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JUSTIFICATION OF METHODS FOR IMPROVING THE TRANSPORT AND OPERATIONAL PERFORMANCE OF LOCAL ROADS

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Abstract: The paper justifies improvement of a local road through an integrated water-subgrade-base-pavement system. The submitted graduation-project materials report, for the km 0-3 section of road 4K96, a 2025 mean elastic modulus of 142 MPa, a skid-resistance coefficient of 0.32-0.38, longitudinal cracking of 104 m/km, and alligator cracking of 137 m²/km. These values were not independently remeasured for this paper, and that limitation is stated explicitly. The engineering strategy prioritises drainage restoration, local treatment of weak subgrade, calculated use of geosynthetics only where supported by testing, base reprofiling, shoulder strengthening, and controlled pavement renewal. An illustrative runoff calculation shows how drainage capacity should be checked against the contributing catchment. The proposed sequence is intended to extend service life and reduce repeated rehabilitation expenditure while retaining pavement materials that remain serviceable.

Keywords: local road, subgrade, base course, drainage, shoulder, geosynthetic, service life

Introduction

On local roads, pavement deterioration is often addressed by renewing the surface. However, if water continues to enter the subgrade, even a strengthened new pavement operates on nonuniform support. Moisture reduces the bearing capacity of the soil, displaces base particles, and causes deformation and potholes to reappear near the pavement edge [7, 8].

For the km 0-3 section of road 4K96, the aim of the study is to evaluate the subgrade, base, pavement, shoulders, and drainage elements as one system and to justify a staged solution that extends service life. The project geometry and pavement structure are based on ShNQ 2.05.02-23 and MQN 46-2021, while diagnostics follow IQN 05-11 [1-3].

The stability of a local road depends on a system broader than the pavement surface alone. When rainfall or irrigation water enters the base through the shoulder, fine particles migrate, layer stiffness decreases, and permanent deformation beneath the wheel paths increases. Surface renewal during the dry season may temporarily conceal this process, but cracking and potholes reappear during the next wet period [7-9].

From this perspective, extending road service life combines two directions: restoring the load-bearing capacity of the existing structure and controlling the routes by which moisture enters it. The first concerns the subgrade, base, and pavement layers; the second concerns the cross-sectional profile, shoulders, ditches, culverts, and discharge channels. If the two directions are designed separately, a strengthened layer may become saturated again, or effective drainage may remain ineffective over weak support.

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Materials and methods

The graduation project and its diagnostic appendix for the km 0-3 section of road 4K96 were used as the source material [11]. The document reports that a visual survey, plate-load testing at five locations, SRT measurements, and laboratory analysis of cores were performed in September-October 2025. This paper analyses those results as source data but does not independently verify the inspection reports or instrument-calibration records. The reported cross section comprises two 3.5 m traffic lanes, a 7.0 m paved carriageway, and 2.5 m shoulders on each side.

The cause-and-effect analysis is traced from the water source through the subgrade and base to pavement distress. Moisture content, soil type, density, and CBR are cross-checked in the subgrade; gradation, thickness, and compaction are evaluated in the base; and cores, roughness, and skid resistance are examined in the pavement [2, 4]. Geotextile, geogrid, or stabilisation is not specified automatically; its function must be justified by field testing and structural analysis [6, 10].

Diagnostic data are separated into chainage-based thematic maps: moisture and water traces, pavement distress, deflection or elastic modulus, skid resistance, shoulder elevation, and drainage assets. Overlaying these layers can strengthen a cause-and-effect hypothesis; for example, alligator cracking that coincides with a low-lying wet segment may indicate moisture-related support loss. The hypothesis is subsequently tested using soil moisture, CBR, cores, and levelling surveys.

The catchment boundary is determined from a topographic survey, and runoff entering from external land is calculated separately from runoff generated on the carriageway. Before a ditch or culvert section is selected, its outlet, the risk of downstream erosion, and the likelihood of sediment blockage are evaluated [5]. Adequate geometric capacity alone does not guarantee operational reliability; access for cleaning and seasonal inspection must also be provided.

