

# Evaluation of Subgrade Stabilized with Natural Geo-textiles by Deflection Data in Semi-field Test Track

Mohan M<sup>1</sup>, Dr.Manjesh L<sup>2</sup>, Rayan Monies<sup>3</sup>

<sup>1</sup>Research Scholar, Department of Civil Engineering, University Visvesvaraya College of Engineering (UVCE), Bangalore University, Bengaluru-560056, India.

<sup>2</sup>Associate Professor, Department of Civil Engineering, UVCE, Bangalore University, Bengaluru-560056, India

<sup>3</sup>PG Student, M.E (Highway Engineering) Department of Civil Engineering, UVCE, Bangalore University

\*\*\*

**Abstract** - The primary purpose for evaluating the deflection of an existing pavement is to determine structural adequacy. The data can be obtained by inference or by direct measurement relative to the stress strain properties of the pavement structure. The deflection method is based on the concept that pavement section which have been conditioned by traffic, deform elastically under a load. In this study a Semi-field test track (4x15m) is constructed, in the Department of civil engineering, Highway Laboratory, Bangalore University, which comprises of two layer pavement system. Granular sub-base layer of grade II (150mm) is acting as a Surface layer and Stabilized subgrade (300mm) is the layer beneath, which is reinforced with different material such as Coir and Jute geotextiles, Coir and Jute fibers in separate sections of dimension 3x4m. Construction is done as per MoRTH (V revision) Specifications [2]. To give a comparative study a unstabilized Subgrade section which is taken as controlled soil section is also constructed along with these four sections. On both of these layers repetitive Dual wheel load test is conducted and Surface deflections were measured. The deflection bowl data obtained further analyzed by Empirical and Theoretical approaches. Also the Surface deflections of these layers were compared with the controlled section. The result of the present study shows that the incorporation of Stabilizing materials at subgrade level improves its strength parameters by large extent and also the overall performance of the model constructed.

**Key Words:** Stabilization, Subgrade, Granular sub-base, Natural geo-textiles, Deflection, Semi-field test track, Dual wheel load.

## 1. INTRODUCTION

India has a vast road network in which major part of roads are located in rural areas. The budget allocation gets difficult to provide paved surface roads everywhere. Therefore the need to find innovative techniques to provide strong and stable roads using the locally available resources with modern construction methodologies is growing day by day. Various studies have been conducted by agencies to incorporate natural fibers in subgrade stabilization which is produced in major areas all over India.

The essential difference between the two types of pavements, flexible and rigid, is the manner in which they distribute the load over the subgrade. In the case of flexible pavement the design and performance of the pavement depends on the type of subgrade soil and its properties including the support or stability value to a greater extent.

The magnitude of the compressive strain within each incremental layer under a given stress is a function of subgrade soil type, conditions of moisture and compaction, thickness and quality of pavement courses, drainage conditions, temperature and a number of minor variables. It would therefore follow that an integrated measure of the total compression, that is, the surface deflection subjected to a wheel load provides an index of the structural capacity of the pavement system. In the usual practice of pavement evaluation, the most popular approach used for structural evaluation was measurement of maximum rebound deflection under wheel load by Benkelman beam [1].

The purpose of this investigation is to study the behaviour of soil subgrade under standard wheel load on stabilization with Fibers and Geo-textiles. Here the analysis is carried out with reference to the Surface Deflections obtained through Dual wheel load test on Stabilized Subgrade while comparing with the unstabilized Soil section.

## 1.1 Materials used for the Semi-field test track construction

### A. Soil

In the present study Red soil is collected from Survey No.8, Manganahalli, Bengaluru, Karnataka. Basic tests were done as per specifications [8].

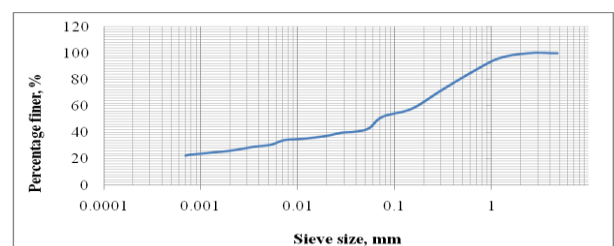


Chart -1: Sieve analysis of Red soil

**Table-1:** Test results of Sieve Analysis of Red Soil

IS Sieve Size(mm)	Percentage finer of Soil (%)
4.75	100
2.36	100
1.18	95.93
0.600	84.68
0.300	71.65
0.015	57.92
0.075	51.88

