



# Subsurface Strategies For Sustainable Infrastructure: Insights From The Nh-66 Kooriyad Collapse

<sup>1</sup>Aparna P.B, <sup>2</sup>Seetha Pisharikkel

<sup>1</sup>UG Student, <sup>2</sup>Assistant Professor

<sup>1</sup>Department Of Civil Engineering,

<sup>1</sup>VAST, Thrissur, India

**Abstract:** The unexpected collapse of a section of NH-66 in Kooriyad, Kerala, has exposed serious flaws in infrastructure planning and construction oversight. The failure occurred in a region characterized by soft loamy clay soils, which are known to retain water and lose strength under load—yet these geotechnical conditions were inadequately addressed during the project. Continuous rainfall, poor stormwater drainage, and possibly uncompact backfill further destabilized the slope, leading to differential settlement and structural failure. This incident highlights the urgent need for thorough soil investigations, site-specific engineering designs, and accountable construction practices, especially in terrain-sensitive zones. Ultimately, sustainable infrastructure demands more than materials—it requires scientific foresight, respect for natural conditions, and a long-term commitment to responsible engineering.

**Index Terms** - Lomay Clay Soil, Geotechnical Failure, Sustainable Infrastructure, Slope Instability.

## I. INTRODUCTION

National Highway 66 (NH 66), formerly NH 17, is a vital 1,650 km coastal corridor connecting Panvel in Maharashtra to Kanyakumari in Tamil Nadu, traversing five states and linking key cities and ports along the western seaboard. It plays a crucial role in trade, transport, and tourism across the Konkan and Malabar coasts and is currently undergoing major upgrades, including lane expansion and climate-resilient engineering. A critical stretch at Kooriyad in Kerala's Malappuram district, part of the midland zone with waterlogged, previously cultivated land, suffered a major collapse in May 2025. The failure was attributed to construction over soft clayey and organic soils, which are weak, compressible, and prone to settlement, compounded by underlying silty clay and weathered laterite that destabilize when saturated. This incident underscores the urgent need for terrain-sensitive design and geotechnical diligence in infrastructure development.

## II. SOIL PROFILE AND TERRAIN OF KOORIYAD

The Kooriyad stretch of NH-66 in Malappuram district traverses a geotechnically fragile and hydrologically complex terrain, making it highly susceptible to failure. The soil profile consists of three critical layers:

1. A top layer (0–1.5 m) of loamy, organic-rich reclaimed paddy soil with high moisture content and low shear strength; a subsoil layer (1.5–4 m) of soft, saturated clayey loam with poor bearing capacity and high plasticity
2. A deeper layer (>4 m) of lateritic soil with variable strength depending on saturation. The area is characterized by a shallow groundwater table (<2 m during monsoon), poor drainage connectivity, and disrupted hydraulic gradients due to embankment obstruction.

Construction activities blocked natural drainage channels and ignored local warnings about the terrain's instability, leading to increased pore water pressure and lateral soil movement. The collapse revealed severe differential settlement in embankment zones, hydraulic uplift in drainage channels, and moderate subsidence in adjacent service roads and residential areas—underscoring the urgent need for terrain-sensitive design, proper soil reinforcement, and hydrological planning.

### III.SUB SURFACE CONDITION OF KOORIYAD

The NH 66 collapse at Kooriyad was primarily caused by construction over weak, waterlogged soils typical of reclaimed paddy fields. The dominant loamy clay in the area retains moisture, has poor drainage, and undergoes swelling and shrinkage, making it highly unstable under load. Ground improvement techniques like preloading and soil reinforcement were either neglected or poorly executed, with soil nailing found inconsistent and untested. Embankments were built directly over saturated subsoil, and natural drainage paths were blocked, increasing pore water pressure and reducing soil strength. These compounded geotechnical failures—low shear strength, high compressibility, and persistent high water table—led to settlement, lateral spreading, and eventual collapse.

