# Eco Friendly Road Technology: RBI Grade-81 Natural Soil Stabilizer & Pavement Material



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प्रकाश जावड़ेकर
**PRAKASH JAVADEKAR**

सत्यमेव जयते

राज्य मंत्री (स्वतंत्र प्रभार)
MINISTER OF STATE (INDEPENDENT CHARGE)
पर्यावरण, वन एवं जलवायु परिवर्तन
ENVIRONMENT, FOREST AND CLIMATE CHANGE
भारत सरकार / GOVERNMENT OF INDIA

## MESSAGE

*It is a matter of immense pleasure that Ministry of Environment, Forest & Climate Change, Government of India is organizing a "Workshop" on our research project for Eco-Friendly Road Technology, RBI Grade-81 Natural Soil Stabilizer & Pavement Material at New Delhi.*

*This will set a platform for sharing of knowledge on innovation of new Technology/methodology and benefit all the delegates from various authorities/departments, who are expected to attend the Workshop.*

*I am sure the deliberations during the Workshop will be fruitful.*

*I wish the Workshop a grand success.*

*(Prakash Javadekar)*

नितिन गडकरी
**NITIN GADKARI**

मंत्री सड़क परिवहन राजमार्ग एव पोत परिवहन
भारत सरकार,
परिवहन भवन, नई दिल्ली - ११० ००१

सत्यमेव जयते

**MINISTER OF ROAD TRANSPORT**
**HIGHWAYS & SHIPPING**
**GOVERNMENT OF INDIA**
**PARIVAHAN BHAVAN, NEW DELHI - 110 001**

## MESSAGE

*I am glad to learn that the Ministry of Environment, Forest & Climate Change, Government of India is organizing a "WorkShop" on their research project for Eco-Friendly Road Technology, RBI Grade 81 Natural Soil Stabilizer and Pavement Material at New Delhi. Modern science and technology offers various opportunities to make ecofriendly roads.*

*I do hope that this Workshop will be useful to all stakeholders in infrastructure, highway professionals, concessionaires and consultants etc. Modern science and technology offers various opportunities to make ecofriendly roads and good roads are essential for the development of any nation.*

*I also hope this Workshop will provide a good opportunity for exchange of views and various issues related to road/highway developments.*

*I extend my greetings and best wishes to all those associated with the Workshop and wish it a grand success.*

*Yours,*

नितीन गडकरी

*(Nitin Gadkari)*

*This New Technology is*
*Dedicated*
*to*

***Dr. T. Chatterjee, IAS***

*Former Secretary, Ministry of Environment and Forests*
*Government of India*

*In recognition of his constant endeavor to develop and implement Cleaner Technologies in Indian Industries will continue to be a source of inspiration for all.*

# ACKNOWLEDGEMENT

We are grateful to Clean Technology Division of the Ministry of Environment, Forests & Climate Change, Government of India for sanctioning this project on "Eco Friendly Road Technology: RBI Grade-81 Natural Soil Stabilizer & Pavement Material.

We are highly grateful to Mr. Ashok Lavasa, Secretary, MOEF&CC, Dr. V Rajgopal, IAS, Addl. Secretary, MOEF&CC, Mr. Susheel Kumar, IAS, Addl. Secretary, MOEF&CC, Dr. Rajneesh Dube, Dr. Rashid Hasan, Mr. Harihar Mishra, whose ideas, initiatives and decision became a guiding force to us.

We extend our special thanks to Prof. B.B. Pandey, Indian Institute of Technology Kharagpur, Prof. L. Kanan, Former Vice Chancellor, Thiruvalluvar University, Vellore, Dr. Sunil Bose, Former Head, FP Division, Central Road Research Institute and Dr. K.C. Gupta, Former Director, Indian Institute of Toxicology Research, Lucknow, Mr. K.C. Varkeyachan, CE/S&R, MOSRTH, Mr. S.K. Nirmal CE/S&R, MOSRTH, Mr. K Sitaram Anjanyelu. Head, PED, CRRI and Mr. Rahul Patil, Deputy Director (Technical), Indian Road Congress.