**Table-2:** Physical properties of Red Soil

Colour	Red
Particle size Distribution	
Gravel, %	0
Sand, %	48.12
Silt, %	24.426
Clay, %	27.454
Atterberg's limits	
Liquid limit, %	36
Plastic limit, %	16
Plasticity index, %	20
Standard compaction test	
Maximum dry density, ( g/cm <sup>3</sup> )	1.91
Optimum moisture content, %	15.3
CBR, %(soaked)	2.54
Unconfined compressive Strength ( kg/cm <sup>2</sup> )	0.72

**B. Jute fiber**

These fibers are generally available in the threaded form. These are mechanically woven fibers with very fine threads. Jute is a coarse natural hast fiber.

**C. Coir fiber**

A fiber material would be suitable for geo-textiles production when it has reasonably good mechanical properties and resistant to microbial attack. The decomposition of coir fiber is generally known to be much less than that of jute due to high lignin content.

**D. Jute geo-textiles**

Jute geo-textile used for this study were procured from a local market near Cottonpete, Bengaluru. A single layer of size 4\*3 m jute geo-textile is used for reinforce the soil subgrade.

**E. Coir geo-textiles**

Coir geo-textile used for this study were procured from a local manufacturing unit near channapatna, Mandya. Single layer of size 4\*3 m geo-textile is used for reinforce the soil subgrade soil.

**F. Sodium hydroxide**

The Sodium Hydroxide was procured from the locally available market. Molecular weight of sodium Hydroxide is 40.00. In 1 litre of distilled water 40 gm is used to prepare 1 molarity solution.

In previous study conducted in Bangalore University [7], experiments were conducted to fix the optimum molarity and soaking time period. In order to fix the optimum molarity and soaking time period, fibers were soaked in varying molarity with varying time periods. The optimum molarity and optimum soaking period for coir fibers are 1Molarity, 4 hours and for jute fibers are 1.5Molarity, 6 hours [7].

**G. Crushed Stone Aggregates**

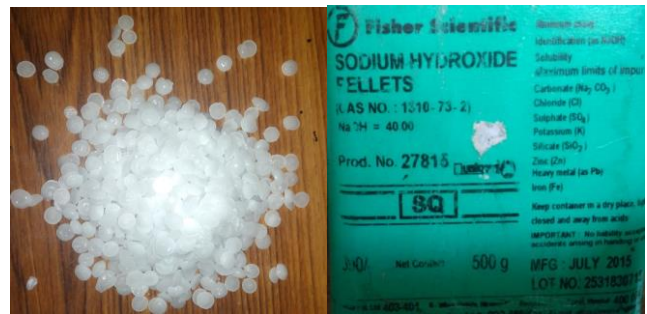
Crushed stone aggregates are used for the Construction of Granular sub-base course above the Stabilized subgrade. Aggregates are free from organic or other deleterious constituents and confirms the Grading As per MORT&H 5th revision (Section 400, Table 400-1) [2] and Physical requirements given in Table 400-2. The tests are done as per codes IS: 2386[8] and IS: 2720[9]. The grading adopted for this work is Grade-II, because of its common use in Construction now-a-days.

**Table-3:** Gradation requirements for Granular Sub-Base Grade-2 As per MORT&H 5th revision

IS Sieve (mm)	% By weight passing the IS Sieve
73	-
53	100
26.5	70-100
9.5	50-80
4.75	40-65
2.36	35-50
0.8	-
0.425	10-15
0.075	<5

**Table-4:** Physical properties of Aggregates as per MoRTH specifications

TEST	Test Values	MORT&H Specified Values
Aggregate Impact Test	19.59%	40% Maximum
Specific Gravity	2.62	---
Combined Flakiness Index & Elongation Index	29.5%	Maximum 35%
Liquid Limit	18.50%	Maximum 25%
Plasticity Index	Non Plastic	Maximum 6%
CBR at 98% dry density	59.3%	Minimum 30%
Laboratory Density in g/cc	2.21	Min 98% should be achieved in Field
Optimum moisture Content	5.35%	---