### IV.PRE CONSTRUCTION MEASURES TAKEN

Before the collapse at kooriyad on nh-66, several stabilization measures were implemented, including reinforced earth walls and soil nailing. However, these were poorly designed and executed. soil nails were spaced too far apart, some were missing, and essential post-installation tests like pull-out testing were skipped. Visible signs of distress—cracks and subsidence—were ignored, and drainage provisions were minimal. Natural water pathways were obstructed, increasing saturation in the already moisture-retentive soil. Despite intentions to stabilize the structure quickly, the measures failed to address the site's geotechnical vulnerabilities, ultimately contributing to the collapse of

#### Stage 1: Reconnaissance

The topographic survey was conducted using GPS and drone mapping, but lacked hydrological overlays and seasonal flood data. Land acquisition targeted reclaimed paddy fields—historically flood-prone—with no ecological compensation for wetland loss. Local concerns about poor soil strength and water retention were dismissed. Environmental clearance was granted by SEIAA, yet no detailed groundwater or drainage study was included. A natural stream was blocked during construction, worsening waterlogging. The alignment routed NH-66 through low-lying terrain to avoid urban congestion, ignoring poor load-bearing capacity and bypassing elevated alternatives like viaducts or flyovers

#### Stage 2: Geotechnical Investigation

Soil testing was inadequate. Loamy soil, known for high water retention and low shear strength, was used as fill without proper profiling. No consolidation or triaxial shear tests were documented. The foundation soil couldn't bear the load, causing differential settlement. Water table profiling was superficial—no seasonal variation study, no piezometers, and monsoon saturation effects were ignored. This led to pore pressure buildup, soil bulging, and cavity formation. Slope stability analysis was not modeled for monsoon conditions; steep slopes (1:1.5 to 1:2) lacked reinforcement, and no FEM or limit equilibrium analysis was performed. The reinforced earth wall failed due to water pressure and poor drainage. Drainage mapping was neglected—natural east-west channels were blocked, and no culverts or box drains were installed, leading to hydraulic uplift during rains.

#### Stage 3: Detailed Explanation

The embankment was designed at 4.5 to 6 meters to span low-lying paddy fields, with a reinforced earth wall on one side. However, subsoil bearing capacity was not validated, and no slope stability modeling was done for saturation or pore pressure. Loamy fill material was used without ground improvement techniques like stone columns or geogrid reinforcement, resulting in uneven settlement and failure. Drainage structures were absent—no culverts or subsurface drains—and natural drainage was blocked, causing waterlogging and uplift. Bitumen sealing was deferred, exposing the embankment to pre-monsoon rains and allowing infiltration that weakened the structure internally.

## Pre-Collapse Measures at Kooriyad NH-66

Soil nailing was executed to stabilize steep cut slopes but was defective. Rod spacing exceeded standard limits, with gaps over 1 meter in laterite soil, and several rods were missing. Vertical hill slicing up to 90° rendered nailing ineffective. No soil testing was done to determine rod depth or shotcrete quantity. The reinforced earth wall was built without validating subsoil strength and failed on the upstream side due to water pressure and poor drainage. Loamy soil was used for embankment fill—unsuitable for saturated terrain—with no ground improvement, and compaction was done in a single stretch rather than in layers. Drainage and sealing were neglected—no culverts or subsurface drains were installed, bitumen sealing was deferred, and natural drainage paths were blocked, leading to severe waterlogging.

### V. THE CONSTRUCTION MISHAP

#### ● Initial Incident (May 19, 2025)

- A section of the under-construction NH-66 collapsed around 2:30 PM IST.
- Retaining wall and service road gave way over reclaimed paddy fields.
- Seven injured; wedding party vehicles narrowly escaped.
- Deep cracks appeared in nearby fields; vehicles were trapped.

#### ● Terrain & Local Warnings

- The site was flat, waterlogged, with high groundwater and clay-rich soils.
- Locals had warned against embankment construction; urged for a bridge.
- Drainage channels were blocked; terrain prone to saturation.

#### ● Official Response

- NHAI admitted design flaws and poor foundation treatment.
- Project director and site engineer suspended.
- KNR Constructions debarred; IIT & CRRI launched investigation.
- Photos showed soil failure and vehicle evacuation.