We would like to acknowledge the support & guidance of all the department, agencies & institutions/organizations associated to this project such as Ministry of Road Transport & Highways (GOI), Indian Road Congress, Indian Institute of Technology Madras, Indian Institute of Toxicology Research Lucknow, Central Pollution Control Board, Central Road Research Institute for monitoring & evaluation of this research project.

We would like to acknowledge the assistance rendered by the Karnataka State Government departments and agencies, such as, the Public Works Department (NH Division), the Forest Department, the Panchayat Raj Department, the Police Department. These departments were particularly helpful at every stage of the research project. In particular we owe sincere thanks to Chief Engineer, PWD NH Circle Bengaluru, Executive Engineer, PWD NH Tumkur Division, Chief Conservator of the Forests, Bengaluru and Assistant Executive Engineer, Panchayat Raj Engineering sub division, Gubbi (Tumkur).

We express our thanks to Maj. Gen. Anil Oberoi, Vice Chairman, Alchemist Limited, Mr. Mohit Verma, General Manager (Technical), Mr. Jitendra Diwan, Finance Controller and other project teams of Alchemist Touchnology Limited for their constant support & hard work for the successful completion of the project.

# CONTENTS

## INTRODUCTION

Sustainable growth in a Country's march towards progress, reach and development is largely based on its infrastructure. Connectivity remains the most important ingredient for infrastructural improvement. Roads, the arteries of a nation, bring rapid transformation along its path, changing socio-economic structure, demographics and environment. In India, roads are being built with little emphasis on the preservation of the environment. Daily reports of damage to the environment, stripping of forest cover, hills and riverbeds are being voiced. While western nations have timely identified the importance of preservation of nature, we still tend to be lackadaisical in our approach. No justification can be offered in the name of progress if it denudes and depletes the very environment that allows its sustenance. It is our endeavor to save the fast depleting natural resources with alternate technology in order to conserve our hills, forests and rivers. Green and environment friendly technologies are available which can create a permanent impact on our environment, as well as end the depletion of good quality conventional material. It would minimize the damage to the environment due to emission of gasses like carbon dioxide and heavy suspended particles in the air.

India has the second largest road network in the world. We have over 4 million km of roads. Our roads are classified as

- Expressways 0.01%
- National Highways 2.78%
- State Highways 3.95%
- Major District Roads 13.99%
- Rural & Other Roads 79.28%

Though we are second in the world in terms of length but our roads quality do not rate very high. In spite of having 4 million km of connectivity, our connectivity is far from being sufficient. The construction of roads currently requires enormous amount of good soil, sand, aggregates and bitumen.


Photo 1 : Hill View before Mining

Photo 2: View After Mining

During road construction unsuitable poor soil is excavated and dumped recklessly in vacant fields simultaneously good suitable soil is excavated indiscriminately and transported to the road construction site. Similarly hills and river beds are destroyed to quarry the required aggregate and these need to be transported to the construction sites.

The current method of road construction requires several layers of aggregate and bitumen. Bitumen has to be laid at very high temperatures and substantial release of greenhouse gas emission takes place in the process. The second environmental issue is using thick layers of the bitumen which during rainfall tends to leach through the road structure and through the subgrade and contaminate ground water.

India is a country which receives rains from North East Monsoon and South West Monsoon and certain regions of the country have monsoon as well as snowfall. This phenomenon reduces the construction time to 6 months in a year and less than 3 months in high snowfall areas.

Photo 3: Pollution during Hot Mixing of Bitumen

There is also an additional problem of rains damaging roads during and after monsoon. Freeze and Thaw effect in snowfall areas also damages roads to some extent. Geographical nature of the country is such that we have extreme temperatures and different types of soil. As part of the development process India needs to construct 20 to 30 km of roads a day. In India, Road infrastructure is used to transport over 60 percent of the total goods and 85 percent of total passenger traffic.

