Report on

Rehabilitation Measures of Distressed High Embankments

of project

Four Laning of Sargaon - Bilaspur of NH-200 section (Package-III) from km 91+026 to km 126+525 section of Raipur-Bilaspur in the State of Chhattisgarh under NHDP-IV on EPC Mode

by

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Submitted to

Project Director, PIU, Bilaspur

National Highways Authority of India

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1.0 Introduction

A detailed technical inspection of the distressed Geosynthetic Reinforced Soil (RS/RE) walls and high earthen embankments was undertaken on 4th and 5th July 2025 for the project "Four Laning of Sargaon – Bilaspur section of NH-200 (Package-III) from km 91+026 to km 126+525 of Raipur–Bilaspur corridor in the State of Chhattisgarh under NHDP-IV on EPC Mode". The inspection was carried out by Dr. Anil Dixit and Dr. Kolli Mohan Krishna, following a request received from the Project Director, PIU–Bilaspur, NHAI (Ref: 13011/1/PD-BSP/SRGN-BSP/2025/1061 and 13011/1/2025/PD-BSP/SRGN-BSP/1075). Subsequent detailed technical discussions were also held on 6th July 2025 with officials of NHAI at the Regional Office, Raipur.

A total of four RE wall locations and three high embankment locations were inspected during the site visit. The project was executed by M/s Dilip Buildcon Limited (DBL) under EPC mode, and the construction was completed around 2018. The nature and severity of distress varied across different locations. A detailed site visit report was submitted on July 15, 2025. Based upon the above, the work of detailed geotechnical investigation, evaluation of existing distress mechanisms, review of earlier remedial measures, and development of appropriate rectification and strengthening solutions was entrusted to M/s Geosynthetic Technology Advisory Services LLP, Jaipur (Ref: 13011/1/2025/PD-BSP/SRGN-BSP/1678).

The detailed technical report covering the evaluation and rehabilitation measures for the RE walls was submitted to NHAI on 31st January 2026.

Further to the above, the present report also provides detailed engineering solutions for rehabilitation and repair of the distressed embankments at three locations, based on field observations, geotechnical investigation results, and stability assessment.

2. Site Observations on Distressed High Embankments

During the site visit, following critical observations (Figure 1) were made:

- Signs of settlement and cracking were observed at km 108+945 on A2 RHS and pavement on A2 LHS, indicating ongoing settlement and potential slope deformation.
- At km 118+650 (A2 LHS), a shallow slope failure with significant surficial slope movement, and the failed slope remains unrepaired.
- At km 123+050 (A1 LHS), settlement of concrete block pitching and a vertical crack indicate slope surficial movements; similar distress has reportedly occurred in nearby locations.

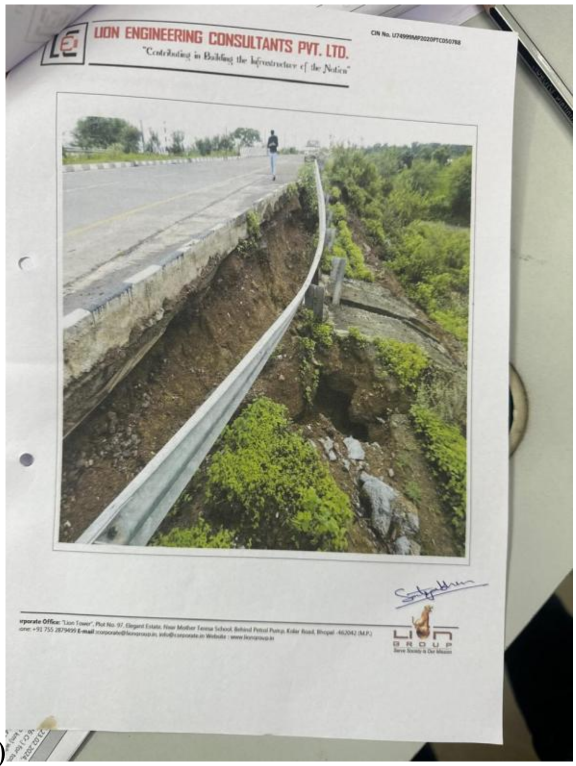
a)

b)

c) 

d) 

e) 

f) 
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g) 