#### ● Technical Failures

- Inadequate subsoil bearing capacity and rainwater seepage.
- Absence of top bitumen layer allowed water infiltration.
- Contractor and consultant banned from future tenders.
- Two senior personnel suspended.

#### ● Legal & Political Action

- The Kerala High Court demanded a detailed NHAI report.
- The Union Minister promised inquiry and viaduct-based redesign.
- Public protests and legal scrutiny intensified.

#### ● Current Status (as of late May 2025)

- **Second Collapse:** Occurred on May 28, near the first site.
- **Cracks & Erosion:** New fissures in protective walls; erosion spread.
- **Waterlogging:** Paddy field remains saturated post-rain.
- **Expert Findings:** Poor soil testing and drainage planning confirmed.
- **Public Demand:** Engineers and locals call for embankment demolition and bridge construction.

### VI. ROOT CAUSE OF THE COLLAPSE AT KOORIYAD NH-66

The failure of the Kooriyad section of NH 66 was not the result of a single mistake, but rather a combination of several critical oversights and poor decisions. One of the main causes was the selection of a weak site for construction—this stretch of road was built over reclaimed paddy fields, where the ground is made up of soft, clayey, and loamy soil that has very low strength and high water retention. This type of soil simply cannot bear the heavy loads of large embankments and retaining structures unless properly treated, which wasn't done here. Another major cause was the poor drainage planning. Natural drainage channels that helped remove excess water from the land were blocked during construction, which led to water stagnating in the soil and raising the groundwater level. This increased pore water pressure in the subsoil, further weakening the already fragile ground. Additionally, although soil nailing and reinforced earth walls were installed, they were done hastily and with poor workmanship. The soil nails were not placed at correct intervals or depths, and crucial safety checks like pull-out tests were skipped. These structures appeared solid on the surface but lacked the

internal strength needed to withstand the pressures over time. Also, the embankment height and loading were excessive for the weak ground, and no proper ground improvement measures like preloading, stone columns, or deep soil mixing were implemented. Perhaps most tragically, early warning signs—like visible cracks and minor subsidence in the area—were ignored, even though local residents and experts had raised concerns long before the collapse. All these issues, when combined, created a situation where the earth underneath the road could no longer support the load, leading to a sudden and dramatic failure. It was not just a collapse of soil, but a collapse in planning, design, execution, and accountability.

### 6.1. FOUNDATION SOIL INADEQUANCY

- Built over **reclaimed paddy fields with soft, compressible, waterlogged loamy soil**
- **Low shear strength and poor bearing capacity** were not addressed
- No ground improvement (e.g. stone columns, deep soil mixing) was done

### 6.2. EXCESSIVE EMBANKMENT LOAD

- Embankment height reached **6 meters**, placing heavy stress on weak subsoil
- Reinforced Earth (RE) wall added lateral pressure
- No staged loading or settlement monitoring was implemented

### 6.3. INADEQUATE DRAINAGE AND WATER MANAGEMENT

- Natural **east–west drainage channels were blocked**
- No culverts or subsurface drains were installed
- Rainwater seeped into the embankment due to **deferred bitumen sealing**
- Result: **Pore water pressure buildup** and hydraulic uplift

### 6.4. NEGLIGENCE IN SOIL TESTING AND DESIGN

- **Geotechnical investigations were superficial**
- No seasonal water table profiling or piezometer installation
- Slope stability under monsoon saturation was **not modeled**
- Design ignored **worst-case hydrological conditions**
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### 6.5. IGNORED EXPERTS AND COMMUNITY WARNINGS

- Geological Survey of India and local residents warned of collapse risk
- Concerns about **waterlogging and soft terrain** were dismissed
- No terrain-sensitive alternatives (e.g. flyover) were considered

### 6.6. PROGRESSIVE FAILURE MECHANISM

- Saturated soil underwent **excessive settlement and lateral spreading**
- Embankment cracked, bulged, and collapsed into adjacent paddy fields
- A cavity formed beneath the structure due to **hydraulic pressure**

## VII. RECOMMENDED MEASURES FOR NH-66 KOORIYAD

### 7.1. Ground Improvement (Before Construction)

- **Stone Columns:** Improve drainage and shear strength in waterlogged soils.
- **Preloading + PVDs:** Accelerate consolidation, reduce settlement.
- **Deep Soil Mixing:** Strengthens loamy soil via soil-cement columns.
- **Geotextiles:** Reinforce slopes, reduce erosion and differential settlement.

