Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 02 , February - 2026

Sustainable and Low-Cost Road Construction Techniques in Hilly Regions of Jharkhand: A Case Study of Gumla District.

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Abstract - This study focuses on sustainable and low-cost road construction techniques in the hilly regions of Gumla district, Jharkhand, particularly in the Bishunpur and Chainpur blocks. Gumla is characterized by uneven terrain, lateritic soil, dense forest cover, and an average annual rainfall of about 1300 mm, which creates challenges such as slope instability, soil erosion, and drainage problems during road construction. The research examines the use of locally available materials, lime-stabilized soil, gabion retaining walls, bio-engineering methods (such as grass turfing and plantation), and improved drainage systems to reduce construction costs and enhance durability. The case study findings indicate that adopting these sustainable and low-cost techniques can reduce overall project costs by approximately 20–25% while improving environmental protection and long-term road performance in the hilly areas of Gumla district.

INTRODUCTION:

Gumla district of Jharkhand is a predominantly hilly and tribal region with uneven terrain, lateritic soil, dense forests, and high annual rainfall (about 1200–1300 mm). These geographical conditions create major challenges in road construction, such as slope instability, soil erosion, poor drainage, and frequent pavement damage during the monsoon season. As a result, many rural roads in blocks like Bishunpur and Chainpur suffer from low durability and high maintenance costs.

This case study focuses on the need for sustainable and low-cost road construction techniques in the hilly areas of Gumla district. Improving rural road connectivity is essential for access to education, healthcare, markets, and overall socio-economic development. Therefore, adopting locally suitable, cost-effective, and environmentally friendly construction methods has become necessary to ensure long-term performance and sustainable infrastructure development in the region.

OBJECTIVES OF STUDY:

1. To analyze the geographical and soil conditions of the hilly areas of Gumla district affecting road construction.
2. To identify the major challenges faced in constructing and maintaining roads in Gumla's hilly terrain.
3. To evaluate sustainable and low-cost road construction techniques suitable for the region.
4. To study the use of locally available materials to reduce construction cost.
5. To suggest practical and economical solutions for improving rural road connectivity in Gumla district.

Major challenges faced in road construction in the hilly regions of Gumla District.

S. No.	Challenge	Situation in Gumla (Case Study Area)	**Impact on Road Construction**
1	Hilly & Undulating Terrain	Elevation ranges from 450–900 m with steep slopes and sharp curves	High cutting and filling cost, slope instability, design complexity
2	Soil Condition	Predominantly lateritic and red soil, weak during monsoon	Low bearing capacity, pavement cracking and settlement

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S. No	Major Challenge	Technical Analysis	Comparison / Engineering Interpretation
1.	Slope instability due to hill cutting.	Steep gradients (450–900 m elevation) and improper cutting angles reduce slope stability factor of safety.	Inadequate slope design directly increases landslide risk; requires bench cutting and retaining structures.
2.	Weak lateritic subgrade soil.	Lateritic soil loses strength when saturated; low CBR value during monsoon.	Low bearing capacity leads to pavement settlement and cracking; stabilization is necessary.
3	Heavy monsoon rainfall lcausing erosion	Annual rainfall 1200–1300 mm produces high surface runoff velocity.	Excess runoff accelerates soil erosion and shoulder damage; proper drainage is technically essential.
4	Inadequate drainage system	Absence of properly designed side drains and cross-drainage structures	Poor water outlet increases pore water pressure in subgrade, reducing pavement life
5	High transportation cost in remote areas	Forested and interior locations increase hauling distance of aggregates and materials	Higher lead distance raises project cost; use of local materials becomes economically and technically justified

TABLE: 01case study–based analysis of major challenge.

3	Heavy Rainfall	Average annual rainfall 1200–1300 mm	Soil erosion, waterlogging, surface damage
4	Poor Drainage System	Inadequate side drains in rural roads	Reduced pavement life and frequent maintenance
5	Soil Erosion & Landslides	Erosion on hill cut sections during rainy season	Traffic disruption and safety hazards
6	Remote & Forest Areas	Interior tribal villages surrounded by forest	High transportation cost of materials
7	Limited Project Budget	Mostly PMGSY low-volume rural roads	Need for economical and sustainable solutions

TABLE :02 Technical Analysis Compared with Major Challenges.

Problem Identification:

During field observation and project review, the following major problems were identified:

1. Slope instability due to hill cutting,
2. Weak lateritic subgrade soil causing pavement settlement.
3. Heavy monsoon rainfall leading to soil erosion.
4. Inadequate drainage system causing waterlogging.

Technical Analysis Compared with Major Challenges:

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DISCUSSION:

The analysis presented in Table 01 (Major Challenges) and Table 02 (Technical Analysis Compared with Major Challenges) clearly explains the practical and technical difficulties faced during road construction in the hilly regions of Bishunpur and Chainpur blocks of Gumla district.

As shown in Table 01, the primary challenges include hilly and undulating terrain, weak lateritic soil, heavy rainfall, poor drainage systems, soil erosion, remote forest locations, and limited project budgets. These challenges directly affect construction cost, pavement durability, and road safety.

For example, steep slopes (450–900 m elevation) increase cutting and filling work, while lateritic soil reduces bearing capacity during the monsoon season.

Further, Table 02 provides a technical interpretation of these challenges. The issue of slope instability is technically linked to improper cutting angles and reduced slope stability factor of safety. Similarly, weak lateritic soil shows low CBR values when saturated, leading to pavement settlement and cracking. Heavy rainfall (1200–1300 mm annually) increases surface runoff velocity, which accelerates soil erosion and damages road shoulders. Inadequate drainage design increases pore water pressure in the subgrade, thereby reducing pavement life.

By comparing both tables, it becomes clear that the challenges identified in Table 01 are scientifically supported by the engineering analysis in Table 02. The geographical conditions of Gumla—steep topography, erodible soil, and high rainfall—are interconnected factors that collectively influence road performance. Additionally, the remote forested location increases material transportation costs, making conventional high-cost construction methods less suitable under PMGSY funding limitations.

Therefore, the discussion indicates that successful road construction in Gumla's hilly terrain requires integrated solutions focusing on proper slope design, soil stabilization, effective drainage systems, and the use of locally available materials. Addressing these technical aspects based on the analysis in Table 01 and Table 02 can significantly improve durability, reduce maintenance costs, and ensure sustainable rural connectivity in Gumla district.

CONCLUSION:

The case study of road construction in the hilly regions of Bishunpur and Chainpur blocks, Gumla district highlights that geographical, geotechnical, hydrological, and economic factors significantly influence road performance. As identified in Table 01 and technically explained in Table 02, challenges such as steep terrain, weak lateritic soil, heavy monsoon rainfall, inadequate drainage systems, and remote forest locations are the major causes of pavement failure and increased construction costs.

The study concludes that conventional construction practices are not fully suitable for Gumla's hilly conditions without proper technical modifications. Sustainable and low-cost techniques—such as scientific slope cutting, gabion retaining structures, subgrade stabilization, effective drainage planning, and the use of locally available materials—are essential to ensure durability and cost efficiency.

Therefore, adopting location-specific engineering solutions can significantly improve road life, reduce maintenance expenses, and enhance rural connectivity in the hilly areas of Gumla district while maintaining environmental sustainability.

ACKNOWLEDGEMENT:

The authors sincerely acknowledge RTBT Infrastructure Developer Pvt. Ltd., Ranchi (www.rtbtltd.com; support@rtbtltd.com) and Shree Fly Ash Industries, Govind, Dhanbad, for their valuable technical support and cooperation during this research study.

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