**Fig-4:** Sodium hydroxide Pellets (NaOH)

### 1.2 Details of Semi-field test track

In department of Highway engineering lab, UVCE, Bangalore University, Bengaluru. A test section of size 4.0 m \* 3.0 m and depth of 0.5 m and 15 m was excavated and Soil Subgrade layer is constructed to check the performance of the Stabilized soil under Standard Wheel load. Test track is of length 15 m long, 4 m wide with 0.3 m depth. This includes following 5 different sections [11];

1. Controlled section of Soil + Granular Sub-base Course
2. Soil reinforced with coir geo-textile + Granular Sub-base Course
3. Soil reinforced with jute geo-textiles + Granular Sub-base Course
4. Soil reinforced with coir fibers + Granular Sub-base Course
5. Soil reinforced with jute fibers + Granular Sub-base Course



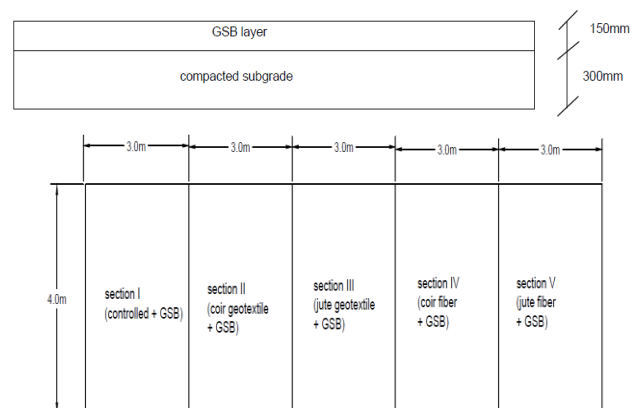
**Fig-1:** Jute fiber and Coir fiber



**Fig-2:** NaOH treated Jute and Coir Fiber



**Fig-3:** Coir and Jute Geo-textiles



**Fig-5:** Section and Plan of Semi-field test track

### Construction Procedure:

- The Test section is cleared and excavation is up to 500mm thicknesses along the 30m length.
- Soil from the Borrow pit is brought and spread on the track in 3 layers of 100mm each.



- Compaction is done using 8 ton Smooth wheel roller starting from the edges.
- On each layer fibers were spread and manually mixed with soil.
- Geo-textiles are installed at 50mm depth from top of the Subgrade.
- After the completion of Dual wheel load test on Subgrade, the Granular Sub-base (GSB) course of 150mm is laid over it.
- The GSB material is brought from the mix plant nearby and directly spread on the re-compacted subgrade section after ensuring the correct moisture content and quality control tests.



**Fig-9:** Compaction using Roller and finished surface



**Fig-6:** Excavation and Filling of Soil in test track



**Fig-10:** Spreading and Compaction of GSB material



**Fig-7:** Spreading and Mixing of Fibers



**Fig-8:** Installation of Coir and Jute Geo-textiles

### 1.3 Instrumentation for Testing of Semi-field Test track

**Loading Attachment:** Loads are applied by means of a hydraulic jack or a screw jack working against a reaction frame. Loading frame of 20 tones capacity was used to conduct the test. The load frame consists of two interconnected portals of span 5m and height 3m.

**Wheel Load assembly:** In order to characterize the materials more realistically, it is necessary to conduct the test under condition approaching as closely as possible to those occurring in the field. Hence wheel load assembly unit have been used to test the test track.

The wheel load assembly consists of dual wheel unit with facility for fixing a pair of truck tyres at the desired spacing's and can be loaded up to 10 tones. The tyres of size 9"x20" are used for testing.

**LVDT'S:** The linear variable differential transformer (LVDT) (also called linear variable displacement transformer, or simply differential transformer) is a type of electrical transformer used for measuring linear displacement (position). The LVDT can be used as an absolute position sensor. Even if the power is switched off, on restarting it, the LVDT shows the same measurement, and no positional information is lost.

**Datum Frame:** The benkelmen beam which is used for BBD studies is modified as datum frame such that 6 LVDT's are attached in front of it with the help of a slender beam.

**Proving ring:** One calibrated proving ring of capacity 25 tones with dial gauge to read to an accuracy of 0.01 mm.

The Dual Wheel Load Test is conducted on both soil subgrade of 300mm thick and over laid Granular sub-base course (grade II) of 150mm thickness.