Table 1

Diagnostic indicators reported for the km 0-3 section of road 4K96

Indicator	Graduation-project value	Adopted criterion	Engineering interpretation
Elastic modulus	142 MPa	≥180 MPa	Examine the need to strengthen the supporting layers
Skid-resistance coefficient	0.32-0.38	≥0.45	Improve wet-surface safety and surface texture
Longitudinal cracking	104 m/km	30 m/km	Identify the cracking mechanism and eliminate water-ingress paths
Transverse cracking	61 m/km	20 m/km	Select treatment for thermal and reflective cracking

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Indicator	Graduation-project value	Adopted criterion	Engineering interpretation
Alligator cracking	137 m²/km	50 m²/km	Investigate fatigue and base weakness by segment
Potholes	8 per km	2 per km	Replace failed material locally down to a sound layer

Source: the 2025 diagnostic table in the graduation project by Mo'minov T.O. [11]; the values were not independently remeasured for this paper.

Main section

The reported elastic modulus is below the adopted criterion of 180 MPa, while skid resistance does not reach the 0.45 criterion [11]. The distribution of cracking and potholes indicates that the problem may not be confined to the surface course. The first stage should therefore restore crossfall in depressions, clean ditches and culverts, and protect discharge channels from erosion. A ditch without a functioning outlet retains water; longitudinal continuity must be verified through hydraulic analysis [5].

In the second stage, weak subgrade locations are opened locally. Moist fine-grained soil is dried or stabilised with lime, cement, or another binder where justified by design; if the depth of nonuniform support is substantial, unsuitable material is replaced. A separation geotextile limits the intrusion of base material into the soil, while a geogrid may act as a tensile reinforcement that distributes deformation. Neither replaces drainage.

The third stage restores the base and pavement. Base-course gradation, moisture content, and density are controlled layer by layer. Pavement type and thickness are selected according to the design load, subgrade properties, and the potential to retain sound existing layers [1, 2]. The shoulder should provide lateral support to the pavement edge without retaining water on the carriageway; its elevation, slope, and material stability are therefore coordinated.

The method used to improve a weak subgrade depends on the soil. Where moisture is high but the material composition is suitable, drying and recompaction may be sufficient. In plastic fine-grained soil, stabilisation with lime, cement, or a blended binder is specified from a laboratory mix design and a field trial. Organic or excessively wet material is replaced to an economically justified depth [10].

A geosynthetic is selected according to its required function rather than its product name. A separation geotextile limits the intrusion of base particles into the subgrade; a filtration geotextile allows water to pass while retaining particles; and a geogrid distributes deformation through tensile reinforcement. An unsuitable opening size or inadequate tensile strength can create problems during filtration and installation. The specification is therefore linked to calculated performance requirements.

Shoulder material and density are selected to provide lateral support to the pavement edge and to withstand emergency vehicle encroachment. A shoulder above the carriageway traps water, whereas a low shoulder creates an edge drop-off. Elevation difference, crossfall, density, and the runoff path are consequently checked together during acceptance.

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Results

Table 1 relates the principal diagnostic indicators in the graduation project to engineering decisions. The mean value E = 142 MPa is 21.1% below the adopted criterion of 180 MPa; the SRT range of 0.32-0.38 is 15.6-28.9% below the criterion of 0.45. These differences demonstrate the need to examine the support capacity of the base and subgrade by segment before renewing the pavement surface [11].

Operational performance is not evaluated solely from the smooth appearance of the surface immediately after construction. Acceptance testing measures cross-sectional profile, density, layer thickness, roughness, and skid resistance; after one rainy season, water ponding, shoulder settlement, edge cracking, and culvert outlets are reinspected. Preventive ditch cleaning and early crack sealing can extend the interval between major rehabilitation works [5, 9].

The indicators reported in the graduation project can establish priorities but do not directly determine the final structural thickness. The ratio of E = 142 MPa to the 180 MPa criterion is 78.9%. The lower and upper limits of the SRT range are 71.1% and 84.4% of the 0.45 criterion, respectively. These ratios indicate that support capacity and wet-surface safety require separate interventions [11].

Segments with the greatest deviation from the adopted cracking criterion are first investigated in relation to water sources and supporting layers. The location with the highest distress quantity is not automatically assumed to require the deepest rehabilitation. Where deflection and moisture are within acceptable limits, crack treatment and surface protection may be sufficient; where support is weak, surface treatment is supplemented by base rehabilitation.