Figure 1 Observations: a-b) signs of settlement at embankment km 108+945; c-d) slope failure at embankment km 118+650; e-f) slope failure at embankment km 118+650; g) signs of surficial slope settlement and failure at embankment km 123+050

3. Investigations

To identify the causes of the above distress and to evaluate the existing soil properties, geotechnical investigations was undertaken near the distressed zones. In total, three boreholes were executed around the distressed embankment locations:

- km 109+050 – one borehole to a depth of 12 m (refusal).
- km 118+840 – one borehole to a depth of 12 m (refusal).
- km 123+080 – one borehole to a depth of 9 m (refusal).

In each borehole, SPT and undisturbed soil sampling were carried out alternately at successive depths to establish a representative soil profile. Laboratory testing of the collected samples was carried out to obtain soil properties.

The detailed results of these investigations are presented in **Annexure-I**, and relevant findings are discussed in the following sections.

4. Investigations Summary and Reasons for Distress

4.1 Fill Material and Foundation Soil

The in-situ dry density values ranging from 1.43 g/cc to 1.56 g/cc indicate that the embankment fill is in a relatively loose state, predominantly consisting of clayey sand and silty soils. The compression index values (0.246–0.276) obtained from laboratory tests suggest that the fill material is moderately to highly compressible, which explains the observed settlements in the embankment sections.

The foundation soil primarily comprises stiff silty clay with medium to high compressibility. The thickness of the clay layer beneath the embankment varies approximately between 1 m and 3 m, underlain by rock strata.

4.2 Reasons for Distress

Based on the investigations and field observations, the settlements are primarily attributed to the compressible nature of the embankment fill material. Although the exact cause of failure cannot be conclusively established due to limited historical records, the distress is likely the result of multiple contributing factors, including loose clayey fill, rainfall infiltration, within the side slope materials, which may have triggered shallow side slope slip failures in the embankment slopes. The observed density values and the pattern of failures are consistent with such mechanisms.

To mitigate further progression of distress, it is recommended that the embankment slopes at locations where slip failures have occurred be stabilized through appropriate remedial measures.

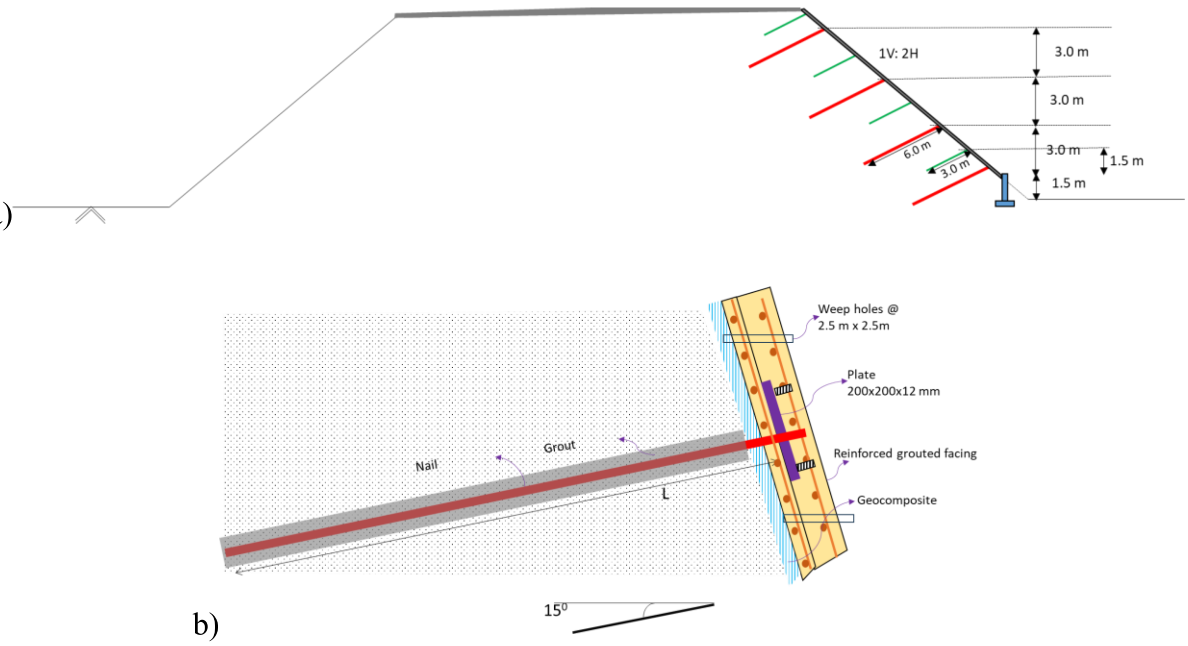
5.0 Stabilization of Distressed Slopes of High Embankments