In spite of all environment issues involved it is necessary to increase the speed of road construction and also resolve environment issues as we move along. The Ministry of Environment, Forests and Climate Change along with the Alchemist Touchnology decided to undertake a research project to identify a technology which will resolve the current problem to provide better quality, durability, less maintenance, less construction time, consuming less aggregate, less bitumen and no leachability in the road structures, to eliminate damage due to rain, perma-frost conditions and high temperatures.

Since India already has road network of over 4 million kms, there is a need to preserve and rehabilitate already constructed roads which has consumed billions of tons of natural resources. To recycle the existing road network and rehabilitate the pavement in full depth is also the need of the hour. The RBI Grade-81 Soil Stabilizer was selected for study which has been certified as non toxic, non leaching and suitable for road construction. It reduces pavement thicknesses and reduces aggregate consumption. With the use of RBI Grade-81 technology, not only the above problems are minimized drastically, it is also useful where conventional technologies are not feasible or applicable. The material was tested at IITR (Indian Institute of Toxicology and Research) in Lucknow for toxicity and leachability and certified as non toxic and non leaching. Since environment issues, technical and quality issues containing roads were involved, Ministry of Environment, Forests and Climate Change decided to constitute a Project Monitoring Committee under the Chairmanship of Prof. A Veeraragavan of IITM Chennai, who is an eminent Scientist in the field of transport and road engineering. The committee was comprised of eminent environmental and road experts. Ministry of Environment, Forests and Climate Change requested Ministry of Roads, Transport and Highways to provide suitable roads to be given for the test projects. The Ministry of

Environment, Forests and Climate Change had taken into account the necessity to test this technology under actual field conditions so that environmental parameters and road performance characteristics can be studied and certified.

Under the expertise of Alchemist Touchnology Limited on stabilized pavements test sections were selected, designed and constructed successfully in the state of Karnataka. Three agencies were appointed to collect the performance and strength data of all the test sections. The parameters to be studied were decided on the basis of today's requirement to conserve natural resources. These are as follows

- To establish the new technology as non toxic and non leaching
- To verify if the soil can be used and aggregate consumption in road construction is reduced by new technology
- To verify if the pavement thickness can be reduced by new technology
- To verify the reduction of bitumen in pavement layers by new technology
- To verify the reduction in construction time by new technology
- To verify the reduction in the permeability and stops ingress of water in pavement layers from top by new technology to increase the strength of the pavement.
- To verify the reduction of transportation of material for the construction of road by new technology.
- To verify that the new technology can be successfully used for full depth reclamation of existing roads and recycle the existing material.
- To demonstrate alternate design methodology in reference of Indian standards and specifications
- To verify the quantum of Greenhouse Gas Emission and reduction in carbon footprints during road construction by new technology
- Documentation of the entire process of construction, quality control and the suitability of the new technology roads to handle the Indian traffic and climatic conditions
- To verify the performance of the new technology roads after construction and after two monsoons

- To collect the evaluation data in at-least three cycles on all the section constructed with new technology
- To check if over a period of time new technology roads develops cracks in stabilized layers
- To establish the suitability of the new technology to conserve the environment and build sustainable roads of good quality, which meets all the standards required by Ministry of Road, Transport and Highways

**INTERNATIONAL SCENARIO**

Road Construction Methods have changed a lot since the first roads were built in about 4000 BC. In ancient times, river transport was much faster and easier than road transport. The Romans were one of the first to build stone paved roads in North Africa and Europe to support their military operations. Later the Arabs built roads that were covered with tar. The roads were constructed by preparing earthworks and lifting the road foundation at the center for water drainage. Road construction techniques gradually improved by the study of road traffic, stone thickness, road alignment, and slope gradients. Initial road construction materials were stones that were laid in a regular, compact design, and covered with smaller stones to produce a solid layer. The building techniques were simple but effective as they reduced the travel time considerably and connected one place to another by land. The Appian Way in Rome still exists although it was constructed 2300 years ago. If Roman roads are considered the beginning of road construction, Telford Pavements are known as the second step of this process, followed by the Macadam Pavements that ultimately lead to the Bitumen Roads. The roads in today's era are broadly classified into three categories

