Final Report

on

Evaluation of three roads (Krishnapatnam port (AP), Poranki (AP) & Hyderabad (TS)) stabilized with cement and stabilroad stabilizer

Submitted to

Vishwa Samudra Engineering Pvt. Ltd. & Avani Eco Projects Pvt. Ltd
Hyderabad - 500033

Geotechnical Engineering Division

1st March 2021

सी एस आई आर - केंद्रीय सड़क अनुसंधान संस्थान, नई दिल्ली-110025
CSIR - CENTRAL ROAD RESEARCH INSTITUTE
NEW DELHI-110025

Final Report
On

Evaluation of Three Roads (Krishnapatnam Port (AP), Poranki (AP) & Hyderabad (TS)) Stabilized with Cement and Stabilroad Stabilizer

Submitted to

Vishwa Samudra Engineering Pvt. Ltd. & Avani Eco Projects Pvt. Ltd
Hyderabad - 500033

Geo-technical Engineering Division
CSIR - Central Road Research Institute
New Delhi - 110025

1st March 2021

वरिष्ठ प्रधान वैज्ञानिक / Sr. Principal Scientist
भूतकनीकी अभियांत्रिकी प्रभाग
Geotechnical Engineering Division
सी.एस.आई.आर.-केन्द्रीय सड़क अनुसंधान संस्थान
CSIR-Central Road Research Institute
नई दिल्ली-110025 / New Delhi-110025

Prof. (Dr.) Satish Chandra

Director

Dr. Pankaj Gupta

Head of the Division

Project Leader

Dr. P. S. Prasad (Senior Principal Scientist)

Project Team

Shri K. Sitaramanjaneyulu (Chief Scientist)

Shri. R.K. Srivastava (Sr. Pri. Sci)

Dr. Rakesh Kumar (Sr. Pri. Sci)

Dr. G. Bharat (Scientist)

Smt. Rekha (Technician)

DISCLAIMER

All the data and technical information furnished in this report are based on the laboratory test data, field test data and field investigations by CSIR - Central Road Research Institute (CRRI). The responsibility of the CSIR - Central Road Research Institute (CRRI), New Delhi is limited to the technical and scientific matters contained in this report.

Any use of the findings of the report without consulting CSIR - CRRI by any other agency or person other than the client will be solely at their own risk and responsibility.

ACKNOWLEDGEMENTS

The project work described in this report was carried out in Geotechnical Engineering Division of CSIR - Central Road Research Institute (CRRI), New Delhi. The project team is grateful to Vishwa Samudra Engineering Pvt Ltd, Hyderabad (India) for giving us an opportunity to work on the project entitled "***Evaluation of three roads (Krishnapatnam port (AP), Poranki (AP) & Hyderabad (TS)) stabilized with cement and stabilroad stabilizer***". We are thankful to Sh. Srinivas Vallabhaneni, Director & CEO, Vishwa Samudra Engineering Pvt. Ltd. and other officials of Vishwa Samudra Engineering Pvt Ltd; Sh. Krishna M Remella, Avani Eco Projects Pvt Ltd and G. Bharath Reddy, General Manager, Krishnapatnam Port for the help and co-operation received during the project work. Authors are grateful to colleagues of Geotechnical Engineering Division & Rigid Pavement Division, who have contributed in the investigations and preparation of report.

Tables

Photos

Figures

EVALUATION OF THREE ROADS (KRISHNAPATNAM PORT (AP), PORANKI (AP) & HYDERABAD (TS)) STABILIZED WITH CEMENT AND STABILROAD STABILIZER

1. INTRODUCTION AND BACKGROUND OF PROJECT

Stabilroad stabilizer is available in powder form (Photo 1) for the purpose of soil stabilisation. To evaluate the effectiveness of the Stabilroad stabilizer for Indian soils, M/s Vishwa Samudra Engineering Pvt Ltd. (VSEPL), Hyderabad vide email dated 20th June 2018 requested CSIR-Central Road Research Institute (CRRI) to investigate the strength and durability characteristics of stabilroad stabilisation when mixed with soil and cement at dosages recommended by the manufacturer.

Photo 1 Pictorial view of Stabilroad stabilizer

CSIR – CRRI submitted the final report (October 2018) on laboratory evaluation to client. The laboratory evaluation clearly indicated that Krishnapatnam (KP) Soil stabilized with stabilroad stabilizer (0.3%) + cement (11.7%) showed significant improvement in the CBR value (> 100%), UCS value (5.3 - 5.9 MPa) and satisfied the durability test (brushing loss after wetting and drying) criteria (<1%) as compared to untreated soil.

Based on the laboratory evaluation it was suggested to evaluate the performance of these stabilization material (stabilroad with cement) in field also by constructing a test track and observing performance of the test track for at least two monsoon seasons for validating the laboratory findings.

P. Subramanya Rao
वरिष्ठ प्रधान वैज्ञानिक / Sr. Principal Scientist
भूतकनीकी अभियांत्रिकी प्रभाग
Geotechnical Engineering Division
सी.एस.आई.आर.–केन्द्रीय सड़क अनुसंधान संस्थान
CSIR-Central Road Research Institute
नई दिल्ली-110025 / New Delhi-110025

M/s Vishwa Samudra Engineering Pvt Ltd. (VSEPL) has done some pilot projects in Andhra Pradesh and Telangana with different combinations as presented in Table 1. Vishwa Samudra Engineering Private Limited, vide letter dated 24.07.2018, had requested CSIR - Central Road Research Institute (CRRI) to submit a project proposal for consultancy assignment ***"Evaluation of roads (Krishnapatnam port (AP), Poranki (AP) & Hyderabad (TS)) stabilized with cement and stabilroad stabilizer".*** Based on the discussions with Shri Srinivas Vallabhaneni, CEO cum Director, Vishwa Samudra Engineering Limited and Shri Krishna Madhav Ramella, Director, Avani EcoProjects Pvt Ltd, Hyderabad, CSIR-CRRI considered to take up the consultancy assignment and submitted its acceptance vide letter no. CRRI/GTE/CNP/SS/2018 - 19/VSEPL-2 dated 25/07/2018 to Vishwa Samudra Engineering Limited (VSEPL), Hyderabad. VSEPL accepted the proposal and approved the project on 1/10/2018.

2. ROADS SELECTED FOR THE PRESENT STUDY

Stabilroad stabilized roads constructed in Krishnapatnam (KP) Port (Andhra Pradesh), Vijayawada (Andhra Pradesh) and Hyderabad (Telangana) are selected for the present study for detailed laboratory and field pavement evaluation for a period of two years. The details (Location, Width, Length and Stabilroad stabilizer combinations with soil / asphalt mixes + cement) of these roads are presented in Table 1 and locations are shown in Google map in Fig. 1, 2 and 3.

2.1. Krishnapatnam Port Roads

Krishnapatnam (KP) port is located in Nellore District (18 km East from Nellore), Andhra Pradesh and is about 190 km (North) from Chennai airport. The KP port started operations in the year 2008. Presently, the port has a capacity to handle about 92 million tonnes cargo from 10 berths. The port has handled about 54.37 million tonnes in the financial year 2019 (https://www.thehindubusinessline.com/economy/logistics/adani - ports - buys - krishnapatnam – port – from – cvr – group – for - 13500-crore/article30471749.ece). The trial sections were laid in important locations like truck terminal parking yard, curved portion (S – curve) and berth-3& 4 area. The combinations of stabilroad stabilized material with cement and soil/ existing asphalt road material are presented in Table 1. The roads selected for the present study is shown in Fig.1.

Table 1: Roads selected for the present study

Place	Roads	Width of road (m)	Length of road (m)	Combination	Crust Details	Year of Construction
Krishnapatnam Port, Andhra Pradesh (Fig. 1)	Truck Parking Yard	7 m	4 roads (length of each road = 450 m)	• Murrum (moorum) soil mixed with cement and stabilroad stabilizer (Dosage per square meter: 84 kg of cement and 2.2 kg of stabilroad stabilizer) • In-situ mill depth = 400 mm	BC=40 mm Stabilized layer=400 mm	2017
	S- Curve	5 m	120 m		BC=40 mm Stabilized layer=400 mm	
	Berth - 3	7 m	350 m	• Existing asphalt road material mixed with cement and stabilroad stabilizer (Dosage per square meter: 45 kg of cement and 1.6 kg of stabilroad stabilizer) • In-situ mill depth = 300 mm	BC=40 mm Stabilized layer=300 mm	
Hyderabad, Telangana (Fig. 2)	NTR Marg to Telugu Thalli Flyover	9.5 m	1100 m	• Stabilized asphalt recycling road material with cement and stabilroad stabilizer (Dosage per square meter: 45 kg of cement and 1.6 kg of satbilroad stabilizer) • In-situ mill depth = 300 mm	BC=40 mm Stabilized layer=300 mm	2018
Vijayawada, Andhra Pradesh (Fig. 3)	Poranki to Salipet	7m	2265 m	**Ch.0 m to 660 m** • Murrum (moorum)soil mixed with cement and stabilroad stabilizer (Dosage per square meter: 35 kg of cement and 1.2 kg of stabilroad stabilizer) In-situ mill depth = 300 mm	BC=40 mm Stabilized layer=300 mm	2018
		3.75 m		**Ch. 660 m to 2265 m** • Existing asphalt road material mixed with cement and stabilroad stabilizer (Dosage per square meter 35 kg of cement and 1.2 kg of stabilroad stabilizer) In-situ mill depth = 300 mm	BC=40 mm Stabilized layer=300 mm	

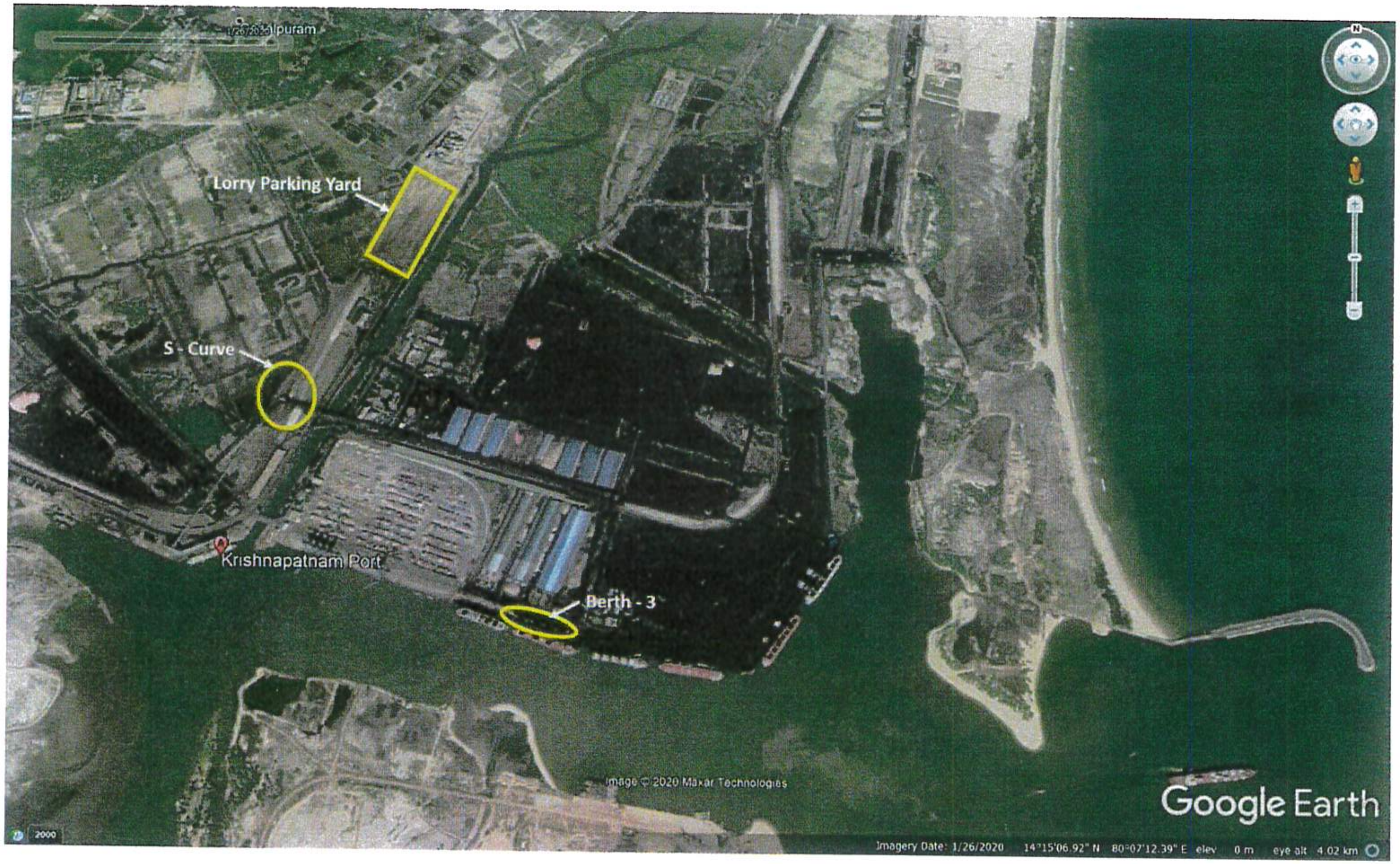

Fig. 1 Roads Selected for the Present Study in Krishnapatnam Port

Fig. 2. Road Selected for the Present Study in Hyderabad (NTR Marg to Telugu Thalli Flyover)

Fig. 3. Road Selected for the Present Study in Vijayawada (Poranki to Salipeta)

2.1.1. Truck Parking Yard/Terminal Roads

This is the first location in KP port selected for the present study (Fig. 1). Original condition of the ground adjacent to truck terminal is shown in photo 2. In the truck terminal area, original soil was removed up to 1 m depth from the existing ground level and filled up with Murrum soil (Photo 3). In the selected road width and length area, top 400 mm murom soil was stabilized with cement and stabilroad stabilizer. In the year 2017, four roads were constructed in Truck terminal area as indicated in Fig. 4. The length of each road is around 450 m and the width is 7m. Heavy loaded trucks and cement bulker are plying and parked on these roads (Photo 4, 5 & 6).