Table 2

Staged improvement and monitoring of the road 4K96 section

Priority intervention	**Supporting evidence**	**Required outcome**	**Monitoring**
Restore drainage	Depressions, water traces, and ditch and culvert condition	A continuous runoff path protected against erosion	Inspection after major rainfall
Treat weak subgrade	Moisture, CBR, density, and E value	Uniform support with the calculated bearing capacity	Construction testing and seasonal settlement monitoring
Reprofile and compact the base	Gradation, thickness, and density	Design profile and a stable layer	Layer-by-layer acceptance testing
Strengthen shoulders and edges	Elevation difference, crossfall, and edge cracking	Lateral support that does not retain water	Erosion and edge-drop monitoring after rainfall

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Priority intervention	Supporting evidence	Required outcome	Monitoring
Renew the pavement	Cores, skid resistance, roughness, and crack map	Safe texture and the designed pavement structure	Periodic SRT, roughness, and crack surveys

Source: compiled by the author from the graduation-project diagnostics and references on drainage and pavement structures [1-11].

Technical and computational analysis

For a small catchment, preliminary surface-runoff discharge may be estimated using the rational formula [5]:

$$Q = 2.78 \cdot \psi \cdot i \cdot F$$

where Q is design discharge, L/s; ψ is the runoff coefficient; i is design rainfall intensity, mm/h; and F is catchment area, ha. In a methodological example only, if F = 0.06 ha, i = 80 mm/h, and ψ = 0.75, the resulting discharge is Q ≈ 10.0 L/s. These values are not observations from road 4K96. In an actual design, rainfall is obtained from local climatic data and F from a topographic survey; the capacity of the ditch or culvert is then verified by hydraulic calculation.

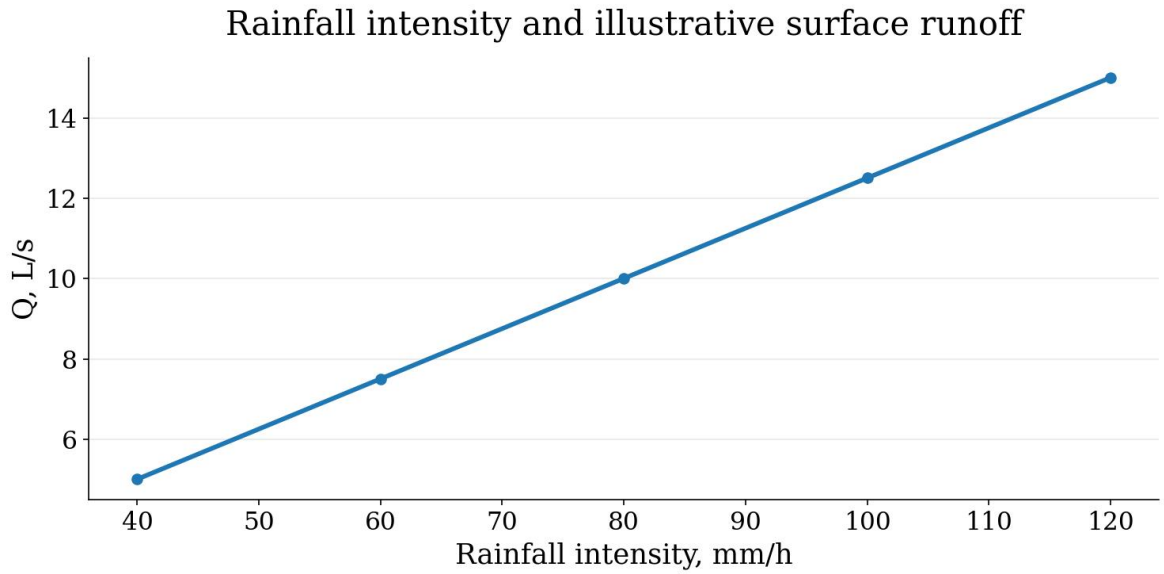


Figure 1 - Methodological calculation for F = 0.06 ha and ψ = 0.75

Note: the graph does not represent observed runoff from the road 4K96 section.

The criterion for reducing rehabilitation expenditure is not the lowest initial cost, but life-cycle cost expressed as $C^{Lc} = C_0 + \Sigma(C_t/(1+r)^t)$. Here C_0 is initial construction cost, C_t is maintenance or rehabilitation cost in year t, and r is the discount rate. Until local prices and intervention periods have been established, reporting a numerical result from the formula would not be scientifically justified.