- Flexible pavement
- Rigid pavement
- Composite pavement

Across globe specially in developed countries like United States, Japan, Germany, France, Italy, Canada, Argentina, Spain and South Korea it was sighted very early that for social and economic development the pavements of good quality that provide good riding surface, having structural durability and that can reduce time of transportation are of utmost importance. With this view leading Road Research and Development Authorities/Agencies were established.

The agencies like CSIR, DOT, FHWA, JH etc. along with many others across world are collectively working to find solutions suitable for various conditions to ensure reduced pollution, improved riding quality, increased pavement life and economically justified pavements. In addition to this, the reclamation of aggregates/construction material and reduced usage of good quality construction material by virtue of suitable stabilization is the way ahead in road construction. More than 90 percent of pavement is rock, no matter what technology holds it together. "We need to keep remembering that rock is the primary ingredient, so there's tremendous energy that goes into the mining, crushing, and hauling of rock in the materials production phase, thus to preserve the aggregate, soil stabilization came into practice” .

The necessity of improving the engineering properties of soil has been recognized for as long as construction has existed. Many ancient cultures including the Chinese, Romans and Incas utilized various techniques to improve soil suitability, some of which were so effective that many of the buildings and roadways they constructed still exist today. Some are still in use. The modern era of soil stabilization began during the 1960's and 70's when general shortages of aggregates and fuel resources forced engineers to consider alternatives to the conventional techniques of replacing poor soils at building sites with shipped-in aggregates that possessed more favorable engineering characteristics. Soil stabilization then fell out of favor, mainly due to faulty application techniques and misunderstandings. More recently, soil stabilization has once again become a popular trend as global demand for raw materials, fuel and infrastructure has increased. This time, however, soil stabilization is benefiting from better research, materials and equipment.

The beginning of modern soil stabilization started in the United States in the 1920’s, a time in which regulations were being imposed on many businesses during the expanding industrial era. Paper mills that once discarded their by-products into their neighborhood rivers had to discover a creative way of disposing of their highly toxic, liquid waste. One solution was to promote the use of their waste as a dust palliative on dirt roads. Surprisingly, some of the treated roads developed a hardened surface.

Other roads did not. It was only decades later after significant private and government research, and the development of better technology during the 1940′s-1960′s that the reason for this change had begun to be understood as being caused by a chemical reaction between the waste solution and the clay particles within the soil. The artificial traditional admixtures in order of their usage are:

- Portland Cement (and Cement-Fly Ash)
- Lime (and Lime-Fly Ash)
- Fly Ash
- Fly Ash with Cement or Lime
- Bitumen and Tar
- Cement Kiln Dust (CKD)

Cement which is one of the major stabilizers used internationally had certain drawbacks like it works very well with sand and aggregates but not with all types of soil.

The second major problem with cement was the excessive heat of hydration when mixed with soil or aggregates which led to excessive cracking. There was also a problem with shrinkage cracks which was due to temperature changes.

A composition of various cementatious and pozzolonic material have been giving better results for stabilization than plain cement.

The inclusion of fibers has also given better results in arresting cracks and prevents widening of cracks

In recent years an increasing number of non-traditional additives have been developed for soil stabilization purposes. These stabilizers are becoming popular due to their relatively low cost, ease of application, and short curing time. Since the chemical formulas of the products are modified often based on market tendency, it is rather difficult to evaluate the performance of a single product.

An important point to be noted, internationally, lot of importance is given to protect the environment while roads are being constructed. The notable environment protection measures are.

