International Journal of Scientific Research in Engineering & Technology
Special Issue, Volume 5, Issue 4 (July-August 2025), PP: 95-99.
https://www.doi.org/10.59256/ijsreat.20250504C16
Recent Advances in Civil Engineering and Technology (REACT)-2025
www.ijsreat.com ISSN No: 2583-1240

Road Safety Audit of Paliyekkara-Nenmanikkara Road

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To Cite this Article: *Renjith R[1], Ananya M T[2], Amity Joy[3], Adith Sivaraman T[4], Ashish R[5], "Road Safety Audit of Paliyekkara-Nenmanikkara Road", International Journal of Scientific Research in Engineering & Technology Volume 05, Issue 04, July-August 2025, PP: 95-99.*

Abstract: *This project report presents a comprehensive Road Safety Audit (RSA) conducted on the Paliyekkara- Nenmanikkara road, a 4.1 km stretch prone to accidents due to its challenging geometry and high traffic volume. The study involved detailed surveys, including preliminary road assessments and traffic volumetric analyses, alongside laboratory and field tests such as Sieve analysis, Dynamic Cone Penetration (DCP) test, Light compaction test, California Bearing Ratio (CBR) test, and roughness measurement using MERLIN. These tests evaluated soil properties, bearing strength, and pavement conditions to inform remedial measures. The proposed solutions include optimized pavement layer thicknesses, a side drainage system, and culvert improvements, visualized using SketchUp software. The project aims to enhance road safety by addressing identified hazards and providing actionable recommendations for infrastructure upgrades.*

Key Word: *Road Safety Audit (RSA), Pavement Design, Traffic Volumetric Survey, Remedial Measures*

I.INTRODUCTION

Road safety remains a critical global concern, with millions of fatalities and injuries reported annually due to traffic accidents. In India, road crashes account for a significant portion of these incidents, emphasizing the urgent need for proactive measures to enhance roadway safety. One such measure is the Road Safety Audit (RSA), a systematic evaluation of existing or planned roads to identify potential hazards and recommend corrective actions. This study focuses on conducting an RSA for the Paliyekkara-Nenmanikkara Road, a 4.1 km stretch in Thrissur, Kerala, characterized by sharp turns, poor drainage, and a high accident rate. The audit aims to assess geometric design, traffic conditions, and pavement integrity while proposing remedial measures to improve safety for all road users. Previous research underscores the importance of RSAs in mitigating accidents. Olawale et al. (2021) compared RSA practices across African nations, highlighting the role of multidisciplinary teams in identifying safety gaps. Similarly, Anandaraj and Vijaya Baskaran (2020) applied Babkov's empirical method to evaluate highways, demonstrating how RSA-driven interventions can reduce accidents. Huang et al. (2020) reviewed global RSA methodologies, emphasizing the need for standardized protocols to address challenges like data scarcity and resource limitations. Wagner et al. (2020) further stressed the importance of RSAs in low- and middle-income countries, where infrastructure often lacks robust safety features. The Paliyekkara-Nenmanikkara Road presents unique challenges, including inadequate drainage, mixed pavement types, and heavy vehicle traffic exceeding design capacity. These issues align with findings by Malaghan et al. (2020), who linked road roughness and geometric inconsistencies to increased accident risks. Our study employs field tests—such as Dynamic Cone Penetration (DCP), sieve analysis, and International Roughness Index (IRI) measurements—to evaluate subgrade strength, soil quality, and surface conditions. These methods, validated by Kieyn and Van Heerden's CBR correlation, ensure data-driven recommendations. The significance of this study lies in its holistic approach, combining empirical testing with modern tools like SketchUp for 3D modeling of proposed improvements. By addressing drainage deficiencies, pavement failures, and traffic management, the audit aligns with IRC SP:72- 2015 guidelines to enhance durability and safety. The findings contribute to the broader discourse on RSA efficacy, particularly in rural contexts, and offer a replicable framework for similar roadways in developing regions. Ultimately, this research seeks to bridge the gap between theoretical safety standards and practical implementation, fostering safer, more resilient transportation networks.

II.GEOGRAPHY AND RECONNAISSANCE OF THE PALIYEKKARA-NENMANIKKARA ROAD

The Paliyekkara-Nenmanikkara Road spans 4.1 km in Thrissur District, Kerala, connecting Manali Bridge Road and Thalore. A portion of the road traverses the Manali River, making drainage a critical concern. The terrain features mixed elevations, with some sections steeply descending (e.g., a 15 m drop near Chainage 0/0), while others are flat or curved. The road passes through agricultural lands, residential areas, and forested zones, with boundaries marked by canals, compound walls, and open drains. A reconnaissance survey revealed inconsistent pavement types (tar, concrete, and interlocked blocks), poor drainage (a mix of earthen and concrete side drains), and obstructions like transformers and signboards along the shoulder.