Photo 2 Original condition of the ground adjacent to Truck Terminal

Photo 3 Original soil replaced with Murrum soil up to 1m depth from the EGL

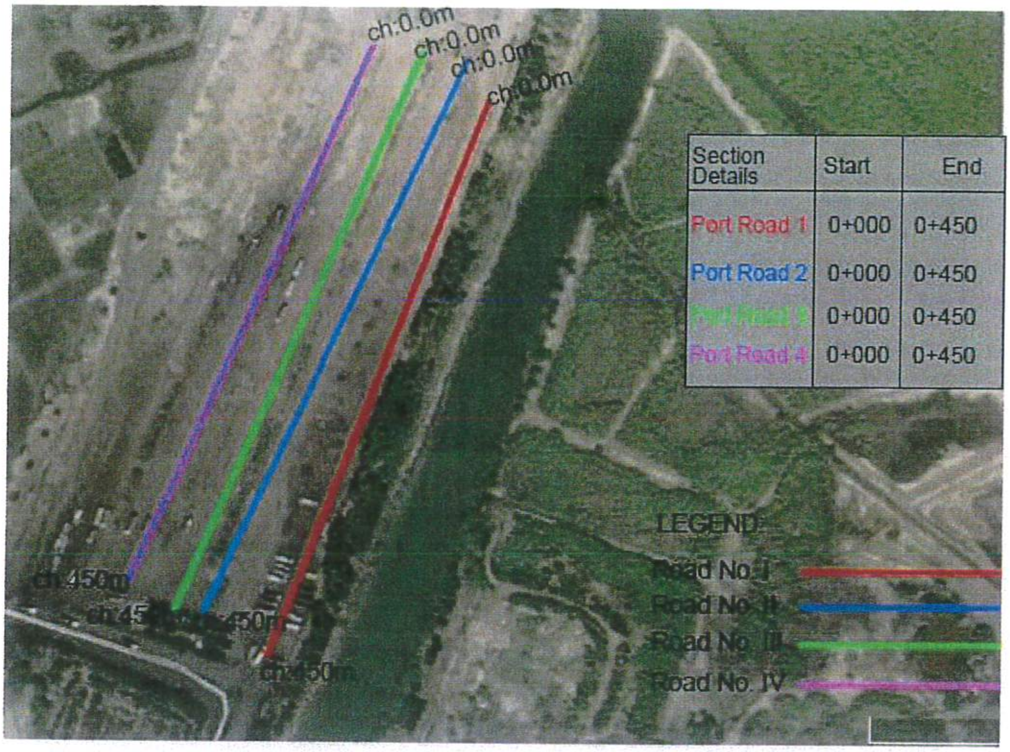

Fig. 4 Truck Terminal Roads at Krishnapatnam Port

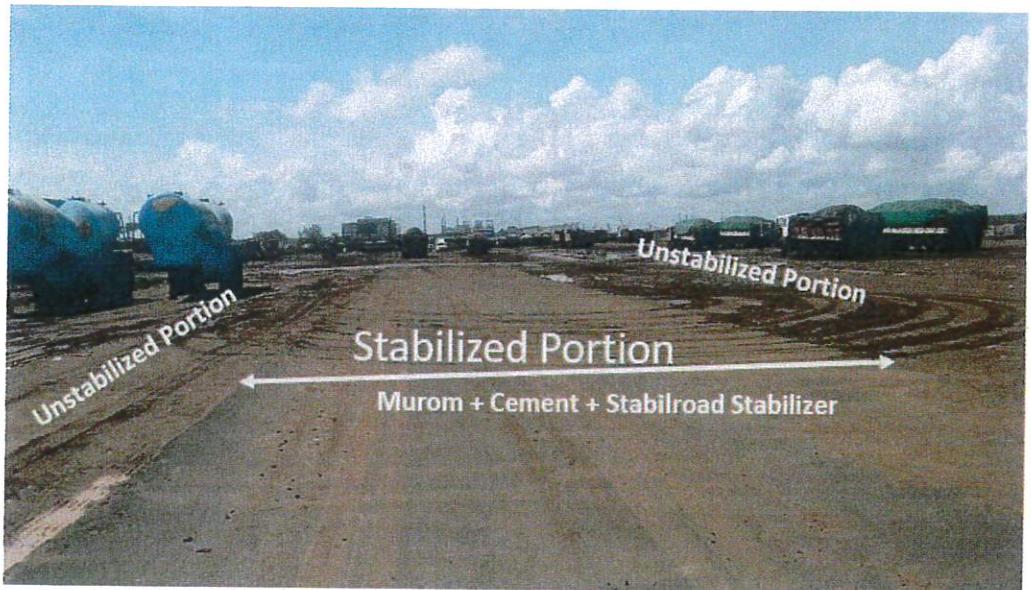

Photo 4 Condition of the Stabilized road number 3 in the year 2018

Photo 5 Condition of the road number 4 in the year 2018

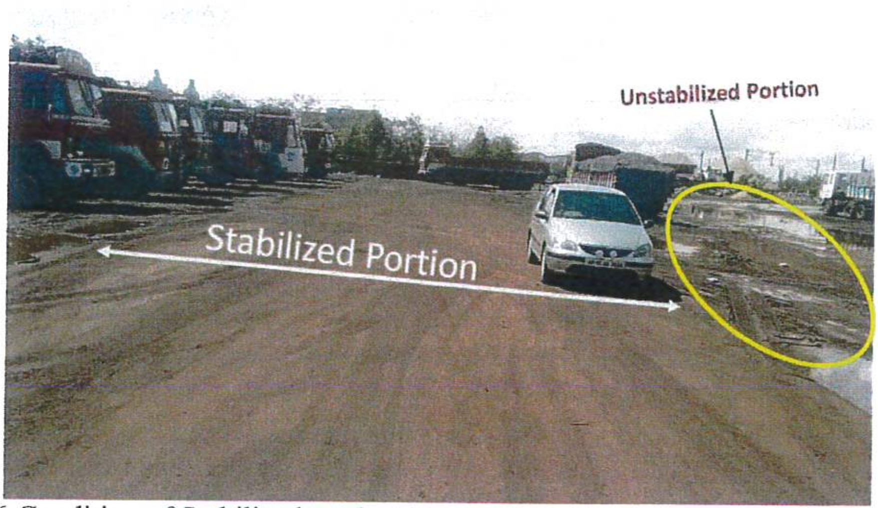

Photo 6 Condition of Stabilized road and Unstabilized Portion in the truck terminal in the year 2018.

2.1.2. S – Curve Road

S- curve portion is the second location in Krishnapatnam port selected for the present study (Fig. 1 and Fig. 5). In this stretch the murrum soil was stabilized with cement and stabilroad stabilizer. The details are presented in Table 1. The stabilized road with asphalt layer is shown in Photo 7. The length of the stabilized road is around 120 m. Due to port activities heavy loaded trucks and cement bulker are plying on this road as shown in Photo 8.

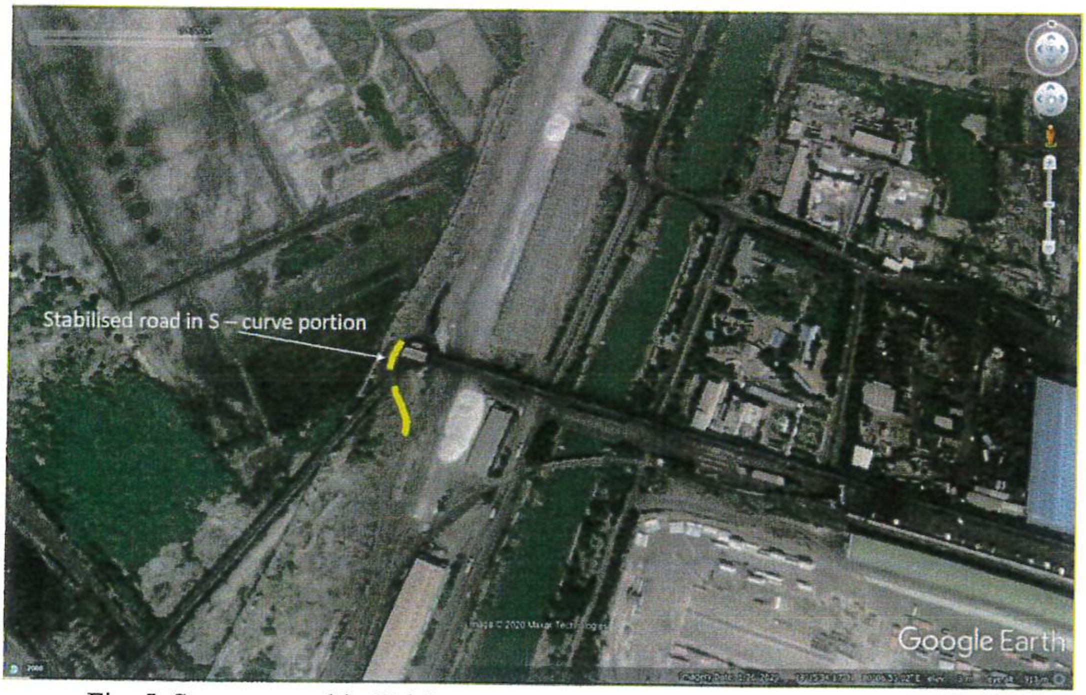

Fig. 5 S- curve road in Krishnapatnam Port area selected for present study

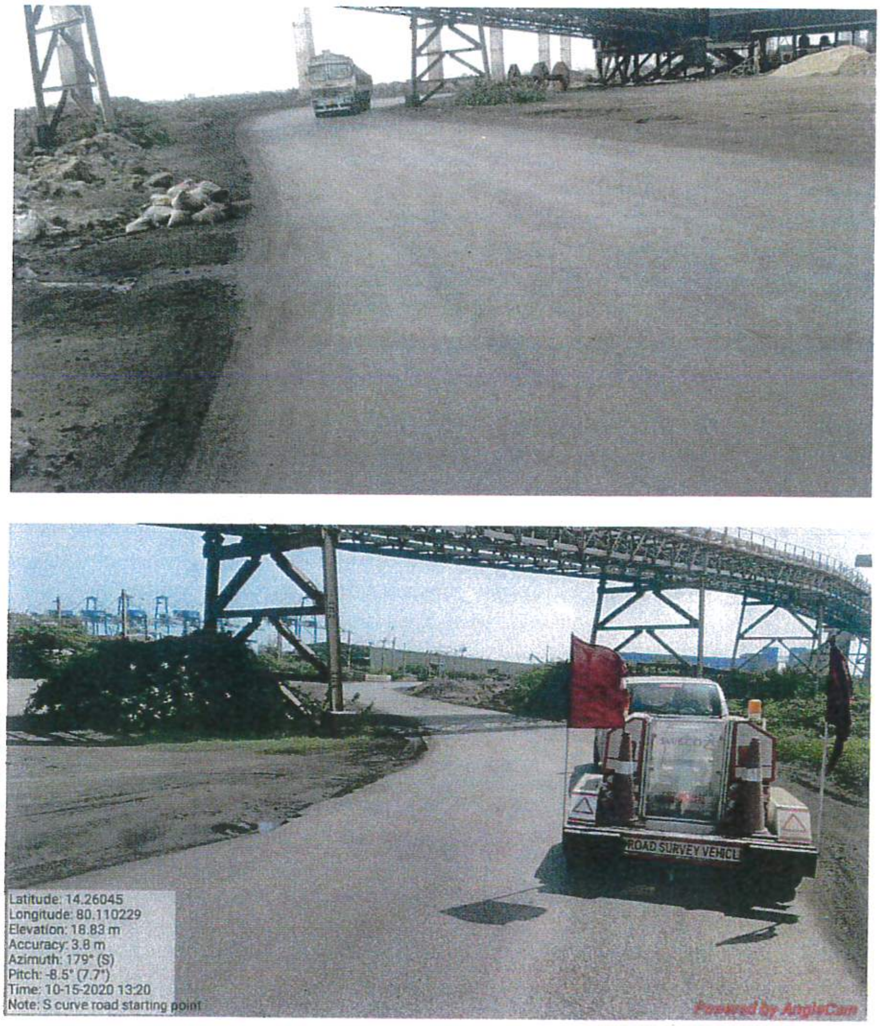

Photo 7 Stabilroad stabilized road in S-curve portion

Photo 8 Heavy loaded trucks are passing in this stretch

2.1.3. Berth Road

The Berth road is the third location in Krishnapatnam port selected for the present study as shown in Fig. 1 and Fig. 6. In this stretch, existing asphalt road material was stabilized with cement and stabilroad stabilizer. The details are presented in Table 1. The stabilized road with asphalt layer is shown in Photo 9. The length of the stabilized road is around 350 m. Here also, heavy loaded trucks and containers ply on this road due to port activities as shown in Photo 10.