**Fig-11:** Linear variable displacement transducer



**Fig-12:** Modified Benkelman beam with fixed LVDT's

### 1.4 Dual wheel load test:

In order to determine the load deflection characteristics of the pavement under wheels loads, a dual wheel assembly with truck tyres of size 9"x20" and tyre pressure of 5.6 kg/cm<sup>2</sup> is used for the test. The assembly was placed centrally over the section for which a frame arrangement has been made such that there will be no movement in the lateral direction, but free to move in the vertical direction [6]. A hydraulic jack and proving ring were placed over the frame of the wheel as shown in the figures

#### Test procedure for deflection measurement:

- Each section dimensions were 3m x 4m, where 3m is the width and 4m is the length of the sections.
- The dual wheel assembly was centered above each section. Loading system consists of a reaction frame and loading hydraulic jack situated on the dual wheel assembly.
- Tyre pressure was checked before conducting the test and maintained 5.6kg/cm<sup>2</sup>.

- The main probe of the modified Benkelman beam was inserted between the dual wheels and placed on centre point. The other five LVDT probe placed at a distance of 200m, 400m, 600m, 800m and 950m respectively. The corresponding lead wires were connected to the digital displacement indicator.
- The beam legs were adjusted so that the plunger of the beam was in contact with the stem of the LVDTs.
- The initial reading of the six LVDT's was recorded.
- The dual wheel load assembly was loaded at 500kg increment up to 5500kg. After each increment of load, longitudinal deflections were recorded.
- The incremental load applied are 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4100, 4500, 5000, 5100, 5500 in kg.
- The wheel load assembly was unloaded in the same decrement of load and all deflection readings were noted. Similar procedure was repeated for 5 more cycles.
- For each section six cycles were conducted with the same procedure



**Fig-13:** Position of LVDT's and position of Dual wheel assembly with jack



**Fig-14:** Dual wheel load test setup

### 1.5 Evaluation of deflection bowl:

The Deflection bowl data obtained through Dual wheel load test is represented in the form of graphs as shown below for 2,500 kg and 5100 kg (Standard load).



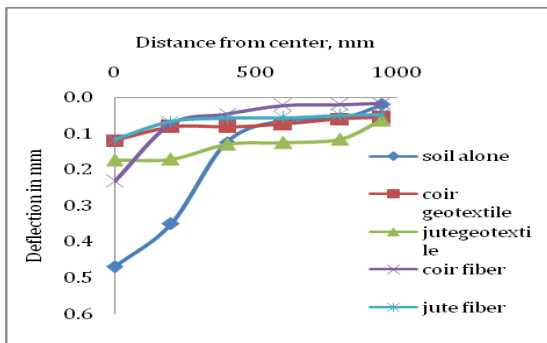


Chart -2: Subgrade Deflection values @2,500 kg

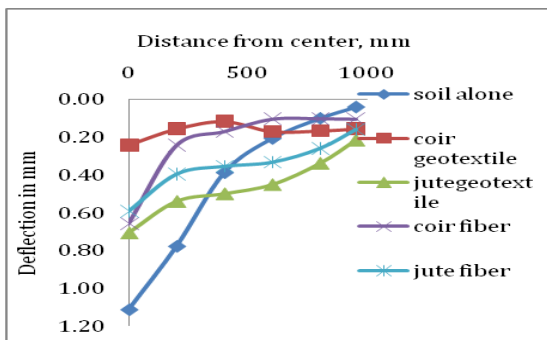


Chart -3: Subgrade Deflection values @ 5100 kg

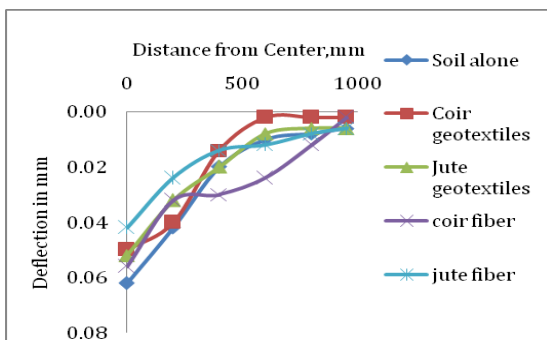


Chart -4: GSB Deflection values @2,500 kg

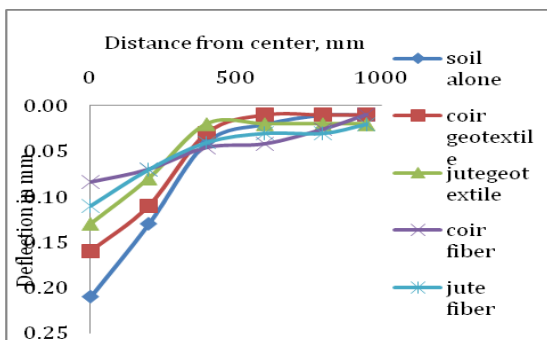


Chart -5: GSB Deflection values @5100 kg

The deflection bowl obtained can be studied under two headings, empirical and theoretical [1] [4].