Table 1 Geometric Design Parameters

Parameter	Existing Conditions	Proposed Standards (IRC Guidelines)
Carriageway Width	3.5 m – 12 m (varies)	3.75 m (uniform)
Shoulder Width	0.65 m (paved) + earthen (inconsistent)	0.65 m (paved) on both sides
Roadway Width	Non-uniform (4 m – 12 m)	8 m (including shoulders)
Side Slopes	Unstable in sections	Max 2H:1V (stone-pitched if steeper)
Curve Design	Sharp bends, poor signage	Speed breakers, reflective markers
Pavement Thickness	150 mm (existing)	175 mm GSB + 75 mm WBM + 20 mm OGPC
Drainage Specifications	Partial concrete drains	0.8 m × 0.65 m RCC side drains

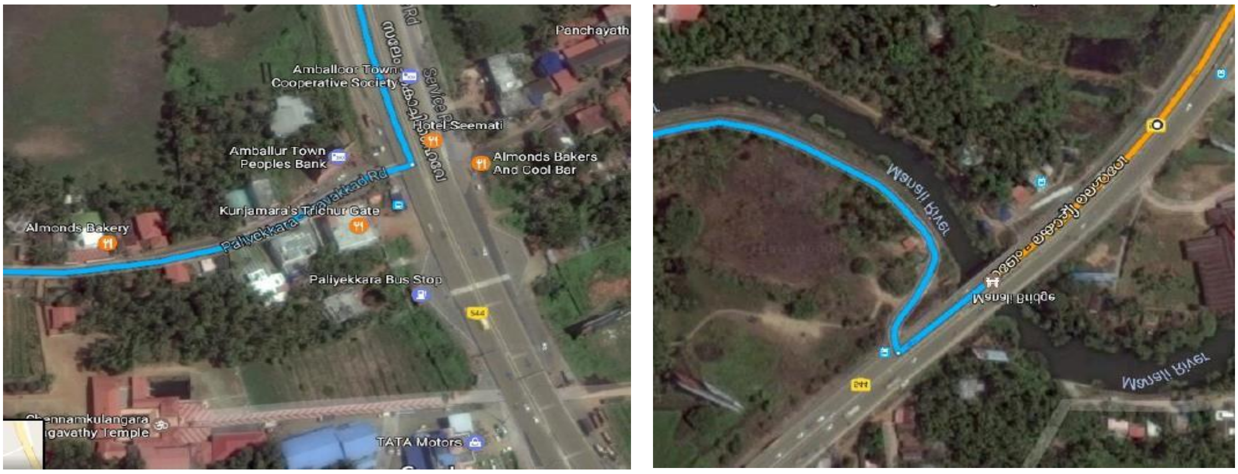

Figure 1 Entry point and exit point of Road to NH 544

Preliminary Survey Observation

The preliminary survey of the Paliyekkara-Nenmanikkara Road was conducted through systematic field inspections to evaluate existing conditions and identify necessary improvements. This essential first step in road safety auditing examined multiple critical aspects including carriageway geometry, pavement conditions, drainage systems, and traffic safety features. The survey revealed significant variations in road width, with sections ranging from 3.5m to 12m, along with inconsistent shoulder conditions that compromised safety. Various pavement types were documented, with 60% tar surfaces showing distresses like potholes and cracking, while concrete and interlocked sections exhibited different failure patterns. Drainage inadequacies were particularly notable, with 60% of the road relying on ineffective earthen drains. Geometric design flaws, including sharp curves and steep slopes without proper safety measures, were identified as major risk factors. The findings from this comprehensive assessment are presented in two structured formats: Table 1 provides an overview of general observations and recommended solutions, while Table 2 details specific defect locations with corresponding remedial measures. These results form the foundation for developing targeted rehabilitation strategies to enhance the road's safety and durability in accordance with IRC standards. The preliminary survey data serves as a crucial baseline for subsequent detailed engineering studies and implementation planning.

Table 1 Defect locations with corresponding remedial measures.