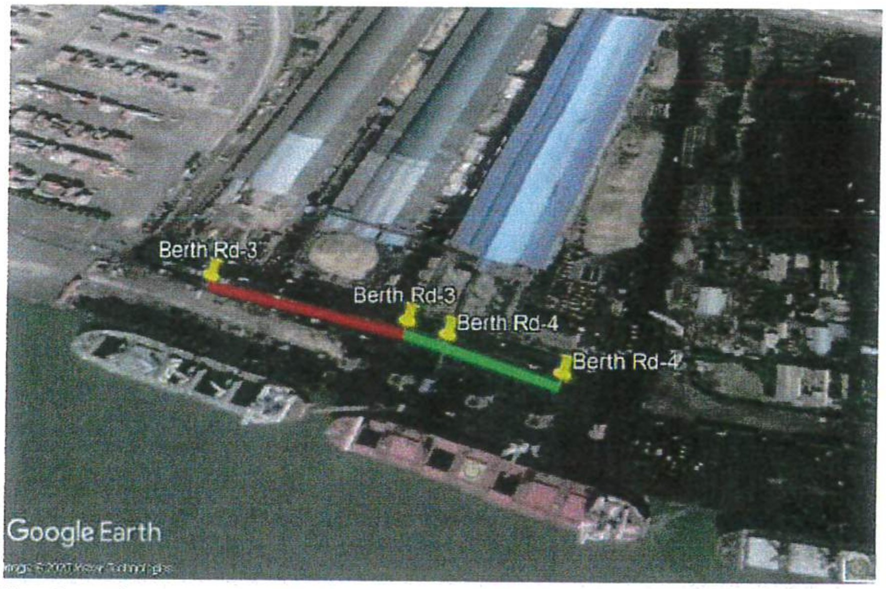

Fig. 6 Berth - 3 road in Krishnapatnam Port area selected for present study

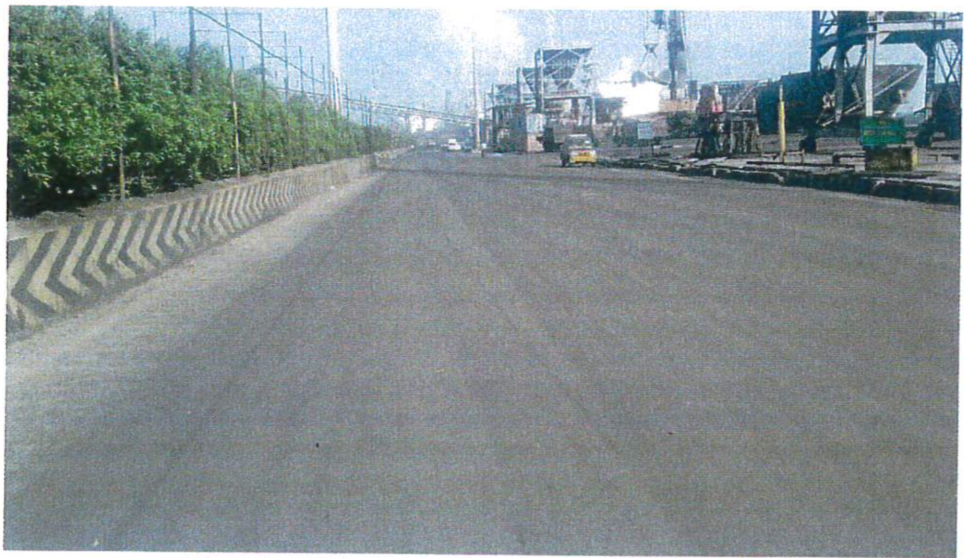

Photo 9 Roads Selected in Berth – 3 & 4Portion

Photo 10 Pavement condition of the stabilised road in berth portion

2.2. NTR Marg – Hyderabad

NTR Marg is adjoining the Hussain Sagar Lake, which connects the Necklace road to Telugu Thalli flyover (Fig. 2), Hyderabad. In the year 2018, the existing asphalt road material was stabilized with cement and stabilroad stabilizer. The details are presented in Table 1. The stabilized road with asphalt layer is shown in Photo 11. The length of the stabilized road is around 1100 m. The road is in CBD area having heavy mixed traffic ply on this road (Photo 11). Several cranes and trucks are also seen moving this road during Ganesh festival.

Photo 11 NTR Marg selected for the present study

2.3. Poranki – Salipeta Road, Vijayawada

Poranki – Salipeta Stabilroad stabilized road, Vijayawada selected for the present study is shown in fig. 3. This road starts from Penumuluru centre and ends at Poranki village (Photo 12). In the year 2018, the existing road material was stabilized with Murrum, cement and stabilroad stabilizer. Total length of the stabilroad stabilized road is 2265 m. This road is having two lane from Penumulu centre to Padmavathi garden Housing society (660 m) and single lane from Padmavathi gardens to Poranki village (1605 m). The details are presented in Table 1. The stabilized road with asphalt layer is shown in Photo 13. Bus, LCV, 2-Axle, 3-Axle are plying on this road up to 660m and only LPV and tractors are plying on remaining road.

Photo 12 Starting and end point of Poranki – Salipeta Stabilroad stabilized road

Photo13 Poranki – Salipeta Stabilroad Stabilized Road

3. OBJECTIVES AND SCOPE OF THE STUDY

The Scope & Objectives of work will be as follows:

- Collection of core samples from stabilized road for two monsoon seasons
- Determination of compressive strength and durability of field core samples for two monsoon seasons
- Field evaluation (Visual inspection, test pits and FWD) for two monsoon seasons
- Analysis of laboratory and field test results (FWD test)
- Submission of Report with Recommendations

4. LABORATORY EVALUATION

CSIR - CRRI scientists visited the Stabilroad stabilized roads of Krishnapatnam Port, Vijayawada and Hyderabad in October 2018, July 2019 and October 2020. The locations for the cores were chosen in such a way that they should cover the entire area and representative stabilized samples are observed. The cylindrical core specimens (Field Sample) were collected from the Stabilroad stabilized roads (Photo 14). These cores were properly packed and transported to laboratory (photo 15) for evaluation of unconfined compressive strength (UCS), durability and residual strength.

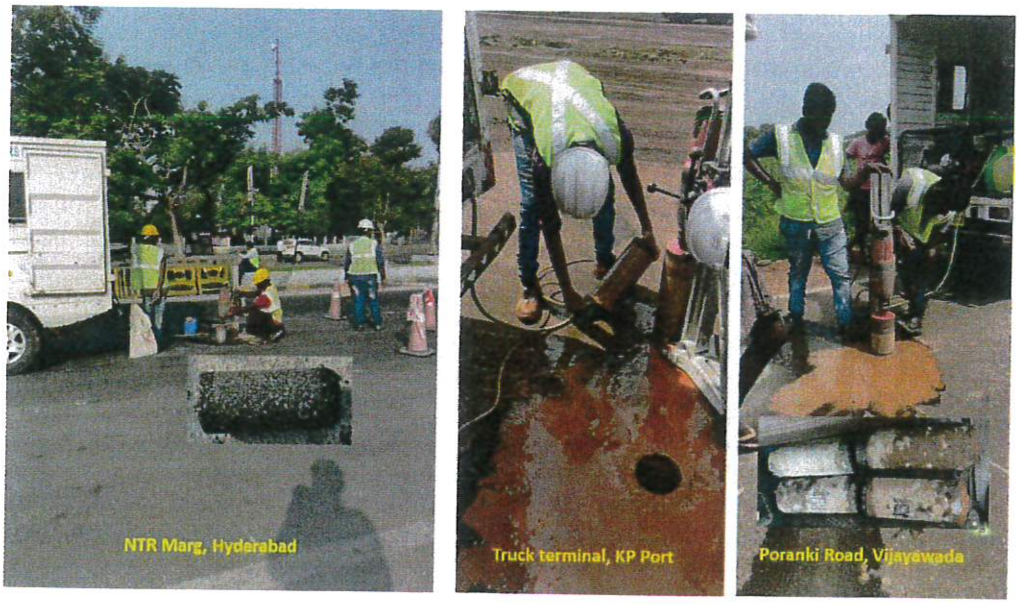

Photo 14 Collection of Field cores for laboratory evaluation

Photo15 Packing of field cores for transportation to laboratory

4.1 Unconfined compressive strength (UCS) test

To assess the gain / diminution in compressive strength characteristic of soils /asphalt road materials due to stabilisation over a period of time, field cores were collected three times (October 2018, July 2019 and October 2020) in a period of two years (minimum two monsoon seasons). The collected cores were properly sliced to cylindrical shape of required length and waxed on top and bottom surfaces to get uniform surface for unconfined compressive strength (UCS) test (Photo 16). The unconfined compressive strength (UCS) test on theses samples were carried out as per IRC: SP: 89 (Photo 17). The results of the same are presented in Table 2A, 2B & 2C and shown in Figures 7, 8 & 9 for Krishnapatnam port, Vijayawada and Hyderabad roads respectively. The failure patterns of UCS specimens are shown in Photo 18. The UCS of Stabilroad stabilized soil / Stabilroad stabilized asphalt road material cores collected from all the sites satisfied the criteria as per IRC: SP: 89 (Part II) - 2018 (section 7.3.2). The UCS value of stabilized field cores is well within and above the IRC specified range (4.5 to 7 MPa in 7/28 days) for cementitious bases.

Photo 16 Field cores Trimmed and Levelled with Wax for UCS test

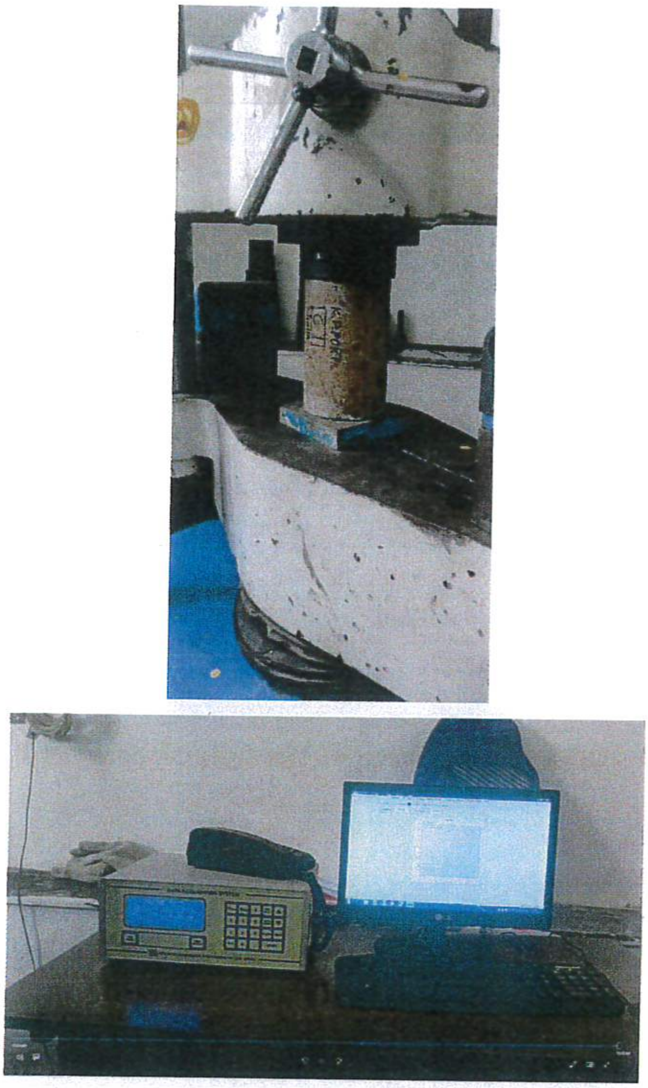

Photo 17 Unconfined compressive strength test of field cylindrical core

Photo 18 Failure pattern of UCS test cubes

Table 2A Compressive strength of stabilized cores collected from roads in Krishnapatnam port (AP)