## 7.2. Elevated Structures Over Weak Terrain

- **Viaducts/Flyovers:** Avoid loading soft ground; allow natural water flow.
- **Pile Foundations:** Transfer loads to deeper stable strata; bypass weak layers.

## 7.3. Drainage Systems

- **Restore Natural Channels:** Reopen blocked paths; install culverts and side drains.
- **Subsurface Drainage:** Use perforated pipes and geotextile wraps; monitor with piezometers.
- **Surface & Cross Drainage:** Proper camber, lined side drains, culverts at stream crossings.

## 7.4. Hydrological Integration

- **Seasonal Water Table Profiling:** Use piezometers to track groundwater fluctuations.
- **Restore East–West Drainage:** Map and reconnect historical flow paths.
- **Rainfall–Runoff Modeling:** Use tools like SWAT/HEC-HMS to simulate saturation and flood risks.

## 7.5. Soil Nailing & Retaining Wall Design

- Use corrosion-resistant nails; ensure correct depth ( $1.5\text{--}2\times$  wall height) and spacing ( $\leq 1$  m).
- Conduct pull-out/load tests to validate bond strength.
- Apply flexible shotcrete facing with mesh; anchor using plates and tiebacks.
- Avoid vertical cuts; use benching/terracing to reduce slope height and pressure.
- Install subsurface drains behind nailed zones to relieve pore pressure.

## 7.6. Lightweight Fill Materials

- Replace heavy soil with low-density alternatives to reduce stress on weak subsoil.
- **Geofoam (EPS):**  $\sim 15\text{--}30$  kg/m<sup>3</sup>; ideal for embankment core.
- **Lightweight Aggregates:**  $\sim 300\text{--}800$  kg/m<sup>3</sup>; for backfill behind RE walls.
- **Coir Composite Fill:**  $\sim 500\text{--}700$  kg/m<sup>3</sup>; sustainable option for shoulders.
- **Foamed Concrete:**  $\sim 400\text{--}1600$  kg/m<sup>3</sup>; used in culvert zones and slope fills

## 7.7 Other Measures

- **Monitoring:** Use inclinometers and piezometers for early warning.
- **Seasonal Planning:** Avoid monsoon construction; design for wet-season soil behavior.
- **Community & Expert Input:** Include local observations and independent geotechnical reviews.
- **Context-Sensitive Design:** Tailor road design to terrain, water flow, and soil conditions.

## VIII. CASE STUDY

### 8.1. Study On Flexible Pavement Design In Waterlogged Terrain Between Nimzari Naka And Nimzari, Shirpur:

**Location:** 7 km stretch in Shirpur, Maharashtra

**Terrain Challenge:** Waterlogged black cotton soil with low bearing capacity

**Design Strategy:**

- Soil stabilization
- Drainage enhancement
- Use of geosynthetics

**Design Standard:** IRC:37-2001

**Traffic Analysis:**

- 102 vehicles/day; 7.5% annual growth
- 20-year design life; 2.6 msa load

## Methodology & Key Measures

### 1. Soil Stabilization with Quarry Dust

- CBR improved from 2.82% (0% dust) to 8.68% (40% dust + 2% cement)
- Enabled reduced pavement thickness and cost savings

### 2. Pavement Layering (Total 440 mm)

- Wearing course: 20 mm
- Binding course: 50 mm
- Granular base: 240 mm
- Sub-base: 150 mm

### 3. Geogrid Reinforcement

- Placed above subgrade, below sub-base
- Improved load distribution, reduced aggregate loss
- Enhanced stability in wet conditions

### 4. Drainage Design

- Surface runoff managed via cambered side drains
- Culverts installed for cross drainage (<6 m stream width)
- Drainage treated as critical for pavement longevity

### Outcomes

- Pavement thickness reduced from 600 mm to 440 mm
- Cost-effective and structurally sound design
- Validated terrain-sensitive approach for waterlogged regions

## 8.2. Highway Surface Drainage System & Problem Of Waterlogging In Road:

### Focus:

Explores how poor drainage design leads to pavement failure, waterlogging, and safety hazards. Emphasizes drainage as both a structural and safety priority.