Category	Observations	Issues Identified	Recommendations
Carriageway Width	3.5m (narrowest) to 12m (widest), average 4.5-5.5m	Inconsistent widths cause traffic bottlenecks	Standardize to 3.75m width with 0.65m paved shoulders
Shoulder Conditions	0.65m paved (sporadic), earthen sections, encroachments	Erosion, lack of emergency space	Construct continuous 0.65m paved shoulders, remove encroachments

Pavement Types	60% tar (flexible), 30% concrete (rigid), 10% interlocked blocks	Potholes, cracking, polished aggregates	175mm GSB + 75mm WBM + 20mm OGPC overlay
Drainage System	40% concrete drains (blocked/damaged), 60% earthen drains	Waterlogging, poor drainage	Install RCC side drains (0.8m × 0.65m)
Geometric Design	Sharp curves, steep slopes (15m drop at Chainage 0/0), poor sight distances	Accident risks, skidding hazards	Add warning signs, superelevation, and stabilize slopes
Traffic Safety	Missing signage, no speed breakers at curves	High accident potential	Install reflective markers, speed breakers, and curve warning signs
Subgrade Quality	CBR values 7-15% (poor to marginal)	Pavement failures, alligator cracking	Strengthen subgrade with granular material

Table 3 Specific chainage and corresponding defect locations with remedial measures

Chainage	Observed Defect	Pavement Type	Proposed Solution
0/350	Alligator cracking	Flexible (Tar)	Full-depth repair with 175mm GSB + fresh overlay
1/500	Potholes	Flexible (Tar)	Patching with DBM + BC layers
1/325-1/375	Paver separation/water pooling	Interlocked	Re-lay blocks with proper slope and joint filling
2/850	Raveling	Flexible (Tar)	Surface renewal with 20mm OGPC
0/900	Polished aggregates	Rigid (Concrete)	Texturing for skid resistance

III.LABORATORY AND FIELD-TESTING PROCEDURES AND RESULTS

Sieve Analysis (Laboratory Test)

The sieve analysis was conducted to evaluate the particle size distribution of the subgrade soil, which is critical for assessing its suitability for road construction. Representative soil samples were collected from two chainages (0+800 and 1+500) along the Paliyekkara-Nenmanikkara Road. The samples were first oven-dried at 110°C for 24 hours to remove all moisture content. The dried soil was then mechanically shaken through a series of Indian Standard (IS) sieves arranged in descending order of mesh size (4.75mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm, and 90µm) for 15 minutes using a sieve shaker. The material retained on each sieve was carefully weighed, and the percentage retained as well as the cumulative percentage passing (finer) were calculated.

Results: The analysis revealed that the soil was poorly graded, with a uniformity coefficient (Cu) of 2.5 (D_{10} = 0.2mm, D_{60} = 0.5mm). More than 50% of the particles were retained on the 150µm sieve, indicating a low fines content. Poorly graded soils typically require stabilization to improve their engineering properties for road construction.

Dynamic Cone Penetrometer (DCP) Test (Field Test)

The DCP test was performed to determine the in-situ strength of the subgrade by measuring its California Bearing Ratio (CBR) equivalent. The test was conducted at two critical locations (Chainage 0+800 and 1+500) to assess variations in subgrade strength. The DCP apparatus, consisting of an 8kg hammer dropped from a height of 575mm onto a cone penetrometer, was used. The penetration depth was recorded after every five blows until a total depth of 350mm was achieved. The penetration rate (mm/blow) was calculated, and the corresponding CBR value was determined using the empirical correlation graph developed by Kleyn and Van Heerden.

Results: The test results showed significant variation in subgrade strength along the road. At Chainage 0+800, the penetration rate was 7.6 mm/blow, corresponding to a CBR of 7%, indicating weak subgrade. At Chainage 1+500, the penetration rate improved to 4.4 mm/blow, yielding a CBR of 15%, which is within the acceptable range for flexible pavement construction as per IRC 37 guidelines.

Light Compaction Test (Laboratory Test)

The light compaction test (Standard Proctor Test) was conducted to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the subgrade soil, essential for achieving proper compaction during construction. Soil samples were prepared at varying moisture contents (3% to 20%). Each sample was compacted in three layers within a standard mold (1000 cm^3 volume) using a 2.6kg rammer, with each layer receiving 25 blows. The wet density of each compacted sample was measured, and the dry density was calculated after determining the moisture content. A graph of dry density versus moisture content was plotted to identify the OMC and MDD.

Results: The test revealed an OMC of 6% and an MDD of 1.8 g/cc. The relatively low MDD indicated that the subgrade soil was loose and required mechanical stabilization, such as the addition of granular material or chemical stabilizers, to achieve the desired compaction and strength.