Oct 2018 *Age of road: 18 months (1 year 6 months)*			(July 2019) *Age of road: 27 months (2 year 3 months)*			(Oct 2020) *Age of road: 42 months (3 year 6months)*		
Core No	Core location from road edge	Equivalent Cube strength (MPa)	Core No	Core location from road edge	Equivalent Cube strength (MPa)	Core No	Core location from road edge	Equivalent Cube strength (MPa)
C - 1	Road No. 3: @Ch 0+069 m, 1.10 m from RHS	10.54	C - 1	Road No. 2: @Ch 0+025 km, 2.95 m (RHS)	9.14	C – 1	Road No – 1: @Ch: 0+40m, 2.2m (LHS)	15.66
C - 2	Road No. 3: @Ch 0+177 m, 1.50m from LHS	15.21	C - 2A	Road No. 2: @Ch 0+355 km, 2.20 m (RHS)	12.76	C – 2	Road No – 1: @CH: 0+130m, 1.8 from (RHS)	7.80
C - 8	Road No. 2: @Ch 0+350 m, 2.30 m from LHS	13.80	C - 3	Road No. 3: @Ch 0+378 km, 4.20 m (RHS)	14.11	C – 3	Road No – 1: @ CH: 0+270m, 3.30m (LHS)	13.67
C - 10	Road No. 1: @Ch 0+115 m, 2.10 m from RHS	10.98	C - 4	Road No. 3: @Ch 0+199 km, 2.65 m(LHS)	9.30	C – 4	Road No – 1: @CH: 0+400m, 1.65m (LHS)	9.58
C - 11	Road No. 1: @Ch 0+337 m, 2.40 m from LHS	9.74	C - 5	Road No. 4: @Ch 0+143 km, 2.00 m (LHS)	16.62	C – 5	Road No – 2: @CH:0+50, 2.30 from LHS	5.99
C - 12	S – Curve : @Ch 0+040 m, 1.30 m (RHS)	9.18	C - 6	Road No. 4: @Ch 0+340 km, 2.80 m (RHS)	15.58	C – 6	Road No – 2: @CH:0+160m, 1.30 m (RHS)	15.83
C - 14	S – Curve: @Ch 0+085 m, 1.40 m (LHS)	9.73	C - 6B	Road No. 4: @Ch 0+330 km, 3.00 m (RHS)	8.62	C – 7	Road No – 2: @CH:0+270m, 3.20 m (LHS)	10.41
C - 16	Berth No. 3: @Ch 0+070 m, 3.0 m (RHS)	7.96	C - 7	Road No. 1: @Ch 0+350 km, 1.75 m (RHS)	9.69	C – 9	Road No – 3: @CH:0+400m, 1.90 m (LHS)	12.08
C - 17	Berth No. 3: @Ch 0+310 m, 3.80 m (RHS)	7.56	C - 8	Road No. 1: @Ch 0+149 km, 2.00 m (LHS)	5.11	C - 16	Road No – 4: @CH:0+400m, 1.50 m (RHS)	8.50
			C - 9	S - curve: @Ch 0.030 km, 1.70 m (LHS)	7.43	C - 17	S - curve Road: @CH:0+25m, 1.50 m (LHS)	13.46
			C - 14	Berth No. 4: @Ch 0.270 km, 6.90 m (LHS)	11.14	C – 20	S - curve Road: @CH:0+68m, 1.20 m (LHS)	12.28
			C - 15	Berth No. 4: @ Ch 0.320 km, 4.00 m (LHS)	14.12	C - 21	S - curve : @CH:0+114m, 1.70 m (RHS)	15.17
						C – 23	Berth No - 3: @CH:0+150m, 1.70 m (RHS)	8.75
						C – 25	Berth No – 4: @CH:0+270m, 4.1m (RHS)	12.99
						C - 26	Berth No - 4: @CH:0+320m, 1.70 m (RHS)	14.98

Table 2B Compressive strength of stabilized cores collected from Salipeta - Poranki road(AP)

(Oct 2018) Age of road: 3.5 months			*(July 2019) Age of road: 12.5 months (1year 0.5months)*			*(Oct 2020) Age of road: 27.5 months (2 year 3.5months)*		
Core No.	Core location from road edge	Equivalent Cube strength (MPa)	Core No.	Core location from road edge	Equivalent Cube strength (MPa)	Core No.	Core location from road edge	Equivalent Cube strength (MPa)
C - 18	@Ch 2+165 km, 0.90m (RHS)	12.69	C - 20	@Ch 1+208 km, 0.85 m (RHS)	17.05	C -31	@CH:0+400m, 1.00 m (RHS)	20.81
C - 19	@Ch 2+030 km, 0.80m (RHS)	10.53	C - 23	@Ch 1+781 km, 1.10 m (RHS)	11.85	C - 32	@CH:0+520m, 1.80 m (LHS)	14.10
C - 20	@Ch 1+878 km, 1.10m (LHS)	12.71	C - 24	@Ch 1+880. km, 1.80 m (RHS)	13.08	C - 33	@CH:0+642m, 1.50 m (RHS)	19.22
C - 22	@Ch 1+623 km, 1.80m (RHS)	6.63	C - 25	@Ch 2+040km, 1.35 m (LHS)	8.57	C - 34	@CH:0+528m, 2.00 m (RHS)	12.02
C - 32	@Ch 0+508 km, 3.50m (RHS)	12.68	C - 17	@Ch 0+240 km, 1.65 m (LHS)	17.28	C - 35	@CH:0+515m, 1.50 m (RHS)	10.83
C - 26	@Ch 0+074 km, 1.40 m LHS	5.69	C - 27	@Ch 0+082 km, 1.40 m (LHS)	7.65	C - 36	@CH:0+293m, 1.40 m (RHS)	21.71
C - 28	@Ch 0+249 km, 1.80 m (LHS)	9.39						

Table 2C Compressive strength of stabilized cores collected from road (NTR Marg to Telugu Thalli Flyover), Hyderabad

Oct 2018 Age of road: 8 months			*(July 2019) Age of road: 17 months (1 year 5 months)*			*(Oct 2020) Age of road: 32 months (2 year 8months)*		
Core No.	Core location from Road edge	Equivalent Cube strength (MPa)	Core No.	Core location from Road edge	Equivalent Cube strength (MPa)	Core No.	Core location from Shoulder edge	Equivalent Cube strength (MPa)
C - 35	Ch 0.070 km, 1.50 m (RHS)	13.14	C - 32	Ch 0.390 km, 1.40 m (RHS)	10.11	C -1	@CH:0+015m, Outer lane, 1.64 m from	13.64
C - 36	Ch 0.310 km, 4.60m (centre)	13.30	C - 35	Ch 0.658 km, 2.30m (LHS)	9.48	C - 2	@CH:0+100m, Middle lane 3.18 m	13.58
C - 37	Ch 1.010 km, 2.10 m (RHS)	8.09	C - 36	Ch 0.851 km, 2.50 m (LHS)	8.07	C - 7	@CH:0+500m, Outer lane, 1.20 m	5.77
C - 39	Ch 0.130 km, 2.20 m (LHS)	8.44				C - 10	@CH:0+700m, Outer lane, 1.00m	12.44
C - 41	Ch 0.960 km, 7.80 m (centre)	7.35				C - 15	@CH:0+350m, Outer lane, 0.80 m	14.07

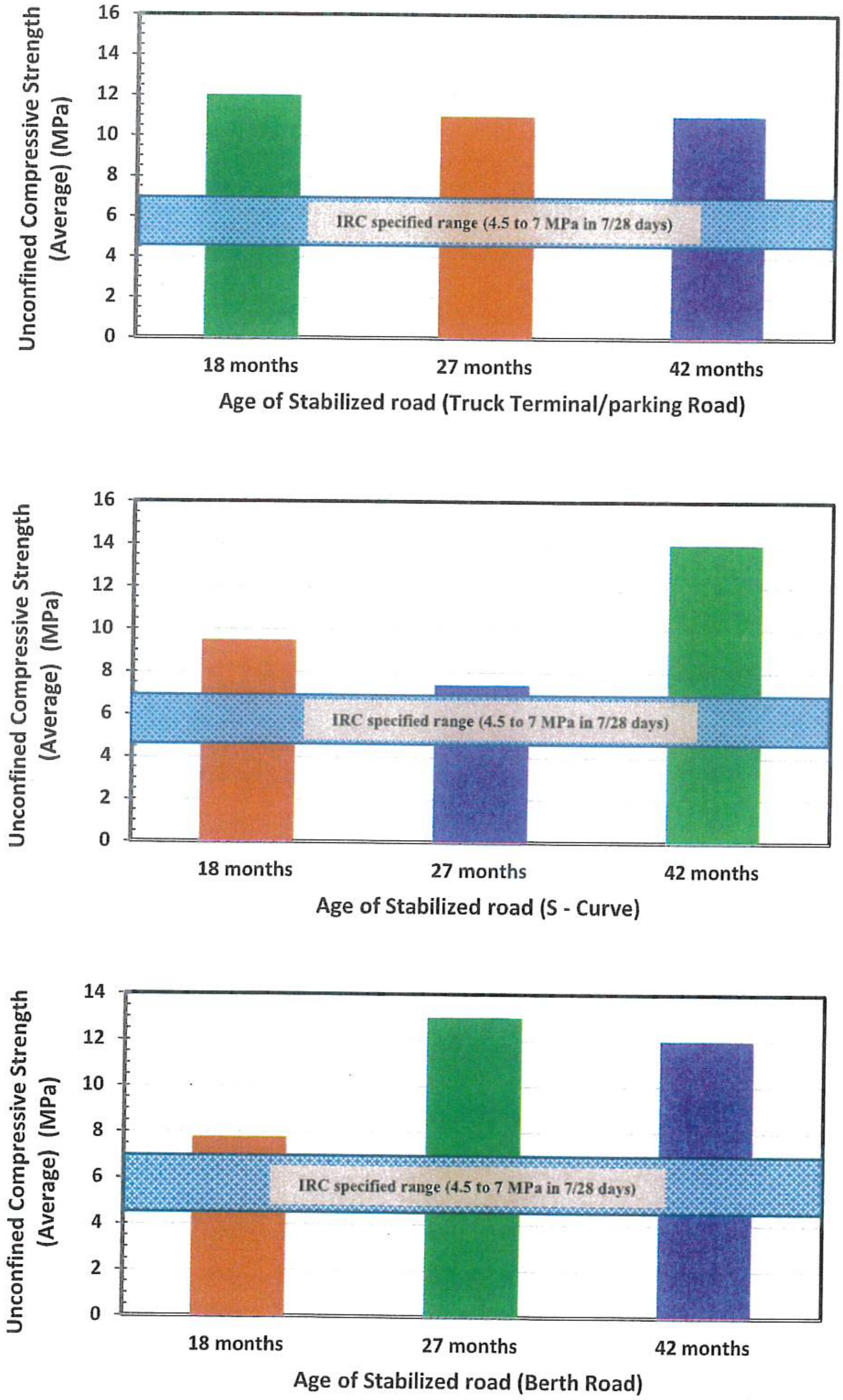

Figure 7 Average UCS of field cores vs. Age of Krishnapatnam stabilized road

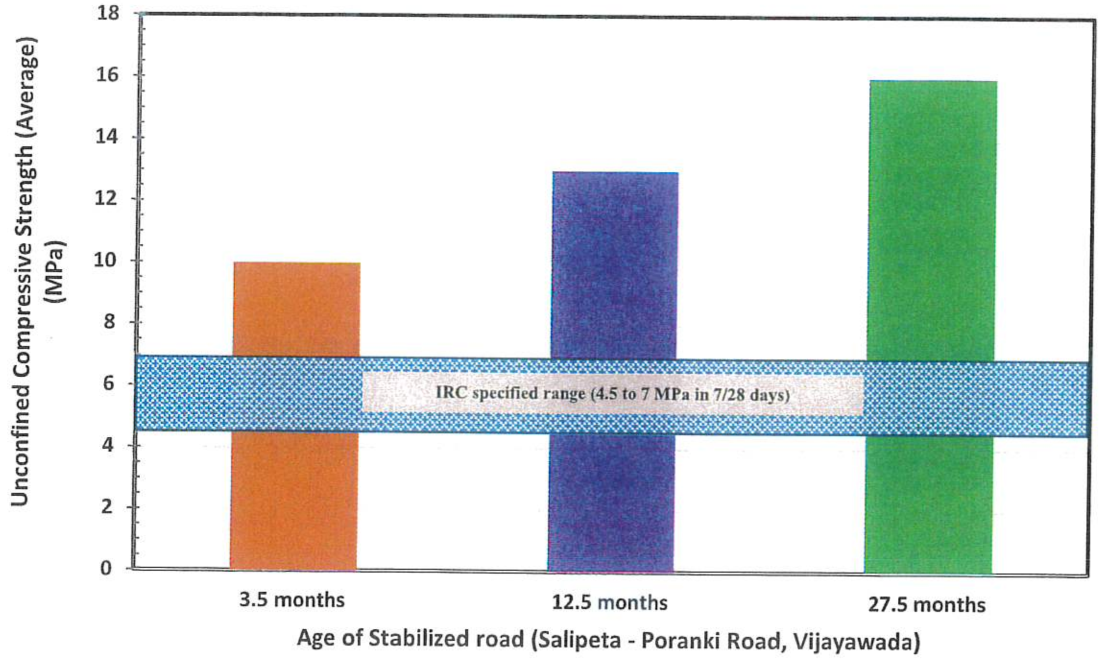

Figure 8 Average UCS of field cores vs. Age of Vijayawada Stabilroad stabilized road