- Only nontoxic and non-leaching material permitted to be used
- Dumping of poor soil and quarrying for good borrow soil highly restricted

- Destroying hills and river beds for rock quarrying prohibited
- Greenhouse gas emissions during construction controlled

**NATIONAL SCENARIO**

India has second largest road network in the world spanning a total of 4.7 million kilometers approx. This is used to transport over 60% of the goods in the country and 85% of the total passengers traffic. The administrative controls of roads in India are divided as per the type of road and its geographical location. The Rural roads are governed by Ministry of Rural Development / State Government/Rural Road Development Agency/NRRDA/Village Panchayat. The State roads are governed by State Government/PWD/Road Development Corporation /Infrastructure development boards. National highways are governed by MORTH/NHAI/BRO and PWD. The roads are primarily divided into following forms

- Expressway
- National Highway
- State Highway
- Major District Road
- Other district Road
- Village Roads

The roads in India are further classified, based on construction technology/material used as Flexible pavement, Rigid Pavement and Composite Pavement. The designs of above categories of roads are done as per specifications provided by prevailing Indian Road Congress (IRC) codes.

In road infrastructure, India in-comparison to the world has woken up very late to the advancement of technologies. Thus the age long technologies involving certain specified construction material are used in construction. This method primarily involves good quality soil and aggregate. The only reason that conventional technology holds on to its users is the awareness among all. Thus for the inclusion of new technology, it’s awareness and engineering must be disseminated. The conventional technology has shown various drawbacks such as excessive use of natural resources, rapid depletion of aggregate, non-sufficient durability, poor riding quality, long hauls of construction material and excessive Pollution to mention a few.

In India unlike the International practice there are no measures to protect the environment during road construction like

- Poor soil and rubble can be dumped anywhere and quarrying for good soil goes on uncontrolled
- There is no check on the toxicity and the leachability of the material being used in road construction
- Rampant destruction of hills and riverbeds are marginalizing the fragile eco system
- There is no control on the emission of greenhouse gas during construction and there are neither penalties nor incentives to build green roads

**RESEARCH OBJECTIVE**

Connectivity remains the most important ingredient for infrastructural improvement. Roads, the arteries of a nation, bring rapid transformation along its path, changing socio-economic structure, demographics and environment. In India, roads are being built with little emphasis on the preservation of the environment. Daily reports of damage to the environment, stripping of forest cover, hills and riverbeds are being voiced. While Western nations have rightly identified the importance of preservation of nature, we still tend to be lackadaisical in our approach. No justification can be offered in the name of progress if it denudes and depletes the very environment that allows its sustenance. It is our endeavor to save the fast depleting natural resources with alternate technology in order to conserve our hills, forests and rivers.

The Ministry of Environment, Forests and Climate Change (MoEF&CC) is the nodal agency in the Central Government for overseeing the implementation of India's environment and forest policies and programs relating to conservation of the country's natural resources including lakes and rivers, its biodiversity, forests and wildlife, ensuring the welfare of animals and prevention and abatement of pollution.

The Ministry is greatly concerned about the large amount of greenhouse gas emission during road construction. A significant amount of research has been carried out in improving the Pavement Design, Construction and maintenance process and strategies but very little research has been done in the field of reducing the carbon footprint in road construction. The prime objective of this study is

- To evaluate the new technology of road construction under Indian conditions for its environmental friendliness, economics and durability benefits with fast pace of construction,
- To study the material to ensure it has no toxicity and prevents leaching so that the ground water is protected,
- To study the acceptability of the revised design methodology of the new technology,
- To construct roads in India, test them during and post construction to study the suitability of the new technology. Suitability indicates either matching or improving the existing quality and durability of current roads,
- To establish beyond doubt the savings to the environment while constructing roads without depleting any of their current characteristics or strength or durability and life,
- To establish the saving in terms of aggregate consumption, bitumen consumption, the overall thickness of the road crust and also the construction time,
- To establish the economic saving as per the new technology compared to the conventional technology and also the savings in the life cycle costing.