Soaked CBR Test (Laboratory Test)

The soaked CBR test was performed to evaluate the subgrade strength under worst-case moisture conditions, simulating prolonged rainfall or flooding. Soil samples were compacted at OMC in CBR molds and subjected to a surcharge load of 4.54kg to simulate the overburden pressure from pavement layers. The samples were immersed in water for 96 hours to achieve full saturation. After soaking, a penetration piston was driven into thesoil at a rate of 1.25mm/min, and the load required for 2.5mm and 5mm penetration was recorded. The CBR value was calculated as the ratio of the measured load to the standard load for crushed stone at the same penetration depth.

Results: The soaked CBR value was 7%, which is marginal for pavement construction as per IRC 37. This result confirmed the need for a robust sub-base layer (e.g., 175mm Granular Sub-Base) to mitigate the effects of water infiltration and ensure long-term pavement performance.

MERLIN Roughness Survey (Field Test)

The MERLIN (Machine for Evaluating Roughness Using Low-Cost Instrumentation) device was used to measure the International Roughness Index (IRI) of the road surface, which quantifies ride quality. The device was wheeled manually over a 500m stretch, and its built-in sensors recorded vertical displacements caused by surface irregularities. The data was plotted as a profile graph, and the IRI was calculated using the formula: IRI=0.593+0.0471× (Cumulative Displacement) IRI=0.593+0.0471× (Cumulative Displacement)

Results: The average IRI value was 1.11 m/km, which is below the acceptable threshold of 1.5 m/km for rural roads. While the road surface was relatively smooth, localized roughness was observed near potholes and cracked sections, necessitating targeted repairs.

IV.RESULTS AND DISCUSSION

IRC: SP:72-Compliant Geometric Design Recommendations for Paliyekkara-Nenmanikkara Road

The proposed pavement design follows IRC: SP: 72-2015 standards, incorporating a multi-layered structure to address variable subgrade conditions (CBR 7-15%) and T6 traffic loads (0.3-0.6 Msa). The subgrade is stabilized with a 150-175mm Granular Sub-Base (GSB) (Grade III aggregates, 53mm max size) at a 3% cross-slope, compacted to 98% MDD for sections with CBR <10%, as per Clause 5.4.2. The base course consists of 75mm WBM Grade III or CRMB, while the binder course uses 70mm Dense Bituminous Macadam (DBM) with 60/70 penetration bitumen, both sloped at 2.5-3% for drainage. The wearing course includes 30mm Bituminous Concrete (BC) or OGPC, meeting Marshall Density requirements (Clause 6.3, IRC: 111).

For shoulders, a 0.65m paved section (compacted gravel/WBM) and 0.5m earthen extension (stabilized soil) are provided, both sloped 4% outward to channel water into 0.6m × 0.6m RCC side drains (IRC: SP:42), designed with a 1:500 longitudinal slope and 0.15m freeboard. Geometric alignment adheres to IRC:73, featuring a 3.75m carriageway (single-lane), 50m minimum curve radius with 4% superelevation, and 100mm-high speed breakers at 150m intervals near habitations (IRC:99). Road markings use 150mm thermoplastic centrelines (IRC:35) for enhanced visibility.

Quality control mandates 97% subgrade compaction, abrasion-resistant aggregates (<40%), and post- construction roughness checks (IRI <1.5 m/km). This holistic design ensures durability, flood resilience, and compliance with rural road standards.

V.CONCLUSIONS

The Road Safety Audit (RSA) of the Paliyekkara-Nenmanikkara Road has systematically identified critical safety and structural deficiencies through field surveys, laboratory tests, and IRC-standard compliance checks. Key findings revealed inconsistent carriageway widths (3.5–12m), poor subgrade strength (CBR 7–15%), and inadequate drainage, contributing to potholes, cracking, and flooding risks. The proposed IRC:SP:72- compliant design addresses these issues with a 175mm GSB layer for weak subgrades, 75mm WBM/CRMB base, and 30mm BC/OGPC wearing course, ensuring durability under T6 traffic (0.3–0.6 Msa). Geometric improvements include standardized 3.75m carriageways, 0.65m paved shoulders, and 0.6m × 0.6m RCC side drains to mitigate waterlogging.

Safety enhancements—such as speed breakers (100mm height), retroreflective road markings, and curve warning signs—align with IRC:99 and IRC:67. The integration of MERLIN-measured roughness (IRI 1.11 m/km) and DCP-based CBR validation ensures data-driven rehabilitation. This RSA underscores the urgency of subgrade stabilization, drainage upgrades, and pavement reinforcement to reduce accidents and extend service life. Future work should prioritize periodic audits and community awareness programs to sustain safety gains. By adhering to IRC standards, the project sets a replicable model for rural road rehabilitation in flood- prone regions.

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