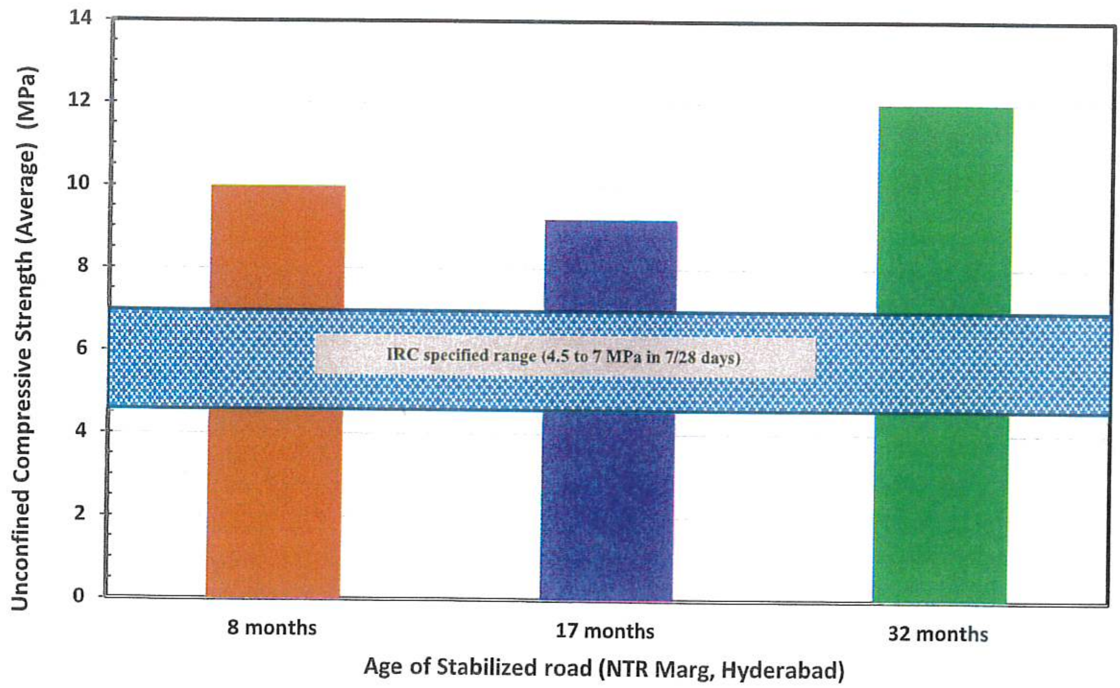

Figure 9 Average UCS of field cores vs. Age of Stabilroad stabilized road (Hyderabad)

4.2 Durability Test

The cylindrical core specimens (Field Sample) were collected (October 2018, July 2019 and October 2020) from the Stabilroad stabilized roads of Krishnapatnam Port, Vijayawada and Hyderabad for durability test. Collected cores were sliced to proper cylindrical shape for Durability test (Photo 19). Durability test was carried out as per IS 4332 Part 4. This test is also known as "Wetting and Drying" test. Two different procedures are given in this code - Wetting and Drying tests and Freezing and Thawing tests. Keeping in view climate of Krishnapatnam Port (Andhra Pradesh), Vijayawada (Andhra Pradesh) and Hyderabad (Telangana) regions, 'Wetting and Drying tests' were adopted. This test broadly determines the weight loss produced by brushing, after repeated number of cycles of the wetting and drying of hardened stabilised soil specimens. In this test specimens are subjected to 12 cycles of wetting and drying, consisting of immersion in water for 5 hours followed by drying at 71^0C for 42 hours. After each such cycle, the specimens are brushed in a standardised manner using a wire-scratch brush (18 to 20 strokes on the sides and 4 strokes at each end). The loss in weight of brushed specimen, after each cycle is determined. After 12 cycles of test, all the specimens are dried to constant weight at 110^0C. The oven dry weight at the end of the test is required for determination of soil/ asphalt road material-cement- stabilroad stabilizer loss after specified number of cycles. The percentage loss of different stabilised (soil/asphalt) road material samples were estimated and compared with the permissible soil + cement + Stabilroad stabilizer loss as per Indian Roads Congress specifications (IRC SP 89-2018). The durability test results of cores collected from Krishnapatnam port, Vijayawada and Hyderabad are presented in Table 3A, 3B and 3C respectively. Average % of weight loss (Durability) of field cores Vs Age of Stabilroad stabilized roads for KP Port, Vijayawada and Hyderabad are shown in Figure 10. As per IRC SP 89-2018 the stabilized soil loss for clayey sand with gravel (SC) type of soil is up to 14 per cent of the original weight of test specimen. The condition of stabilized soil specimens/ asphalt mixes after durability test is shown in Photo 20. All these Stabilized cores satisfied the durability test (brushing loss after wetting and drying) criteria as per IRC: SP: 89 (Part II) – 2018 even after more than 30 months. The weight loss of stabilized soil/asphalt mixes (soil/asphalt mixes + cement + Stabilroad stabilzer) is very within IRC specified limit i.e. less than 14%.

Table 3A Durability of stabilized cores collected from roads in Krishnapatnam port (AP)

Oct 2018 Age of road: 18 months (1 year 6 months)			*(July 2019) Age of road: 27 months (2 year 3 months)*			*(Oct 2020) Age of road: 42 months (3 year 6months)*				Maximum Permissible weight loss (%) *(IRC : SP: 89 (Part II) - 2018)*
Sample designation	Bulk Density (kN/m^3) *(Field samples)*	Weight loss of stabilised samples (%) *(After 12 cycles)*	Sample designation	Bulk Density (kN/m^3) *(Field samples)*	Weight loss of stabilised samples (%) *(After 12 cycles)*	Location	Sample designation	Bulk Density (kN/m^3) *(Field samples)*	Weight loss of stabilised samples (%) *(After 12 cycles)*	
C - 7	22.4	0.60	C - 2	22.8	4.72	Truck terminal	C -11	20.78	7.19	14
C - 9	21.8	0.47	C - 12	22.7	4.85		C - 13	21.60	2.42	
C - 13	21.0	1.11	C - 13	25.2	2.16		C - 14	21.69	4.64	
						S – curve	C - 19	20.85	2.64	
						Berth - 3	C - 24	25.27	3.64	

Table 3B Durability of stabilized cores *(Field samples)* collected from Salipeta - Poranki road(AP)

(Oct 2018) Age of road: 3.5 months			*(July 2019) Age of road: 12.5 months (1year 0.5months)*			*(Oct 2020) Age of road: 27.5 months (2 year 3.5months)*			Maximum Permissible weight loss (%) *(IRC : SP: 89 (Part II) - 2018)*
Sample designation	Bulk Density (kN/m^3)	Weight loss of stabilised samples (%) *(After 12 cycles)*	Sample designation	Bulk Density (kN/m^3)	Weight loss of stabilised samples (%) *(After 12 cycles)*	Sample designation	Bulk Density (kN/m^3)	Weight loss of stabilised samples (%) *(After 12 cycles)*	
C - 21	22.0	1.16	C - 16	21.0	5.66	C - 28	19.57	3.72	14
C - 27	24.7	1.03	C - 26	24.0	3.59	C - 29	24.18	3.93	
			C - 28	22.3	6.75	C - 37	23.61	7.48	

Table 3C Durability of stabilized cores *(Field samples)* collected from road (NTR Marg to Telugu Thalli Flyover), Hyderabad

Oct 2018 Age of road: 8 months			*(July 2019) Age of road: 17 months (1 year 5 months)*			*(Oct 2020) Age of road: 32 months (2 year 8months)*			Maximum Permissible weight loss (%) *(IRC : SP: 89 (Part II) - 2018)*
Sample designation	Bulk Density (kN/m^3)	Weight loss of stabilised samples (%) *(After 12 cycles)*	Sample designation	Bulk Density (kN/m^3)	Weight loss of stabilised samples (%) *(After 12 cycles)*	Sample designation	Bulk Density (kN/m^3)	Weight loss of stabilised samples (%) *(After 12 cycles)*	
C - 41	22.6	0.74	C - 30	22.9	2.21	C - 5	22.26	3.38	14
C - 42	22.5	0.91	C - 33	22.8	2.50	C - 9	23.11	3.82	
			C - 34	23.2	1.73				

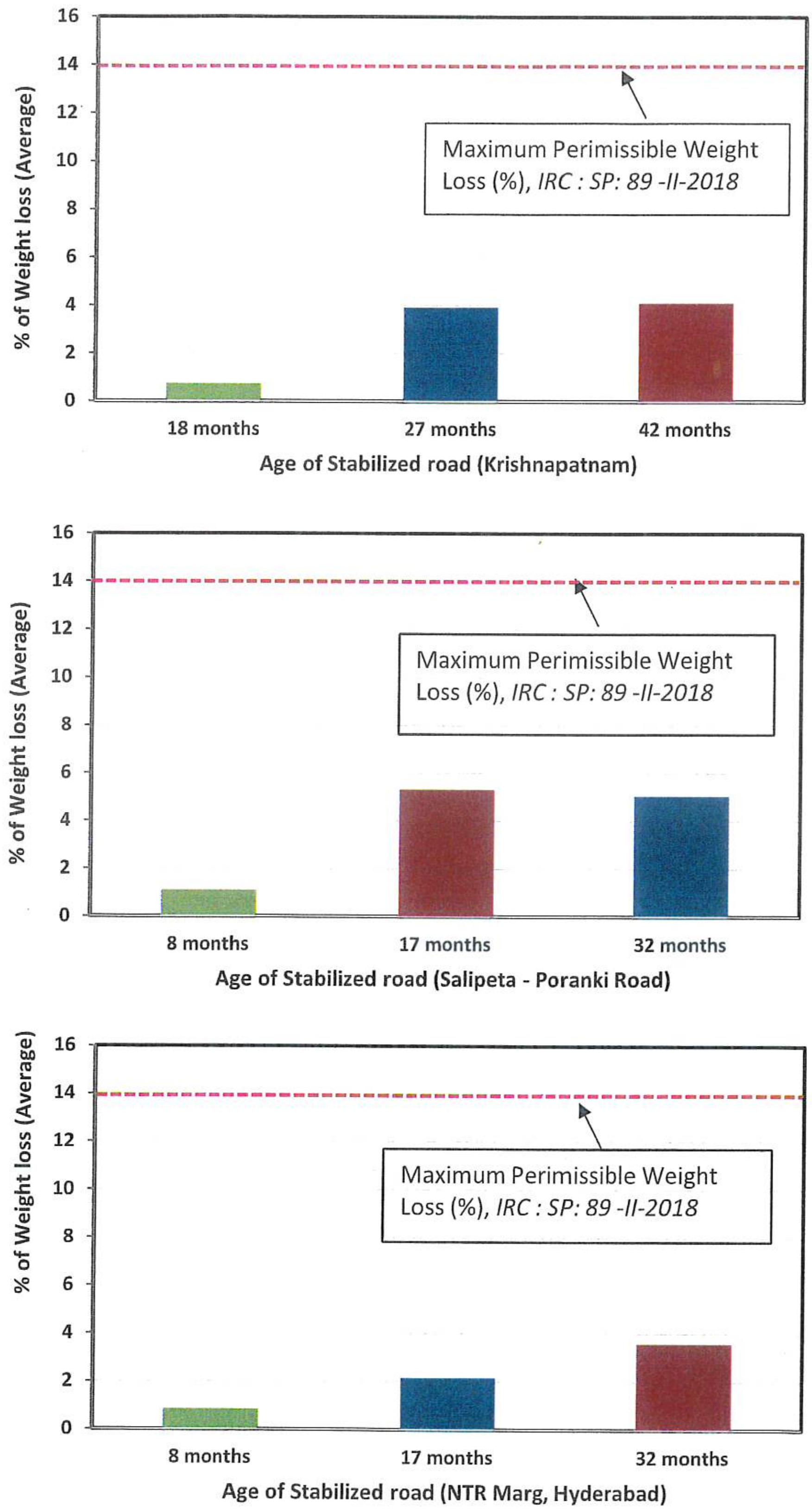

Figure 10. Durability of Stabilroad Stabilized cores collected from KP Port, Vijayawada & Hyderabad

Photo. 19 Condition of stabilised cores before durability test(Samples collected in the year October 2020)

Photo. 20 Condition of stabilised cores after durability test (Samples collected in the year October 2020)

4.3 Residual Strength Test

After durability test, as per IRC: SP: 89 (Part II)-2018, residual strength test (UCS test after 12 cycles of wet/dry) was carried out on these stabilized soil/asphalt road material samples (Photo 21). The residual strength test results are presented in Table 4. The residual strength of Krishnapatnam port core samples (Stabilroad Stabilized soil samples/ asphalt road material), Vijayawada core samples (Stabilroad Stabilized soil samples / road material) and Hyderabad core samples (Stabilroad Stabilized asphalt road material) satisfied the IRC SP 89 criteria.

