalent cement dosage. Series E examines whether this improved chemical environment can support a lower-cement blended binder, while Series F and G test neutraliser compatibility and the upper treatment boundary. Such controlled comparisons are preferable to unrelated binder percentages because soil-cement performance depends jointly on binder chemistry, dosage, soil properties, mixing and curing conditions [18]. Besides, Petti et al. [19] emphasised the value of corresponding cement-only controls when distinguishing structural from chemo-mechanical effects.

Mixing sequence should also be treated experimentally. Immediate binder addition should be compared with controlled mellowing after conditioning. The selected interval must allow acidity, buffering and calcium demand to stabilise without causing excessive drying, carbonation or loss of workability. The laboratory programme should therefore define the treatment composition, mellowing duration and moisture-control window required for translation to the JKR field trial.

3.4 Road-Relevant Performance Verification

Treatment qualification should be anchored to JKR requirements but extend beyond minimum compliance. Under JKR/SPJ/2018-S18 [20], stabilised material for paved-road subgrade should achieve a four-day soaked CBR of at least 12% at 95% of maximum dry density and a seven-day UCS of at least 0.3 MPa, with the stabilising-agent application rate determined through laboratory testing. These values provide baseline thresholds but do not, by themselves, demonstrate OTMS treatability.

Specimens should therefore be assessed at early, intermediate and longer curing ages using UCS, soaked and unsoaked CBR, strength retention, moisture-density response, volumetric stability and wetting-drying durability. Resilient modulus or repeated-load response should be included for mixtures progressing toward field validation. Microstructural analysis should be limited to representative control, successful and failed mixtures to explain, rather than replace, geotechnical performance. Shi et al. [21] showed that environmental cycling can alter both strength and pore structure in cement-fly ash-treated organic soil, reinforcing the need to assess durability beyond initial strength.

Acceptance should consequently be stricter than simple CBR or UCS attainment. A mixture meeting JKR thresholds may still be unsuitable if moisture sensitivity, volumetric instability or treatment inconsistency persists. By contrast, OTMS that satisfies neutralisation demand, meets the relevant JKR criteria and retains performance after wetting provides stronger evidence of geotechnical treatability. The laboratory programme therefore supports a clear decision to advance treatment to field validation, optimise the design further, or reject shallow stabilisation in favour of removal or alternative ground improvement.

4. LABORATORY-TO-FIELD VERIFICATION

Laboratory qualification establishes treatment potential; field validation determines whether that potential survives construction variability, moisture exposure and scale. For the JKR application, the field trial must therefore verify both geotechnical performance and construction reproducibility under representative roadwork conditions.

4.1 Field-Trial Configuration

The controlled road trial should comprise comparable sections of untreated OTMS, conventional cement treatment, neutralisation-first cement treatment and the selected blended-binder system. Wherever practicable, the sections should occupy the same geotechnical unit with similar treatment depth, drainage exposure and initial moisture condition. Baseline sampling should confirm material comparability before treatment. Furthermore, construction should use the spreading, pulverising, mixing, watering and compaction equipment intended for JKR implementation. This is critical because field performance depends on lift thickness, moisture condition, compaction sequence and treatment uniformity. Chen et al. [22] showed that such variables materially influence field compaction and stiffness, while Ayers et al. [23] reported measurable variations in density, UCS and elastic modulus even within controlled full-scale stabilisation trials.

The untreated and cement-only sections provide field baselines. The neutralisation-first section determines whether laboratory improvements persist at construction scale, while the blended-binder section evaluates whether reduced Portland cement demand remains viable under actual mixing and compaction conditions.

4.2 Construction Control and Field Verification

Field quality control should verify neutraliser spreading, pulverisation, treatment depth, mellowing duration, moisture condition, binder distribution and achieved density. Field pH should be measured at multiple locations and depths to confirm reproduction of the laboratory-defined conditioning state, but should remain a process-control indicator rather than an independent acceptance criterion. Also, mechanical verification should include early trafficking capability, dynamic cone penetration resistance and, where appropriate, field CBR or plate response. Testing should extend longitudinally and transversely across each section to identify local deficiencies. Subedi et al. [24] noted that field-prepared soil-cement specimens can capture construction-related variability and provide mechanical properties comparable with recovered cores, supporting their use in quality assurance.

In addition, post-rainfall or controlled-wetting behaviour is equally important because moisture changes within subgrades can be substantial and spatially variable, directly affecting bearing response [25]. Field cores or block samples should therefore be recovered from representative and low-performing locations for strength and selected microstructural assessment. Laboratory-to-field strength and stiffness ratios should also be established as project-specific measures of treatment transferability, rather than assumed correction factors.