**Empirical methods:** The principle under laying these methods is the determination of some characteristic features of the deflection bowl. This can be considered to be correlated to pavement structural condition and its deterioration. Some of the characteristics which have been popularly used are

1. Maximum deflection ( $\Delta_{max}$ )
2. Diameter of deflection bowl
3. Radius of curvature
4. Bending index
5. Deflection ordinate ratio
6. Spread ability
7. Area of deflection basin.
8. Layer curvature indices

- Surface curvature index
- Base curvature index
- Base damage index

Table -5: Deflection bowl parameters

Section	Layer	$\Delta_{Max}$ mm	Radius of curvature	Spread ability	Bending index	Slope of $\Delta$ , deg	SCI mm
I	1	1.11	59.5	0.39	53.5	0.087	0.53
	2	0.21	232.5	0.33	1096.9	0.018	0.12
II	1	0.24	128.2	0.69	529.7	0.007	0.10
	2	0.16	400.0	0.34	2439	0.015	0.09
III	1	0.71	119.3	0.65	168.6	0.025	0.11
	2	0.12	416.7	0.36	3255.2	0.011	0.10
IV	1	0.66	48.0	0.35	72.8	0.053	0.45
	2	0.08	450.6	0.55	5364.2	0.004	0.02
V	1	0.59	101.6	0.59	171.4	0.003	0.22
	2	0.11	243.9	0.44	2217.2	0.008	0.08

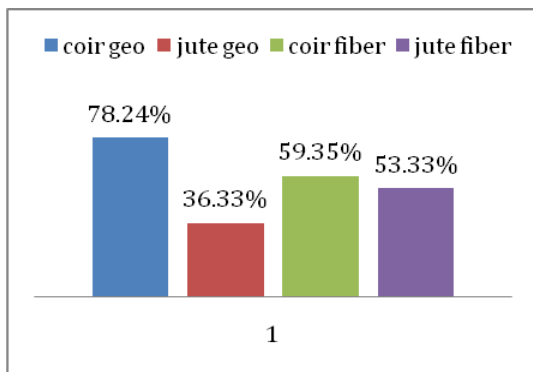
**Theoretical method:** The elastic modulus is defined as the ratio of stress to the strain. It is a measure of strength and stiffness of the material, a higher value indicates that the material is stronger [3]. And also a higher value indicates its load carrying capacity is high. In this study using the Burmister's two layer theory the modulus of elasticity is calculated taking dual wheel as Flexible plate action [5].

Table -6: Reduction in deflection value in Subgrade compared to controlled section at 5100kg load

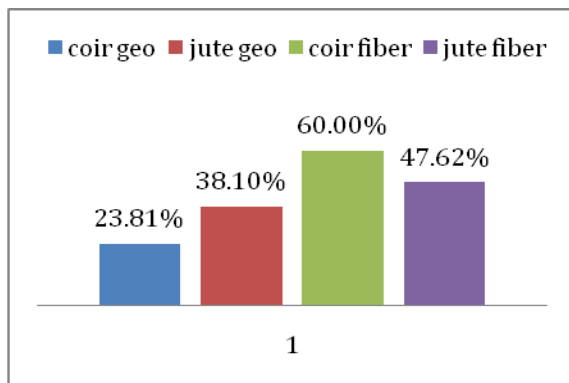
Section	Different radial locations in mm					
	0	200	400	600	800	950
II	0.66	0.24	0.17	0.10	0.10	0.10
III	0.59	0.39	0.35	0.33	0.26	0.16
IV	0.87	0.62	0.27	0.03	0.03	-0.02
V	0.40	0.23	-0.11	-0.24	-0.23	-0.17