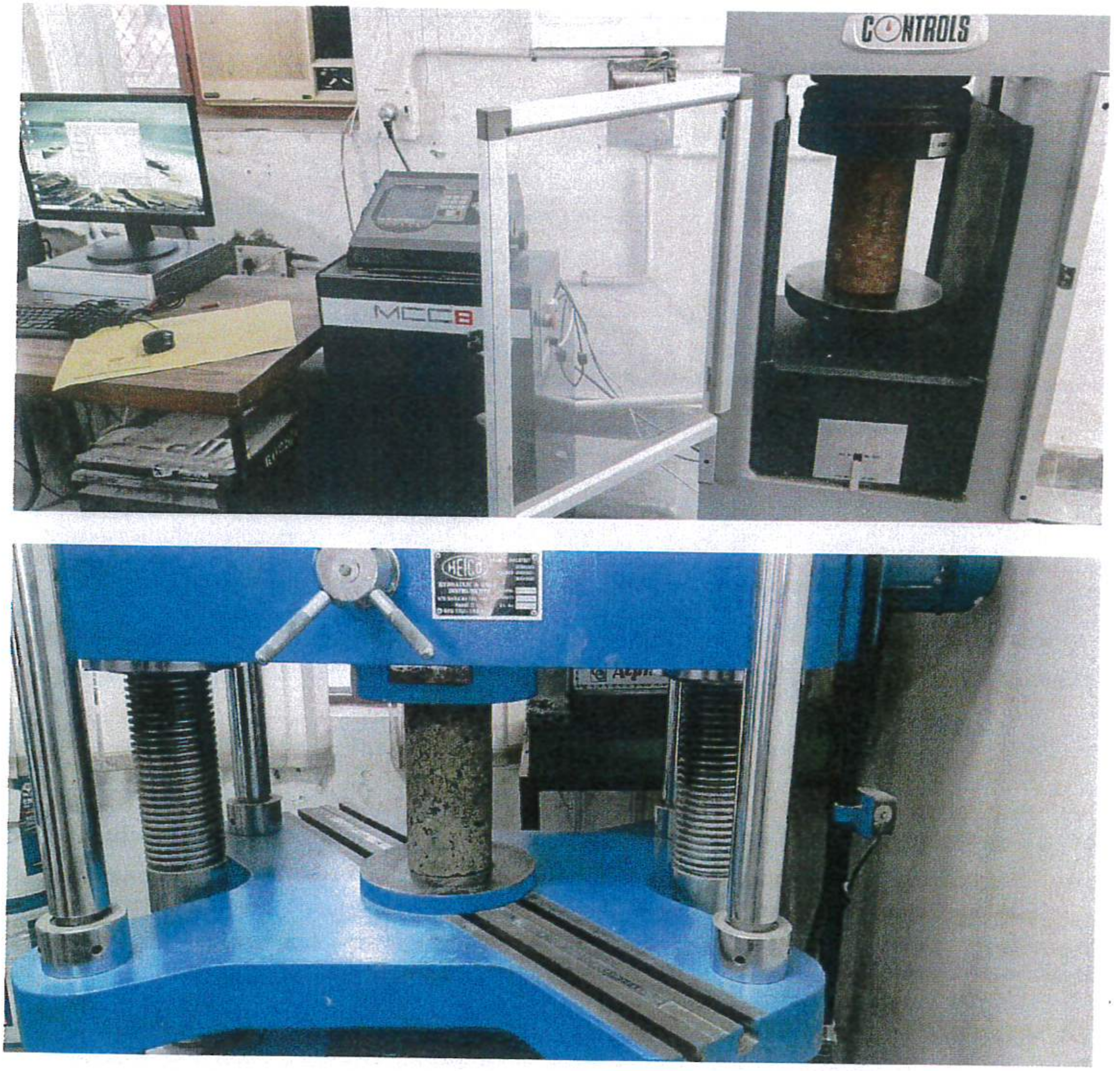

Photo 21 Residual UCS test (after durability cycles) on Stabilized cores

Table 4 Residual strength of Stabilroad Stabilised (Soil/ asphalt) road material cores (collected in the month of October 2020) after Durability Test

Location		Ave. Residual UCS (MPa) *(After 12 cycles)*	Ave. of UCS strength (MPa) of Field core	Remarks
KP Port	Truck terminal Roads	20.0	13.82	*For all the roads, residual strength criteria satisfied As per IRC : SP: 89 (Part II) - 2018*
	S- curve Road	15.01	13.58	
	Berth Road	16.36	14.69	
Vijayawada	Poranki to Salipeta Road	11.61	13.32	
Hyderabad	NTR Marg- Telugu Thalli flyover Road	14.02	12.94	

5. FIELD EVALUATION

For structural evaluation of these stabilized roads, Falling weight Deflectometer (FWD) was used, four times (October 2018, July 2019, October 2019 & October 2020) on Krishnapatnam port, two times on NTR Marg-Hyderabad and one time on Poranki –Vijayawada.

5.1. Structural Evaluation

Falling Weight Deflectometer (FWD) is used to measure pavement deflections in response to a stationary dynamic load, similar to a passing wheel load. The interpretation of FWD data is a key method for estimating the in situ moduli of pavement layer materials. The data obtained are used to evaluate the structural capacity of pavements for research, design, rehabilitation, and pavement management purposes. It is an impulse-generating device with a guided system. This device allows a variable weight to be dropped from a variable height. It has a load cell for measuring the actual applied impulse. It consists of minimum seven geophones to measure deflection basin.

The principle of FWD is illustrated in Figure 11. SWECO PRI 2100 Falling Weight Deflectometer (Photo 22) equipment was used for the survey. Nine geophones are arranged in a geophone frame at radial distances of 0 mm, 200 mm, 300 mm, 450 mm, 600 mm, 900 mm, 1200 mm, 1500 mm and 1800 mm from the centre of the loading plate to measure the pavement surface deflections.

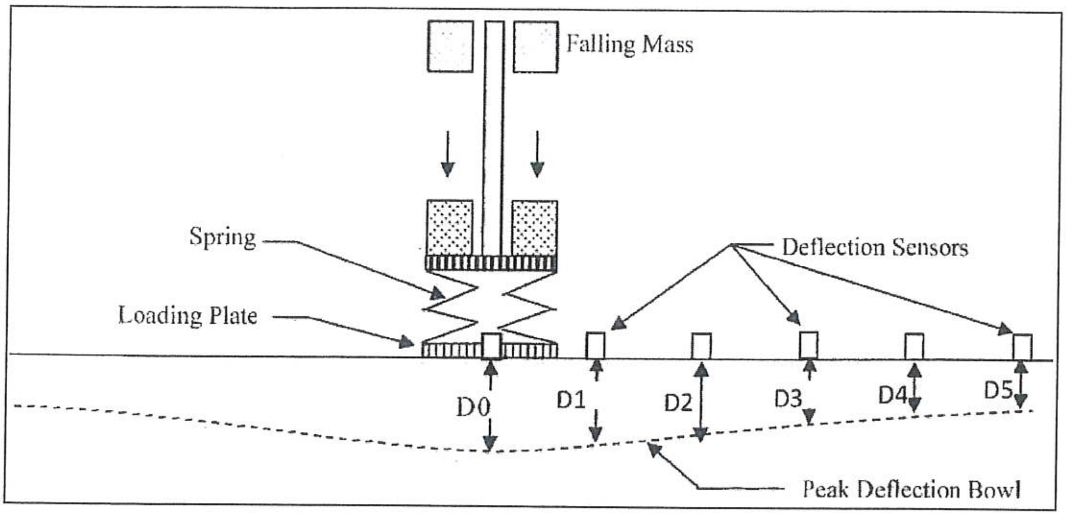

Figure 11: Working Principle of FWD

Photo 22: SWECO PRI 2100 FWD equipment

5.1.1 Traffic volume data

Traffic volume data for the study roads were collected by covering various categories of commercial vehicles viz., Light Commercial Vehicles (LCVs), and different types of Heavy Commercial Vehicles like, buses, 2&3 Axle trucks and multi-axle trucks etc. The data collected manually under the direct supervision of VSEPL team by engaging the trained enumerators who recorded vehicle counts in a prescribed Performa devised for the purpose. The traffic volume surveys were carried out for 72 hours continuously for all the study roads and the data given in **Table 5**.

Table 5: Traffic Volume for various Study Roads

Road	LCV	Bus	2-Axle	3-Axle	Multi Axle	commercial vehicles per day (CVPD)
Krishnapatnam Port Roads: (S curve and Berth Road)	—	—	85	150	4292	4527
NTR Marg, Hyderabad	91	131	25	33	2	282
Poranki Road, Vijayawada	95	45	93	63	2	298

5.1.2 Axle load data

Axle load survey was conducted to assess the extent of actual loads carried by various types of heavy commercial vehicles viz. buses, 2&3 Axle trucks and multi-axle trucks and to determine the damage caused to the road by such axle loads. This data was essential to work out the current traffic loading and the anticipated/ projected traffic loading of the road will be subjected to. Analysis of axle load data was also done to determine the Vehicle Damage Factors (VDFs), for various categories of vehicles, in order to compute the projected traffic loading over its service life. The survey was done for a continuous period of 24 hours, for various study roads, using static Weigh Pads for all types of vehicles. The axle load data was collected under the direct supervision of VSEPL for study roads and the results of VDF are presented in **Table 6**.

Table 6: VDF values for different category of vehicles for various roads

Road	LCV	Bus	2-Axle	3-Axle	Multi Axle
Krishnapatnam Port Roads: (S curve and Berth Road)	—	—	2.81	5.387	14.05
NTR Marg, Hyderabad	0.12	0.32	1.09	0.98	3.15
Poranki Road, Vijayawada	1.58	0.18	1.8	9.64	16.74

5.1.3 Projected design traffic loading

In order to examine the performance of existing pavement, corresponding to the current and projected traffic loading, the information on composition of traffic using the road section, and the axle loads, carried particularly by the heavy commercial vehicles, during its design life is needed. For the analysis purpose, the data on directional traffic and axle loads, collected during the field surveys were used. The relative damaging effect of different axle loads is determined based on a characteristic relationship termed as the "Fourth Power Law". The design traffic in terms of Cumulative Standard Axles (CSA) is worked out by considering the heavy commercial traffic and their damaging effects (VDF), as explained earlier, for a convenient design life duly accounting for the anticipated traffic growth. In the present case, the cumulative standard axles have been worked out for various periods (18, 27 and 42 months) of design life, by taking respective traffic and VDF values for each section.

$$N_s = \frac{365 * A * \{(1+r)^x - 1\}}{r} * D * F$$

N_s : The cumulative number of standard axles to be catered for in the design

A : Initial traffic, in the year of completion of construction, in terms of the number of commercial vehicles per day (CVPD).

r : Annual growth rate of commercial vehicles

x : Design life (in years)

D : Lane distribution factor

F : Vehicle damage factor

The cumulative standard axles (in million standard axle (msa)) computed for various periods, are given in **Table 7**.

Table 7: Computation of Cumulative Standard Axles

Road	CVPD	VDF	LDF	Traffic (msa)			
				18 months	27 months	42 months	10 years
Krishnapatnam Port Roads: (S curve and Berth Road)	4527	13.55	0.75	25.50	38.97	62.55	211.24
NTR Marg, Hyderabad	282	0.426	0.75	0.05	0.08	0.12	0.41
Poranki Road, Vijayawada	298	3.243	1	0.54	0.82	1.31	4.44

5.1.4 Elastic Modulus

Elastic Modulus of pavement layers are critical inputs for the analysis and design of pavements. Selection of appropriate elastic moduli of pavement is an important step in the design of new pavements. Layer moduli is determined as per IRC: 115-2014 "Guidelines for Structural Evaluation and Strengthening of flexible road pavements using Falling Weight Deflectometer (FWD) Technique". Back calculation of layer moduli is carried out by KGPBACK program for the actual load and deflection data measured. Falling weight deflectometer (FWD) survey was carried out for the study roads and the summary of test section locations and the period of testing are given in Table 8.

Table 8: Summary of Test Section Locations

Section Location		Section Length (m)	Width of Road, m	Age of road at the time of FWD Survey
Krishnapatnam port (AP)	Truck terminal Roads	1800	7	1st time:18 months, 2nd time : 27 months, 3rd time: 42 months
	S Curve Road	120	5	
	Berth Road	350	7	
NTR Marg Road, Hyderabad		1100	9.5	1st time: 4 months 2nd time: 32 months
Poranki Road, Vijayawada		0 to 660	7	1st time: 27.5 months
		660 to 2265	3.75	

Steps to determine Elastic modulus values

- The raw data was normalized to a standard load (40 kN)
- The normalized deflections were then back calculated using the KGPBACK application to obtain Elastic Modulus values of Bituminous layer, Granular layer and Sub-grade.
- The correction factors are applied to all layers as suggested in IRC 115:2014.

KGPBACK has been used to back calculate the effective layer moduli from the measured deflections. For back calculating the layer moduli, one has to input upper and lower limits of the moduli value in the program. The upper and lower bounds were adjusted for subsequent analysis when the back calculated value was close to either of these two bounds. Elastic Modulus values (average) for various sections for 1st, 2nd and 3rd time survey are given in Table 9 and Table 10 respectively.

Table 9: Elastic Modulus (average) values for Krishnapatnam port (AP) of various study sections

Study Sections	Stabilised layer Moduli Value, MPa		
	(First observation: 18 months old)	(Second observation: 27 months old)	(Third observation: 42 months old)
Truck Terminal Roads (Parking)	7494	7240	7422
S Curve Road	8225	7717	6341
Berth Road	9453	8613	7321

Table 10: Stabilised Layer Elastic Modulus (Average) values of NTR Marg and Poranki road

Road	Elastic Modulus, MPa	Remarks
NTR Marg Road, Hyderabad	7214	Age of the road: 4 months
	7987	Age of the road: 32 months
Poranki Road, Vijayawada	6806	Age of the road: 27.5 months

Figure 12 and 13 shows the stabilised layer elastic modulus values with cumulative traffic loading for S curve and Berth roads in KP port. After plying traffic of around 62 MSA, the back calculated elastic modulus values (both S Curve and Berth roads) are significantly higher than the cement treated base (CTB) design value (5000 MPa). Reduction in back calculated elastic modulus for stabilised layer after plying traffic around 62 MSA is around 23 % for both S - Curve and Berth roads.