4.3 Field Acceptance Logic

Field acceptance should not rely on a single average strength or stiffness value. Each trial section should first satisfy the applicable JKR requirements established in Section 3, after which acceptance should consider individual test-location compliance, spatial coefficient of variation, minimum retained performance, density uniformity, post-wetting response and the absence of persistent weak pockets. This variability-based approach is particularly important for OTMS because local differences in reactive organic matter may produce corresponding variations in neutralisation demand. Savila et al. [26] reported coefficients of variation of 0.12-0.61 in recovered stabilised-soil strength despite satisfactory site-average values, showing that acceptable means can conceal substantial local variability. Forsman et al. [27] likewise demonstrated that in-situ strength development and variability must be assessed directly rather than inferred from laboratory values.

Three outcomes are therefore proposed (Figure 1). Treatment is accepted where JKR requirements are consistently satisfied and moisture-resistant performance is reproducible; optimised and retrialled where deficiencies appear correctable through dosage, mixing, moisture or compaction control; and rejected where weak zones or moisture sensitivity persist despite adequate construction control. Field validation thus provides the final OTMS treatability test: whether chemically conditioned, structurally adequate and moisture-resistant behaviour can be reproduced across the treated road section, not merely demonstrated in selected specimens.

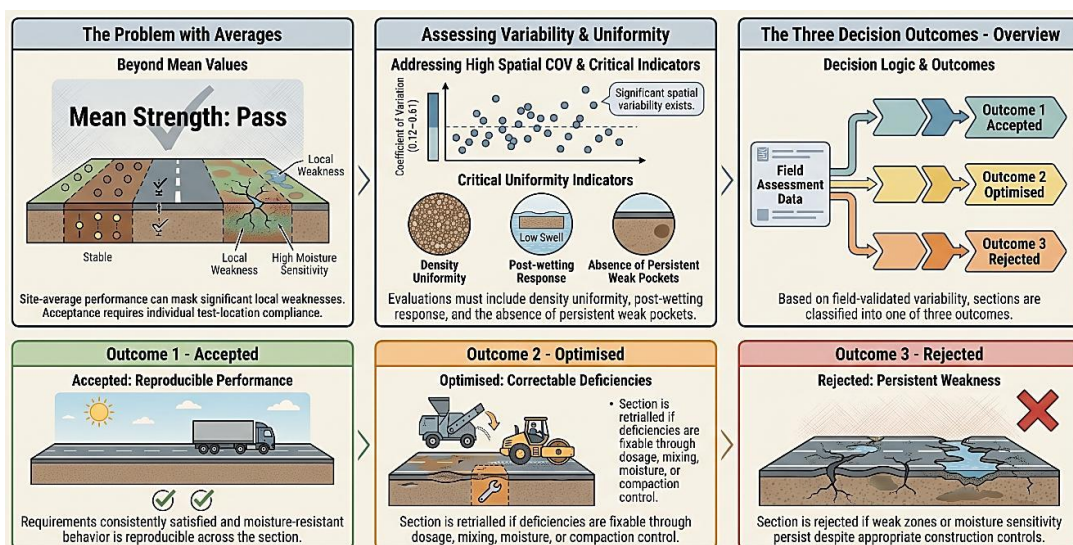


Fig. 1. The Field Acceptance Logic for OTMS treatment – shift from simple average values to a variability-based decision framework for stabilised subgrade road sections. Source: Authors' conceptualisation.

5. PERFORMANCE-BASED TREATABILITY AND IMPLEMENTATION FRAMEWORK

The laboratory and field procedures developed in Sections 3 and 4 ultimately require a clear engineering decision: Whether OTMS can be treated reliably, requires advanced conditioning, or should be excluded from shallow stabilisation. The proposed framework therefore classifies treatability by demonstrated response rather than by a universal organic-content or binder threshold.

Table 3. Proposed performance-based OTMS treatability categories

Category	Indicative condition	Treatment pathway
OTMS-A	Low organic interference	Conventional binder screening
OTMS-B	Moderate, controllable interference	Neutralisation-first treatment
OTMS-C	Severe but shallow interference	Advanced conditioning assessment
Excluded	Peat fabric, deep compression or excessive moisture	Replacement or deeper ground improvement

The boundaries are intentionally performance-based. Zri et al. [28] showed that comparable binder systems can produce markedly different road-performance outcomes where material composition differs, supporting the need for a treatment envelope rather than unrestricted binder escalation. On a similar note, Abdul Azam et al. [29] showed that peat-type materials remain strongly governed by compressibility and settlement despite strength improvement. Classification should therefore integrate neutralisation demand, sustained alkalinity, soaked CBR, retained strength, compressibility, treatment depth and construction feasibility.