MoEF&CC initiated the research for eco friendly road technologies and vide letter no. 1-7/2010-CT under Clean Technology Division grants aids for construction of different research stretches on National Highway, Rural Road, Forest Road and Cold Recycling technology with a natural soil stabilizer "RBI Grade-81".

## BRIEF METHODOLOGY

The MoEF&CC has sanctioned a jointly funded project to M/s. Alchemist Touchnology Limited dated 29th March 2012. Consequently different categories of roads were constructed in Karnataka using RBI Grade-81, manufactured in India with indigenous raw-materials. Roads were constructed during the month of June and July, 2012. Testing of road for quality control during construction, evaluation after first and second monsoons has been carried out in 3 cycles for this a project monitoring committee consisting of eminent and renowned experts from the field of environment and road construction was formed. The primary objective of the committee along with the Alchemist team was to:

- Study the existing design methodology, suggest and develop an alternate design taking into account equivalency factors.
- Documentation of the construction process and data collected during and post construction,
- Establish State of the art testing and evaluating equipment to be used for getting precise and flawless data.
- Place all obtained data and information and analysis before the expert committee at regular intervals for periodical guidance taken to ensure no mistakes were made and any initial omissions may be rectified.

## DESCRIPTION OF STUDY AREA

Ministry of Environment and Forests has requested various Government Departments of India and State Governments to allot the test sections for the study. Following departments accepted the requisition

- Chief Engineer, National Highways, KR Circle, Bangalore
- The Principal Chief Conservator of Forests, Bangalore
- The Principal Secretary, Rural Development and Panchayat Raj Department, Bangalore

A joint visit was conducted between Alchemist Engineers and Departmental Engineers on 10th May 2012 to select the test sections. After considering the importance and urgency following sections were identified and selected for the construction of test sections:

**National Highway Experimental Test Stretch**: The Research Project corridors for National Highway are located in the State of Karnataka on NH-206. Taking into consideration, the convenience of road users it was decided to construct Bus Bays on National Highway. The location of bus bays are in km 46 and km 49 selected on the basis of facility requirement to the user.

**Cold Recycling Experimental Test Stretch**: The Research Project corridor for Cold Recycling on National Highway is located in the State of Karnataka on NH-206 between KM 9.30 – 9.80. This section was high moisture area because of a reservoir bund nearby. Due to high moisture content in subgrade, the section use to fail very frequently.

**Forest Unpaved Experimental Test Stretch**: The Research Project corridor for Forest Road is located in the State of Karnataka in Jarakabande forest Road B block near tree park area, Yelanka, Bangalore. This section of forest is under development for the public use for nature walk. The test track is a part of walk way proposed.

**Rural Road Experimental Test Stretch**: The Research Project corridor for Rural Road is located in the State of Karnataka in Tumkur District from NH-206 to Basaweshwara Temple, N Mattigatta Village. At the end of this section there is a sand quarry, the road was heavily deteriorated by heavy sand loaded trucks. Although this is a rural road section but the traffic loading is very high as compared to other rural roads.

## APPROACH

For the selected research stretches under MoEF, detailed laboratory analysis was conducted by BMS College of Engineering, Bengaluru and Alchemist Touchnology Limited, as per prevailing codes (Indian and International). The results obtained were utilized in designing the pavements with RBI Grade-81.

Composite pavements, when compared to traditional flexible or rigid pavements, have the potential to become a better alternative because they may provide better levels of performance, both structurally and functionally. Therefore, they can be viable options for high volume traffic corridors. Countries, such as the U.K., Australia, South Africa, Japan, Spain and many other countries, which have used composite pavement systems in their main road networks, have reported positive experiences in terms of functional and structural performance. Composite pavement structures can provide long-life pavements that offer good serviceability levels and rapid, low maintenance operations, which are highly desired, especially for high-volume, high-priority corridors.