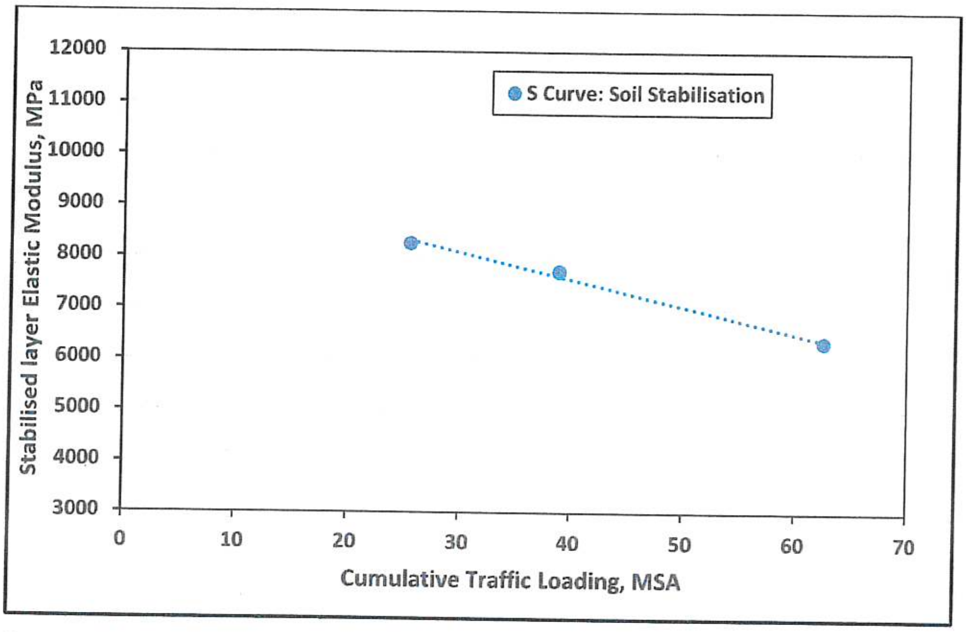

Figure 12: Elastic Modulus of Stabilroad Stabilized soil section (S - Curve road)

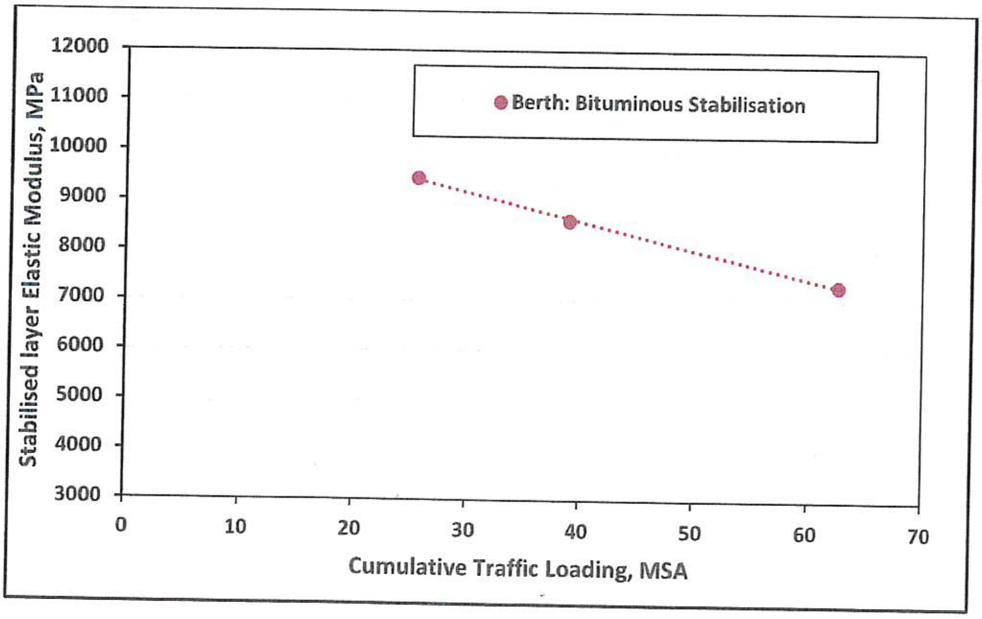

Figure 13: Elastic Modulus of Stabilroad Stabilized bituminous layer (Berth Road)

Figure 14 shows the stabilised layer elastic modulus values for different periods of truck terminal parking area of KP port. Similar to the S - curve and Berth roads, the back calculated elastic modulus values are significantly higher than the cement treated base (CTB) design value (5000 MPa). Generally, Slow-moving traffic imposes greater damage to pavement than fast-moving traffic. No significant change was observed in stabilised layer elastic modulus values after plying traffic around 62 MSA.

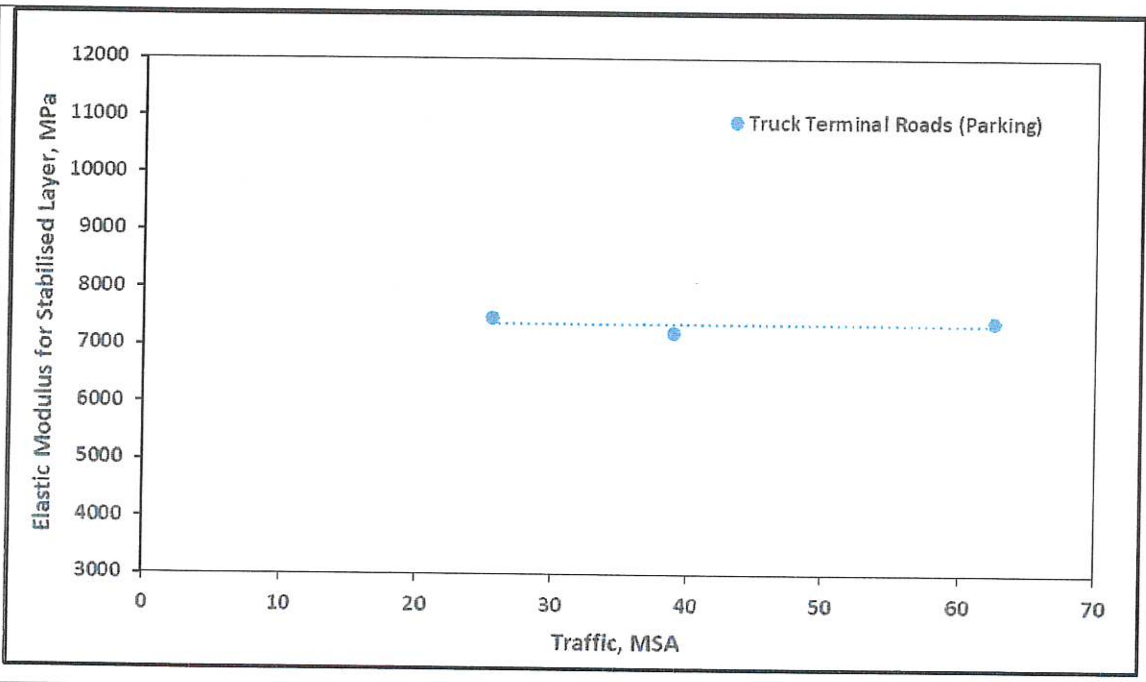

Figure 14: Elastic Modulus of Stabilroad Stabilized sections (Truck Terminal: KP Port)

Figure 15 shows the back calculated elastic modulus values for NTR Marg and Poranki Roads, similar to the other study roads the back calculated elastic modulus are significantly higher than the design value (5000 MPa).

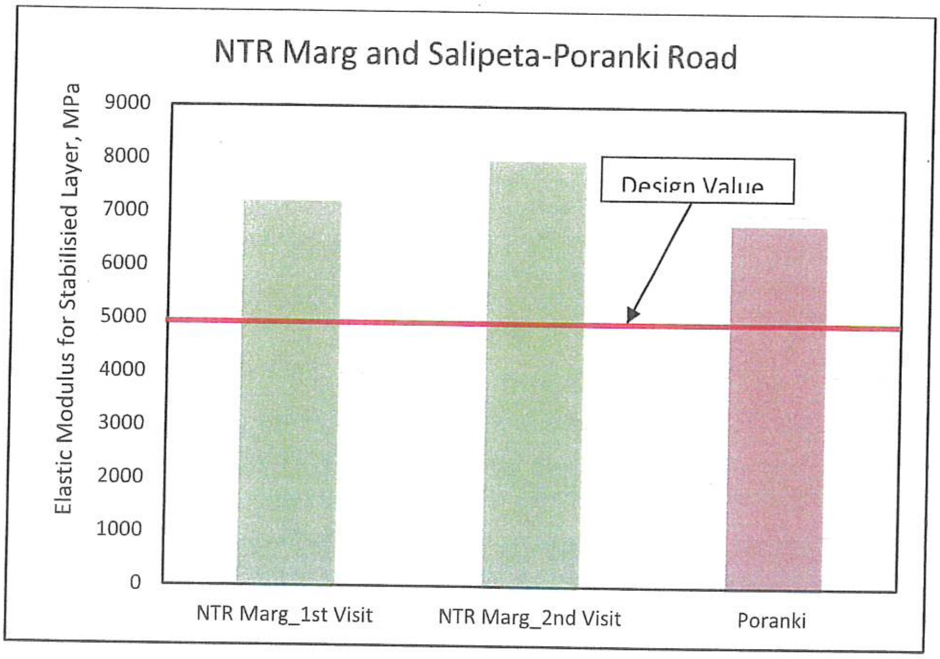

Figure 15: Elastic Modulus of Stabilroad Stabilized sections (NTR Marg and Poranki Road)

The FWD tests were performed on the control sections (Without Stabilisation) along with the stabilised sections for the comparison purpose. The FWD test results (Back calculated modulus values) are presented in Figure 16 and 17 for NTR Marg and Poranki Roads respectively. Relative to control (conventional) sections, all the stabilised sections shows significantly higher average elastic modulus values.

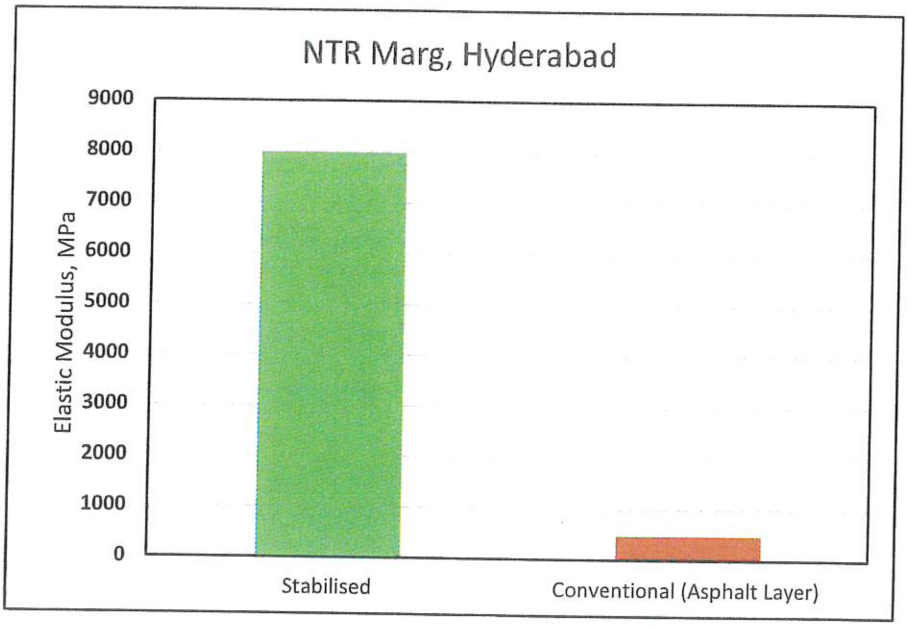

Figure 16: Comparison of Elastic Modulus of Stabilroad bituminous Stabilized sections with Conventional Section (NTR Marg, Hyderabad)

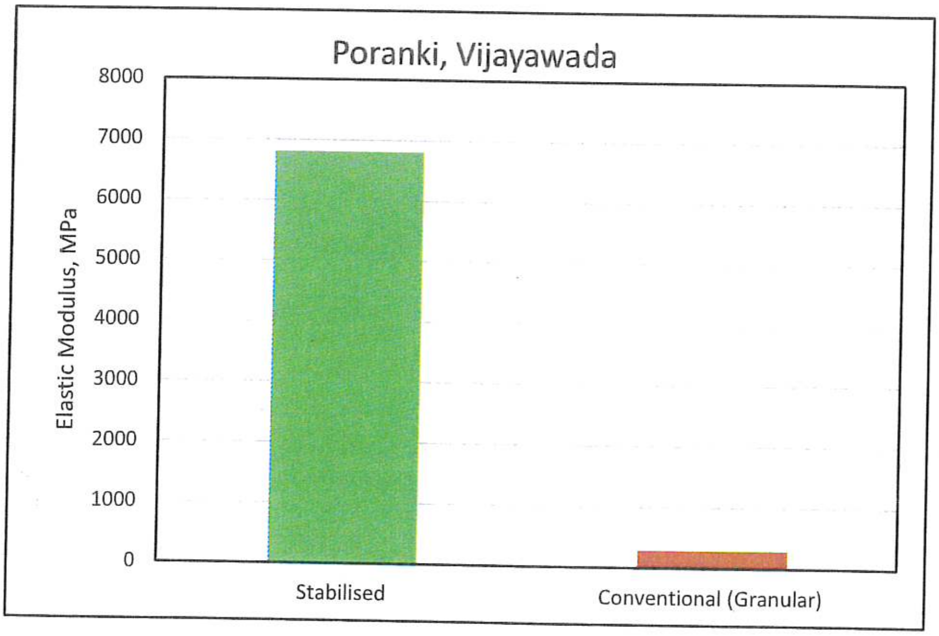

Figure 17: Comparison of Elastic Modulus of Stabilroad soil Stabilized sections with Conventional Section (Poranki, Vijayawada)

5.2. Condition Survey

Condition survey of KP Port roads (Truck terminal roads, S-curve road and Berth roads), Salipeta – Poranki road (Vijayawada) and NTR Marg – Telugu Thalli fly over (Hyderabad) have been carried out manually to identify the cracks and its propagation on pavement surface. Field cores are also taken on cracked surface of pavement to find its depth of propagation (Photo 23). Longitudinal and Transverse cracks were observed on these roads (Photo 24).