Based on the site observations and investigation results, appropriate stabilization and erosion protection measures are recommended to prevent further progression of distress at the identified locations.

At km 118+650 (A2 LHS) and km 123+050 (A1 LHS), the observed failures appear to be surficial slope failures. To prevent further progression of failure and enhance slope stability, it is recommended to stabilize these slopes using **a soil nailing system** with grouted reinforced face (Figure 2). It is to be noted that soil nailing is to provide resistance against any further shallow slip surfaces that may develop due to present weak or loose surface fill material. The overall slope stability is in general stable with static FOS > 1.6 and seismic FOS>1.15 satisfying minimum FOS requirement of 1.4 and 1.1, respectively. The slope stability analysis results of slope for investigated properties are given Figure 3.

<u>Specifications of Nails:</u>

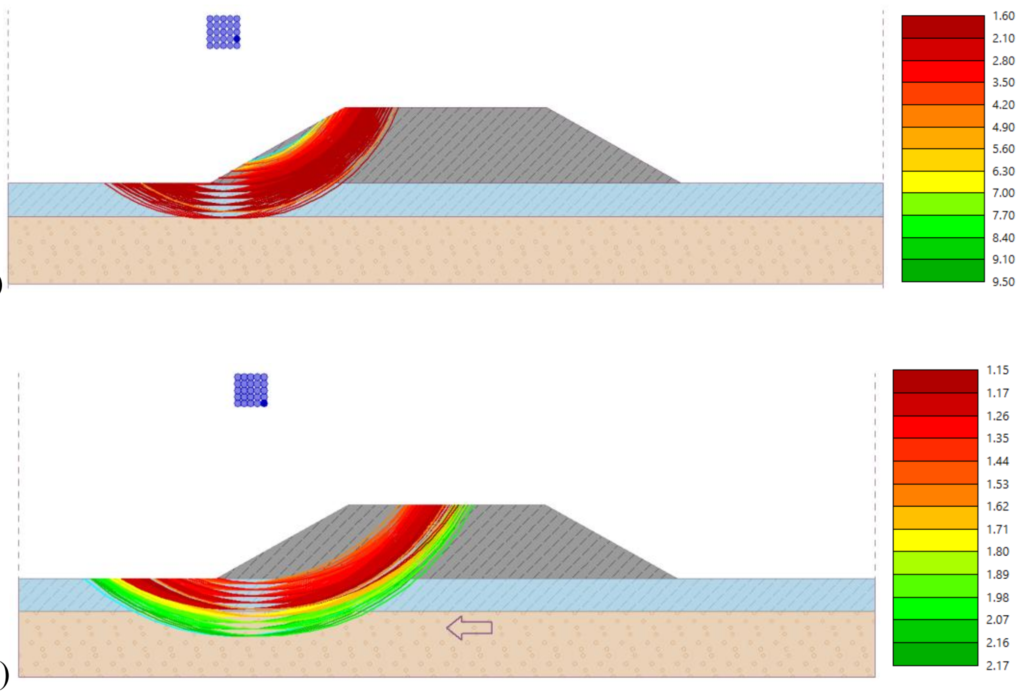
- Grouted Nails in panels: 25 mm solid nails with ~115 mm grout hole diameter.
- Grade of nails: Minimum 500 MPa yield strength solid nails – hot-dip fully threaded and galvanized.
- Nail installation angle: $10\text{-}15^0$
- Length: As per Figure 2.
- Spacing: 1.5 m X 1.5 m
- Installation of nails and grout specifications shall be followed as per FHWA-NHI-14-007.
- Corrosion protection to nails and other accessory parts is preferable.