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The result of the rational formula is directly proportional to rainfall intensity. In the methodological scenario where F = 0.06 ha and ψ = 0.75 are constant, increasing i from 40 to 120 mm/h increases Q from approximately 5.0 to 15.0 L/s. The graph demonstrates that an unjustifiably low local rainfall intensity can lead to selection of an inadequate ditch or culvert capacity.

In life-cycle analysis, the benefit of drainage restoration is not represented solely by the direct cost of a separate construction layer, but by postponement of repeated rehabilitation. If drainage works increase initial cost yet delay premature pavement failure by several years, discounted total cost may decrease. Demonstrating this effect requires at least two scenarios based on local quantities, annual maintenance costs, and rehabilitation intervals.

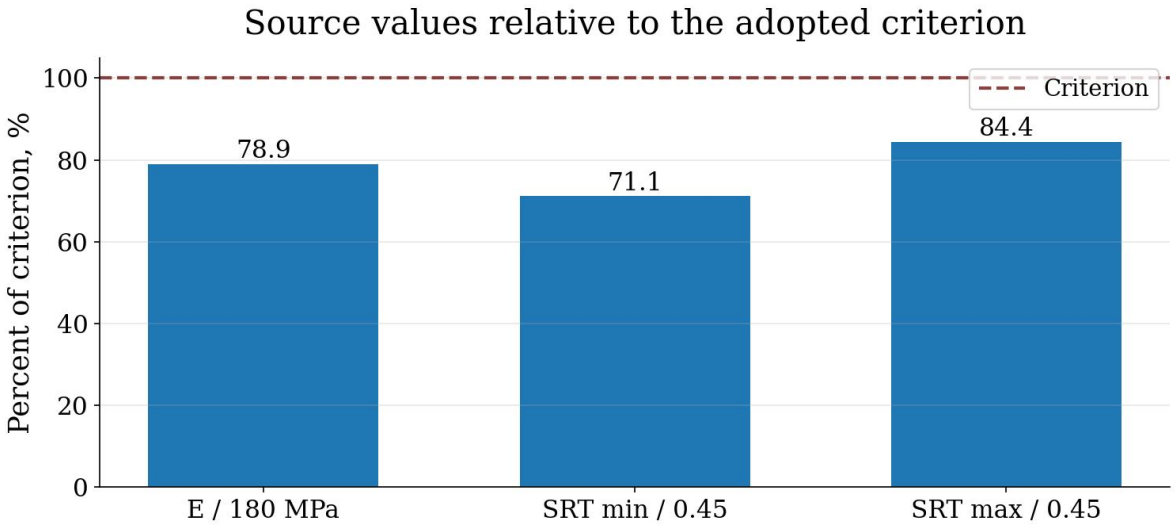


Figure 2 - Relative assessment of the E and SRT values reported in the source

Source: diagnostic table in the graduation project by Mo'minov T.O. [11]; values were not independently remeasured.

Discussion

The main advantage of the proposed sequence is that drainage, subgrade, and pavement are considered within one cause-and-effect system. At the same time, the diagnostic values in the graduation project were not independently remeasured for this paper. Before they are converted into final design decisions, they must be confirmed using instrument-calibration records, chainage coordinates, soil-laboratory results, and repeated field measurements.

Operational monitoring should be seasonal. After rehabilitation, runoff paths, culvert outlets, and shoulder erosion are inspected during the first major rainfall; after the winter-spring period, cracking and settlement are remapped. These observations support the subsequent maintenance plan and permit evaluation of the actual performance of the applied stabilisation or geosynthetic solution.

Conclusions and practical recommendations

1. The mean value E = 142 MPa reported in the graduation-project materials is 21.1% below the adopted criterion of 180 MPa, indicating the need for segment-based investigation of supporting layers before rehabilitation.

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http://houghtonstreetreview.com/index.php/hsr

2. The reported SRT values of 0.32-0.38 are below the 0.45 criterion; pavement texture and rapid removal of surface water should therefore be integral components of the road-safety solution.

3. The distribution of cracking and potholes requires cause-oriented rehabilitation of drainage, base, and subgrade rather than simple sealing of the pavement surface.

4. The shoulder should provide lateral support to the carriageway while being constructed at an elevation and crossfall that do not retain water on the pavement.

5. Geosynthetic type, stabilisation treatment, and final pavement thickness should be adopted as design values only on the basis of calibrated testing, subgrade CBR, hydraulic analysis, and life-cycle cost.

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