Majorly transverse cracks were observed in all selected study roads at an interval of 5 to 50 m. These cracks were seen in the entire length of the road (all sections under investigation) and in full depth of the layer (Photo 23). At some locations these cracks were sealed at the surface by bituminous material. Transverse cracks/shrinkage cracks/reflection cracks are very common in chemical stabilized with stabilzers such as cement (Adaska and Luhr (2004), Sebasta, S. and Scullion, T. 2004, D. H. Chen, F. Hong, and F.J. Zhou, 2011), lime, fly ash and other cementitious stabilizers (IRC – 37 – 2012 & 2018). IRC – 37 – 2012 & 2018 recommended that pavements with cementitious base, a crack relief layer should be provided between the bituminous layer and the cementitious base which delays considerably the refection crack in the bituminous course. Since all these pilot projects (stabilroad stabilized soil sections and stabilroad stabilized asphalt material sections) were constructed without crack relief layer (SAMI/Aggregate/WMM layer), the reflective cracks due to stabilization have been extended up to bituminous surface.

IRC 37 – 2018 states that 20% of cracking area in bituminous layer is considered as failure criteria for pavements. From the condition survey, it was observed that very few longitudinal cracks (i.e. < 3 - 4%) are there in all the considered roads after 27 to 42 months of their age.

For all the study roads, no permanent deformation (Rutting) and Potholes were observed even after 2.5 - 3.5 years (age of road) of traffic.

Photo 23 Depth of Crack propagation on Stabilized Pavement

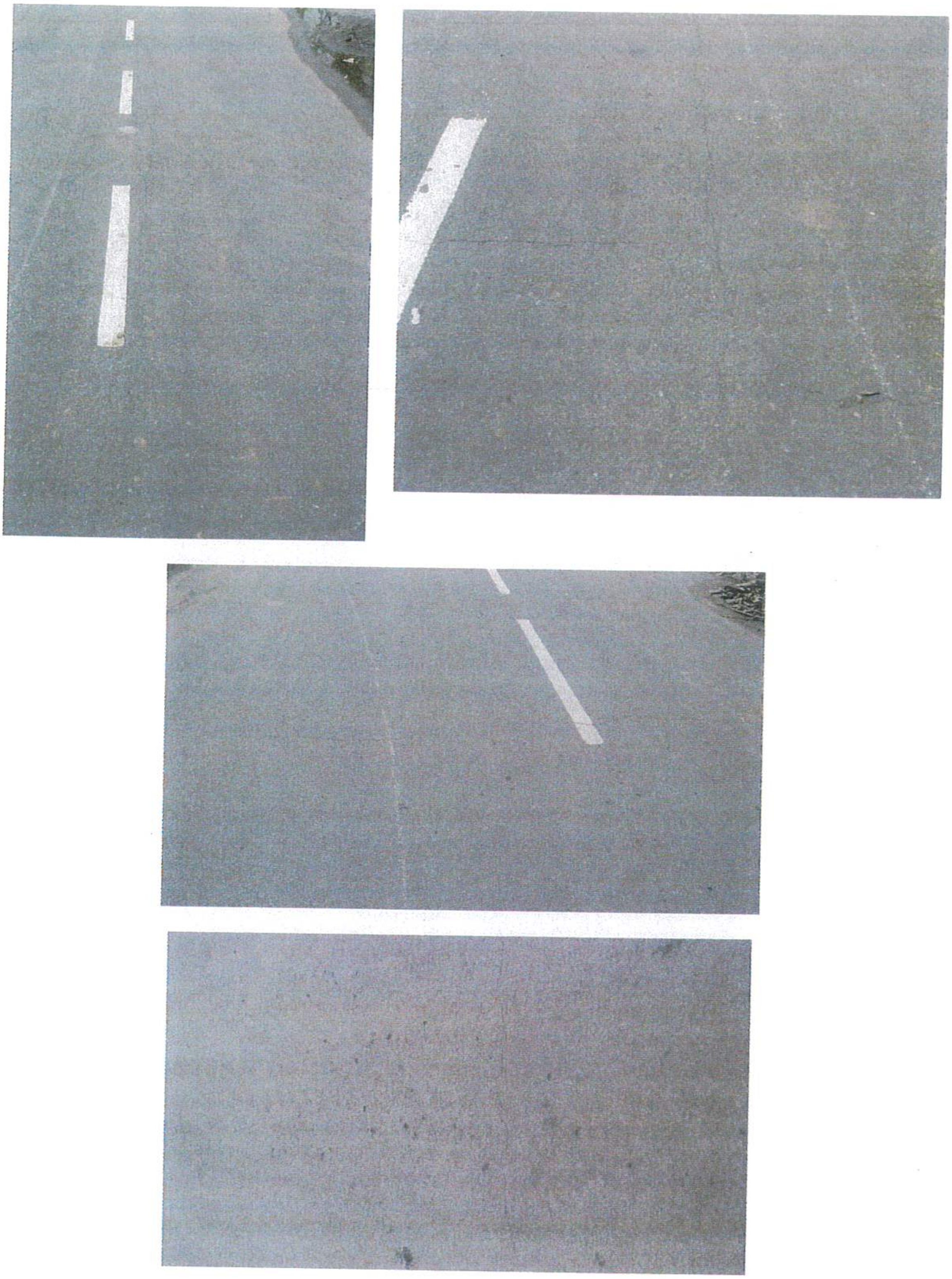

Photo 24 Types of cracks observed on field

7. CONCLUSIONS

M/s Vishwa Samudra Engineering Pvt Ltd. (VSEPL) has done some pilot projects in Krishnapatnam (KP) Port (Andhra Pradesh), Vijayawada (Andhra Pradesh) and Hyderabad (Telangana) with different combinations (Stabilroad stabilized soil and stabilroad stabilized road asphalt material) ***are selected for the present study for detailed field pavement evaluation for a period of two years***. The major conclusions based on laboratory tests (UCS, Durability, Residual strength) carried out on field cores collected from Krishnapatnam Port roads (Andhra Pradesh), Salipeta – Poranki road (Vijayawada, Andhrapradesh) and NTR Marg – Telugu Thalli fly over (Hyderabad, Telangana) and Field studies (Condition survey and FWD test) on these roads are given below.

- The UCS of field stabilized cores (collected from Krishnapatnam port (AP), Poranki (AP) & Hyderabad (TS)) satisfied the criteria as per IRC: SP: 89 (Part II) - 2018(section 7.3.2). The UCS value of stabilized cores/samples is well within and above the IRC specified range (4.5 to 7 MPa in 7/28 days) for cementitious bases.
- All field stabilized cores/samples satisfied the durability test (brushing loss after wetting and drying) criteria and Residual UCS after durability test are significantly higher than that of specified by IRC: SP: 89 (Part II) - 2018.
- The field performance of the stabilised roads was investigated through FWD. The use of stabilroad stabilised base leads to a significant improvement in the structural capacity of the pavement.
- After traffic plying around 62 MSA, the back calculated elastic modulus values (Truck terminal roads (Parking), S-curve and Berth roads) are significantly higher than the cement treated base (CTB) design value (5000 MPa).
- Reduction in back calculated elastic modulus for stabilised layer after traffic consuming around 62 MSA is around 23 % for both S - Curve and Berth roads. However there is no significant change in elastic modulus for stabilised layer was observed for truck terminal roads (Parking).
- The FWD tests were performed on the controlled (Conventional) sections (Without Stabilisation) along with the stabilised sections (NTR Marg – Telugu Thalli road and Poranki Road) for the comparison purpose. Relative to conventional sections, all the stabilised sections shows significantly higher average elastic modulus values (> 5000 MPa).

वरिष्ठ प्रधान वैज्ञानिक / Sr. Principal Scientist
Geotechnical Engineering
CSIR-Central Road Research Institute
नई दिल्ली-110025 / New Delhi-110025
01/03/2021

- The back-calculated elastic modulus for the stabilized layers are higher than the design values mentioned in IRC 37-2018 (i.e. > 5000 MPa) and IRC SP: 89-2018 (> 1700 MPa) respectively.
- Cracks (majorly transverse cracks) were observed in all selected study roads. Transverse cracks/shrinkage cracks/reflection cracks are very common in chemical stabilized with stabilzers such as cement, lime, fly ash and other cementitious stabilizers (IRC – 37 – 2012 & 2018). Since all pilot projects (stabilroad stabilized soil sections and stabilroad stabilized asphalt material sections) were constructed without crack relief layer (SAMI/Aggregate/WMM layer), the reflective cracks due to stabilization have been extended up to bituminous surface. IRC 37 – 2018 specified that crack relief layer should be laid in between bituminous surfacing and stabilized base layer for retarding the reflective cracks in bituminous layer.
- IRC 37 – 2012 & 2018 states that 20% of cracking area in bituminous layer is considered as failure criteria for pavements. From the condition survey, it is observed that very few longitudinal cracks (i.e. < 3 - 4%) are there in all the considered roads after 27 to 42 months of their age.
- For all the study roads, no permanent deformation (Rutting) and Potholes were observed even after 2.5 - 3.5 years (age of road) of traffic.
- The riding quality of all stabilroad stabilized roads are good even after more than 2.5 years period (age of road) for NTR Marg – Telugu Thalli road and Poranki road; 3.5 years period ((age of road) for Krishnapatnam port roads.

The stabilroad stabiliser with cement can be used for the stabilized base and sub-base of pavements after satisfying the laboratory criteria as per* IRC: SP: 89 (Part II) – 2018 *with crack relief layer (SAMI/Aggregate/WMM layer) as indicated in IRC 37 – 2018 (Sec. 8.3)

01/03/2021

वरिष्ठ प्रधान वैज्ञानिक / Sr. Principal Scientist
भूतकनीकी अभियांत्रिकी प्रभाग
Geotechnical Engineering Division
सी.एस.आई.आर.–केन्द्रीय सड़क अनुसंधान संस्थान
CSIR-Central Road Research Institute
नई दिल्ली-110025 / New Delhi-110025

References

1. IS 4332-Part 5 "Methods of test for stabilised soils: Determination of unconfined Compressive Strength of stabilised soils". *Published by Bureau of Indian standard, New Delhi, India.*

2. IRC: SP: 89 - 2010 "Guidelines for soil and granular material stabilization using cement, lime and fly ash". *Published by Indian Roads Congress, New Delhi, India.*

3. IRC: SP: 89 -2018 (Part-II) "Guidelines for the design of stabilized pavements". *Published by Indian Roads Congress, New Delhi, India.*

4. IRC: 37 – 2018 "Guidelines for the design of Flexible Pavements (Fourth revision)." *Published by Indian Roads Congress, New Delhi, India.*

5. IRC: 115-2014 "Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements Using Falling Weight Deflectometer FWD Technique". *Published by Indian Roads Congress, New Delhi, India.*

6. IRC: 37 – 2012 "Guidelines for the design of Flexible Pavements (Third revision)." *Published by Indian Roads Congress, New Delhi, India.*

7. Adaska, W.S., and D.R. Luhr. Control of Reflective Cracking in Cement Stabilized Pavements, 5th International RILEM Conference, Limoges, France, May 2004.

8. Sebasta, S. and Scullion, T. 2004. Effectiveness of Minimizing Reflective Cracking in Cement treated Bases by Micro cracking. College Station, TX: Texas Transportation Institute, The Texas A&M University, FHWA/TX-05/0-4502-1.

9. D. H. Chen, F. Hong, and F.J. Zhou, "Premature cracking from cement-treated base and treatment to mitigate its effect," J. Perform. Constr. Facil., Vol. 25, pp. 113-120, April 2011.