a)

b)

Figure 2 Sectional view of nailing configuration (Adjust configuration as per height)



a)

b)

Figure 3 Results of slope stability analysis of maximum height (~11.5 m) embankment

At km 108+945, the distress is primarily associated with localized settlement, and no major slope failure has been observed. Therefore, it is recommended to implement slope

erosion protection measures using geocells (100 mm depth and specifications as per IS 17483 part-2) filled with concrete and sufficiently anchored, to prevent further erosion of the slope surface. All erosion protection measures should be continuous and extend up to the cement concrete (CC) pavement, ensuring that no gaps are left between the pavement edge and the slope protection system.

Additionally at km 108+945 (LHS and RHS), 118+650 (A2 LHS) and km 123+050 (A1 LHS), **a toe wall** of approximately 1.5 m height should be provided at the base of the slope to offer structural support and to function as part of the erosion protection system. Proper drainage arrangements should also be incorporated, including toe drains, chute drains, and longitudinal drains, to safely convey surface runoff and minimize water infiltration into the embankment. The chute drains should be provided at a spacing of approximately 10 m along the slope.

Furthermore, the cracked CC pavement observed at the three sites should be removed and replaced to restore structural integrity and prevent infiltration of surface water into the embankment.

6. Summary

Based on the site inspections, subsurface investigations, and laboratory test results carried out at the distressed locations along the project corridor, the following conclusions are drawn:

- Geotechnical investigations conducted through three boreholes near the distressed zones indicate that the embankment fill primarily consists of clayey sand and silty soils in a relatively loose state, as evidenced by in-situ dry density values ranging from 1.43 g/cc to 1.56 g/cc. The compression index values (0.246–0.276) further confirm that the fill material is moderately to highly compressible, which has contributed to the observed settlements in the embankment sections.

- The distress observed along the slopes is interpreted to be primarily surficial in nature, likely triggered by a combination of loose embankment fill, rainfall infiltration, and reduction in soil strength within the side slope materials. These factors appear to have contributed to localized shallow slip failures and deformation of slope protection systems.
- Stability analysis indicates that the overall stability of the embankment slopes remains within acceptable limits under both static and seismic conditions. However, the observed surficial failures and erosion-related distress require localized stabilization measures to prevent further progression.
- Accordingly, soil nailing with grouted reinforced facing is recommended for stabilizing the distressed slopes at km 118+650 (A2 LHS) and km 123+050 (A1 LHS) to control potential shallow failures. At km 108+945, where distress is mainly related to localized settlement and erosion, surface protection measures such as geocells filled with concrete are recommended.
- In addition, toe walls, chute drains, toe drains, and longitudinal drainage systems should be provided at the identified locations to improve slope stability and prevent water infiltration. Replacement of cracked CC pavement and ensuring continuous erosion protection up to the pavement edge are also necessary to maintain long-term performance of the embankment slopes.
- Detailed drawing of rehabilitation works may be submitted for review before construction activity starts.

Acknowledgement

We extend our sincere gratitude to the National Highways Authority of India (NHAI) for entrusting us with this prestigious work.

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ANNEXURE I

LANDMARK
Material Testing And Research Laboratory Pvt. Ltd.