**Table -7:** Reduction in deflection value at GSB compared to controlled section at 5100kg load

Section	Different radial locations in mm					
	0	200	400	600	800	950
II	0.12	0.06	0.00	-0.02	-0.01	0.00
III	0.10	0.06	0.00	-0.01	-0.02	-0.01
IV	0.05	0.02	0.01	0.01	0.00	0.00
V	0.08	0.05	0.02	0.00	-0.01	-0.01



**Chart -6:** Percentage reduction in deflection due to various stabilizing materials in subgrade



**Chart -7:** Percentage reduction in deflection in GSB due to stabilized Subgrade

**Table -7:** E value calculated from Maximum deflections

Section	$\Delta_{Max}$ mm	Subgrade load kg	$E_2$ kg/cm <sup>2</sup>	$F_2$	$E_1/E_2$	$E_1$ kg/cm <sup>2</sup>
I	0.17	3500	321.8	0.5	14	4506.2
II	0.17	2250	861.4	0.6	6	5168.8
III	0.12	2100	764.4	0.5	5	3822.0
IV	0.09	1500	644.8	0.7	5	3224.1
V	0.22	1250	558.8	0.5	6	3353.0

### 3. CONCLUSIONS

When modulus of elasticity was compared the Coir fiber section is giving the 168% increase in strength to the Controlled Section which is a remarkable increase than other reinforced sections. Among the other sections coir fiber section shows less deflection, maximum radius of curvature, higher value of bending index, and elastic modulus.

In overall the Coir fiber section can take higher magnitude of loads with little deflections, it has higher elastic modulus, has better bowl parameters and it can reduce the deflection value uniformly throughout the section. Hence the performance of Coir fiber stabilized section is superior under Standard wheel load when compared to other natural geo-textiles used in this study.

### ACKNOWLEDGEMENT

We would like to thank Centre for Transportation Engineering, Bangalore University, for giving such facilities. Also we would like to extend our gratitude to Professor M.S. Amarnath, Department of Civil engineering, Bangalore University, for the guidance and immense support throughout the project.

### REFERENCES

- [1] J. K. Dattatreya "Structural Evaluation of Flexible Pavements by Deflection Bowl Measurement" Summer school program by Bangalore university for Scholars and Practicing Engineers.
- [2] Ministry of Road Transport and Highways, Specifications for Road and Bridge Works, Fourth Revision, Indian Roads Congress, New Delhi.
- [3] E. J. Yoder and Witczak M.W "Principles of Pavement Design" Jhonwiley & sons, INC, second edition ,1975.
- [4] B. Rajib.Mallick and Tahar El-Korchi,"Pavement engineering" second edition, CRC press, 2013.
- [5] S. K Khanna, C. E. G Justo, Veeraragavan, "Text Book of Highway Engineering (Revised 10th edition)". Nemichand Bros, Roorkee, India-2014.
- [6] M. S. Anandkumar, "Analysis of Stresses in Flexible Pavement Layers Using Deflection Data", Dissertation report, Bangalore university, unpublished.
- [7] M Mohan, L Manjesh, "A Study on Durability Characteristics of Natural Fiber Reinforced in Weak Soil", IJSRST 1737131, September-October-2017 [(3) 7: 760-765.
- [8] IS: 2386 – 1963, Bureau of Indian Standard Methods of Test for aggregates, (Reaffirmed 1997).
- [9] IS: 2720-1987, Bureau of Indian Standard Methods of Test for soil, (Reaffirmed 1997).

- [10] IS: 9669 – 1980, Bureau of Indian Standards, Indian Standard specification for CBR (Reaffirmed 1997).
- [11] M Mohan, L Manjesh, “A Study on Stabilization of Subgrade Soil Using Natural Fibers (Coir And Jute)” (September 2017), ISSN:2347-6710, ijirset.2017.

## BIOGRAPHIES



Mohan M did his ME, Highway engineering at Department of Civil Engineering, UVCE and he is currently a Research Scholar at UVCE, Bangalore University and an active member of IRC.



Dr. Manjesh L is Associate Professor at Department of Civil Engineering, UVCE, Bangalore University. He is also holding the post of Co-ordinator, Centre for Transportation Engineering, Bangalore University. He did his M.E. Highway, and PhD at Department of Civil Engineering, UVCE. and member of IRC (Indian road congress).



Rayan Monies is a Post Graduate student, M.E (Highway Engineering) Department of Civil Engineering, University Visvesvaraya College of Engineering, Bangalore University.