5.2 Acceptance and Rejection Boundaries

Acceptance for neutralisation-first treatment requires convergence of chemical compatibility, retained geotechnical performance and field reproducibility. Conditioning should improve structural-binder efficiency at equivalent dosage, while soaked and cyclic performance, volumetric stability, density and mixing uniformity remain satisfactory. Dosage should therefore be selected from treatment response rather than maximum additive content. This is in line with findings by Razali et al. [30], that lime-treated residual soil exhibits an optimum rather than continuously improving response; for OTMS, the preferred neutralisation dosage is similarly the minimum practical level that sustains compatible chemistry and produces measurable structural benefit.

Shallow treatment should be rejected where neutralisation demand becomes excessive, alkalinity or calcium availability cannot be sustained, wetting causes unacceptable deterioration, field variability remains uncontrolled, or compressibility and settlement govern behaviour. The acceptance boundary is therefore not a single numerical threshold, but a performance envelope within which chemical conditioning, structural response and construction reproducibility collectively justify shallow stabilisation.

5.3 Implementation Relevance to Road Agencies

For road agencies, the framework addresses two opposing risks: unnecessary removal of potentially treatable mineral soil and acceptance of chemically incompatible treatment based on

5.1 Treatment Categories and Decision Variables

Four treatment categories are proposed (Table 3). OTMS-A represents mineral-dominated soil with limited chemical interference, for which conventional binder screening may remain adequate. OTMS-B defines the principal neutralisation-first domain, where interference is measurable but controllable at a practicable conditioning dosage. OTMS-C represents severe but shallow interference requiring advanced conditioning assessment. Materials governed by peat fabric, deep compressibility or excessive moisture are excluded because their dominant behaviour cannot be resolved through shallow chemical stabilisation.

satisfactory dry strength. The former increases excavation, imported fill, haulage and disposal, while the latter transfers moisture sensitivity and weak treatment zones into pavement service. Implementation should therefore integrate mechanical performance, constructability and resource efficiency. Yu et al. [31] demonstrated this broader approach by validating a calcium-carbide-residue-based stabiliser through laboratory strength and bearing tests, environmental assessment and full-scale highway application, confirming that treatment viability must extend beyond specimen-scale strength. Ghimire and Bheemasetti [32] similarly showed that reduced-cement pavement mixtures can retain wetting-drying performance while lowering environmental and economic burdens.

Environmental acceptability should form an additional prerequisite for field implementation. Candidate conditioning systems should be screened for leachability and for the potential migration of high-pH pore water and dissolved ions, mobilisation of dissolved organic matter or trace constituents, groundwater proximity, and drainage or runoff pathways. Where these pathways are credible, baseline and post-treatment monitoring should be incorporated into the field-verification programme. Such assessment is particularly relevant where OTMS occurs adjacent to agricultural land, surface drainage or shallow groundwater. As the present paper reports no environmental-monitoring dataset, these requirements are proposed as safeguards for implementation rather than as evidence of quantified environmental performance.

For JKR and comparable road authorities, the proposed framework adds a treatability decision layer to specification-based acceptance by distinguishing when OTMS should undergo conventional treatment, neutralisation-first stabilisation, advanced conditioning or removal. Its purpose is not to broaden acceptance of organic-bearing soils, but to improve discrimination between reusable OTMS and material whose chemical or geotechnical limitations make shallow stabilisation unreliable. In this context, neutralisation demand becomes a practical risk-management parameter linking material characterisation, binder efficiency, field quality and pavement performance.

6. CONCLUSION

This Part II operationalises the OTMS treatability framework established in Part I by translating organic interference and neutralisation demand into an experimentally testable and field-verifiable treatment protocol. ND is defined from sustained chemical compatibility rather than engineering strength, while equivalent-binder controls provide the subsequent means of determining whether conditioning improves structural-binder efficiency. For road applications, qualification should extend beyond dry UCS to soaked performance, retained strength, durability, volumetric stability and construction reproducibility. The proposed framework therefore does not prescribe a universal neutraliser, dosage or acceptance value; instead, it establishes a performance-based pathway for conventional treatment, neutralisation-first treatment, further optimisation or exclusion. Part I establishes the conceptual and mechanistic treatability boundary, whereas Part II provides the operational means by which that boundary can subsequently be tested. Ultimately, OTMS should be retained for shallow treatment only where chemical interference can be controlled sufficiently for durable cementation to be developed and reproducibly achieved under field conditions.

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