Project : Four Laining of Sargaon - Bilaspur NH-200 (PKG-III) Chhattisgarh	Date of field Testing	Borehole Location	R.L.	Chainage	Structure	Depth of Water Table	Termination Depth	Easting	Northing	Ref. Code
	12.12.2025	A2 LHS (High Embankment) Edge of embankment - Near distressed portion	-	109+050	-	Not Encountered	12.00 m	612456	2430400	Sr-80-1125

Type of Sample	Depth (m) from EGL	Observed N Value	Correction Factor (C_n)	Corrected N Value (N_n)	Soil/Rock Description	Soil Classification	Soil Sample																	Rock Sample							Remark
							Grain Size Analysis				Atterberg Limits %			Bulk Density (g/cc)	Dry Density (g/cc)	Natural Moisture Content (%)	Specific Gravity	Free Swell Index (%)	UCS (kg/cm^2)	Cc	Type of test	Shear Strength Parameter		Core Recovery (%)	RQD (%)	Specific Gravity	Water Absorption (%)	Porosity (%)	UCS (N/mm2)	PLI (MN/m2)	
							Gravels (%)	Sand (%)	Silt (%)	Clay (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)									c kg/cm^2	ϕ Degree								
DS	0.00 - 1.00	-	-	-	Pavement Crust	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SPT	1.50 - 3.00	15	1.00	15	Clayey Silts of High Plasticity	MH	2.92	32.56	64.52		52.8	30	22.8	-	-	-	-	33	-	-	-	-	-	-	-	-	-	-	-	-	-
UDS	3.00 - 4.50	-	-	-	Clayey Silts of High Plasticity	MH	4.58	14.76	54.13	26.53	52.2	29	23.2	1.85	1.45	27.65	-	42	-	0.246	-	-	-	-	-	-	-	-	-	-	-
SPT	4.50 - 6.00	26	1.00	26	Clayey Silts of Medium Plasticity with Gravels	MI	17.96	37.82	44.22		48.3	29	19.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UDS	6.00 - 7.50	-	-	-	Clayey Silts of High Plasticity	MH	5.84	43.95	25.46	24.75	50.6	29	21.6	1.88	1.48	27.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SPT	7.50 - 9.00	32	1.00	32	Silty Clay of Medium Plasticity	CI	8.74	44.24	47.02		49.6	28	21.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UDS	9.00 - 10.50	-	-	-	Clayey Silts of High Plasticity with Gravels	MH	16.97	16.09	41.58	25.36	51.3	30	21.3	1.84	1.50	22.86	-	-	-	-	UUT	0.79	11	-	-	-	-	-	-	-	-
SPT	10.50 - 12.00	>50	-	-	Silty Clay of Medium Plasticity with Gravels	CI	11.50	55.97	32.53		47.1	27	20.1	-	-	-	-	27	-	-	-	-	-	-	-	-	-	-	-	-	-
SPT	12.00	>50	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

LANDMARK
Material Testing And Research Laboratory Pvt. Ltd.

Project	Date of field Testing	Borehole Location	R.L.	Chainage	Structure	Depth of Water Table	Termination Depth	Easting	Northing	Ref. Code
Project : Four Laining of Sargaon - Bilaspur NH-200 (PKG-III) Chhattisgarh	13.12.2025 to 14.12.2025	A2 LHS (High Embankment) Edge of embankment - Near distressed portion	-	118 + 840	-	Not Encountered	12.00 m	620690	2432123	Sr-80-1125