### Methodology

#### 1.Literature Review

- Cites AASHTO, IRC standards and global case studies (India, Bangladesh, UK).
- Reviews drainage failures and their impacts.

#### 2.Drainage System Breakdown

- **Surface Drainage:** Cambered roads, side ditches, gutters, kerbs.
- **Subsurface Drainage:** Storm sewers, catch basins, manholes.
- **Cross-Drainage:** Culverts (metal/concrete) for storm flow and erosion control.

#### 3.Design Software Use

- Hydraulic modeling for peak flow, culvert sizing, and inlet spacing.

#### 4.Field Observations

- Identifies poor geometry, missing shoulders, unmarked intersections, and inadequate pedestrian facilities as contributors to waterlogging.

## Key Takeaways

- Drainage must be integrated with road alignment and gradient.
- Surface and subsurface systems must work in tandem.
- Regular maintenance and public awareness are essential.
- Waterlogging is a multi-factor issue—beyond just hydraulics.

### 8.3. Case Study On Soil Nailing For Slope Stabilization

#### Technique:

Steel nails inserted into slopes, grouted, and faced with shotcrete or mesh. Praised for cost-efficiency, minimal excavation, and suitability in urban/hilly terrain.

#### Methodology

- Site investigation
- SPT testing
- Slope stability analysis
- Pull-out testing

#### Case Studies

##### 1. Hotel Excavation (11 m Deep Cut)

- Soil: Cemented sand over disintegrated rock
- Challenge: Collapse beyond 4 m due to seepage
- Solution: 8 m nails, 0.5 m × 0.5 m spacing, shotcrete facing
- FoS ≥ 1.4; pull-out tests confirmed bond strength

##### 2. Reservoir Slope (200 m Length)

- Soil: Low-cohesion casing soil (2–10 kPa); hearting soil (30 kPa)
- Challenge: Erosion and monsoon-induced sliding
- Solution: 5 m nails, 0.5 m × 1 m spacing
- FoS improved from <1 to >1.6

##### 3. Underpass Approach Road

- Soil: Made-up and silty sand (SPT 6–17)
- Challenge: Collapse beyond 1 m excavation
- Solution: 7 m nails, 0.5 m × 0.5 m spacing
- FoS = 1.4; enabled safe construction

#### Key Outcomes

- Stability improved across all sites
- Pull-out resistance matched theoretical (~3.6 kN/m)
- Effective for both temporary and permanent works
- Recommended for deep cuts, bunds, and urban slopes

## IX. CONCLUSIONS

The collapse of NH-66 at Kooriyad was not accidental—it stemmed from ignoring fragile terrain, monsoon dynamics, and community warnings. Built over saturated paddy wetlands, the highway disrupted natural drainage, causing flooding and soil saturation. Poor soil investigations, skipped hydrological studies, and unmodeled slope stability under monsoon conditions compounded the risk. Loamy fill without reinforcement and delayed bitumen sealing allowed rainwater infiltration, triggering pore pressure buildup

and hydraulic uplift. The reinforced earth wall and service road failed under saturated subsoil. Despite local calls for elevated flyovers, cost-driven shortcuts prevailed, eroding public trust. This failure demands reform: terrain-sensitive design, robust geotechnical and hydrological integration, ground improvement, elevated structures, and real-time monitoring must become standard. Environmental clearances should mandate seasonal water profiling and community consultation. In Kerala's rain-shaped landscape, resilience begins with respect—for the land, the climate, and the people.

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