Type of Sample	Depth (m) from EGL	Observed N Value	Correction Factor (C_n)	Corrected N Value (N_n)	Soil/Rock Description	Soil Classification	Soil Sample																	Rock Sample							Remark
							Grain Size Analysis				Atterberg Limits %											Shear Strength Parameter									
							Gravels (%)	Sand (%)	Silt (%)	Clay (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Bulk Density (g/cc)	Dry Density (g/cc)	Natural Moisture Content (%)	Specific Gravity	Free Swell Index (%)	UCS (kg/cm^2)	Cc	Type of test	c kg/cm^2	ϕ Degree	Core Recovery (%)	RQD (%)	Specific Gravity	Water Absorption (%)	Porosity (%)	UCS (N/mm2)	PLI (MN/m2)	
DS	0.00 - 1.00	-	-	-	Pavement Crust	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SPT	1.50 - 3.00	22	1.00	22	Clayey Sand with Gravels	SC	28.23	36.92	34.85		49.3	30	19.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UDS	3.00 - 4.50	-	-	-	Clayey Silts of High Plasticity	MH	5.85	38.89	29.14	26.12	52.9	30	22.9	1.92	1.54	24.44	-	50	-	0.261	UUT	0.62	13	-	-	-	-	-	-	-	-
SPT	4.50 - 6.00	26	1.00	26	Clayey Silts of High Plasticity	MH	4.56	32.22	63.22		51.0	29	22.0	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-
UDS	6.00 - 7.50	-	-	-	Clayey Silts of High Plasticity with Gravels	MH	14.07	18.99	38.49	28.45	53.2	30	23.2	1.96	1.53	28.16	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-
SPT	7.50 - 9.00	37	1.00	37	Clayey Silts of High Plasticity with Gravels	MH	21.13	38.87	40.00		51.0	29	22.0	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-
UDS	9.00 - 10.50	-	-	-	Clayey Silts of High Plasticity with Gravels	MH	16.31	43.51	14.55	25.63	52.8	30	22.8	1.97	1.56	25.88	-	33	-	-	-	-	-	-	-	-	-	-	-	-	-
SPT	10.50 - 12.00	88	1.00	88	Clayey Silts of High Plasticity with Gravels	MH	13.85	39.88	46.27		53.2	30	23.2	-	-	-	-	33	-	-	-	-	-	-	-	-	-	-	-	-	-
SPT	12.00	>50	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

LANDMARK
Material Testing And Research Laboratory Pvt. Ltd.

Project : Four Laining of Sargaon - Bilaspur NH-200 (PKG-III) Chhattisgarh	Date of field Testing	Borehole Location	R.L.	Chainage	Structure	Depth of Water Table	Termination Depth	Easting	Northing	Ref. Code
	14.12.2025	A2 LHS (High Embankment) Edge of embankment - Near distressed portion	-	123 + 080	-	Not Encountered	9.00 m	623484	2435231	Sr-80-1125

Type of Sample	Depth (m) from EGL	Observed N Value	Correction Factor (C_n)	Corrected N Value (N_n)	Soil/Rock Description	Soil Classification	Soil Sample																	Rock Sample							Remark
							Grain Size Analysis				Atterberg Limits %			Bulk Density (g/cc)	Dry Density (g/cc)	Natural Moisture Content (%)	Specific Gravity	Free Swell Index (%)	UCS (kg/cm^2)	Cc	Type of test	Shear Strength Parameter		Core Recovery (%)	RQD (%)	Specific Gravity	Water Absorption (%)	Porosity (%)	UCS (N/mm2)	PLI (MN/m2)	
							Gravels (%)	Sand (%)	Silt (%)	Clay (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)									c kg/cm^2	ϕ Degree								
DS	0.00 - 1.00	-	-	-	Pavement Crust	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SPT	1.50 - 3.00	36	1.00	36	Clayey Sand with Gravels	SC	14.96	65.17	19.87		48.3	28	20.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UDS	3.00 - 4.50	-	-	-	Clayey Silts of High Plasticity	MH	4.70	31.11	36.07	28.12	54.3	30	24.3	1.76	1.51	16.58	-	-	-	0.276	UUT	0.53	12	-	-	-	-	-	-	-	-
SPT	4.50 - 6.00	30	1.00	30	Clayey Silts of High Plasticity	MH	5.48	20.06	74.46		51.0	29	22.0	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-
UDS	6.00 - 7.50	-	-	-	Clayey Sand with Gravels	SC	14.31	52.85	5.85	26.99	52.2	29	23.2	1.74	1.43	21.42	-	42	-	-	-	-	-	-	-	-	-	-	-	-	-
SPT	7.50 - 9.00	39	1.00	39	Clayey Silts of High Plasticity	MH	1.23	44.29	54.48		51.0	29	22.0	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-
DS	9.00	>50	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-