IRC: 37-2012 have guidelines for "Bituminous pavements with cemented base and cemented Sub base having 100 mm of aggregate interlayer for crack relief or with SAMI at the interface of base and the bituminous layer". The Interlayer is must for cemented layer, but with RBI Grade-81, the crack relief layer is not mandatory.

For designing the pavement crust with RBI Grade-81, IRC: 37-2012 has been considered. The design procedure is supported by the Software IITPAVE for analysis. All the parameters w.r.t. materials properties are taken from the laboratory investigation done on locally available material.

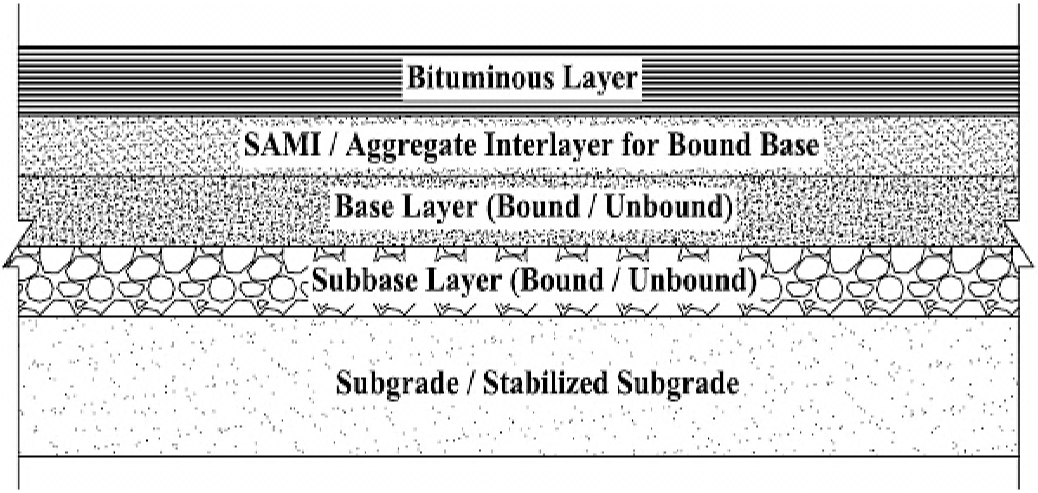


*Figure 1: Typical Pavement Layers of Stabilized Pavement*

All materials to be used, methods to be adopted and works to be performed strictly in accordance with the requirements provided in Ministry of Road Transport and Highways "Specifications for road and bridge works". The field laboratory was set up by M/s Alchemist Touchnology Limited at Gubbi Village with adequate equipment and personnel in order to carry out Quality Control for works. The quality control was under the supervision of BMS College of Engineering, Bengaluru.

The construction was commenced on 8th June 2012 and completed on 31st July 2012. All the construction work was implemented with strict quality control measures as provided in Ministry of Road Transport and Highways "Specifications for road and bridge works". The latest available machinery and equipment were used for quality control.

## AGENCIES INVOLVED IN MONITORING MECHANISM

Indian Institute of Technology Madras, Chennai was appointed as nodal agency for monitoring mechanism of the research project. The project location was visited during various stages of the project. Following three agencies are given in table 1 were hired to collect the specific specialized data on all the test sections.

*Table 1: List of Evaluation Studies and their Scope of Work*

| Sr. No. | Institute / Organization | Scope of Work |
|---|---|---|
| 1. | BMS College of Engineering, Bengaluru | Documentation of Construction Methodology, Material Investigation, Quality Control during Construction, Traffic Studies, Evaluation in 3 cycle BBD Test, Condition Survey and Roughness Test |
| 2. | Indian Institute of Science, Bengaluru | Ground Penetration Radar (GPR) Survey and analysis |
| 3. | Indian Road Survey and Management, Chennai | Falling Weight Deflectometer (FWD) Survey for deflection and modulus and Network Survey Vehicle (NSV) survey for condition survey |

**OUTCOME OF THE PROJECT**

5 test stretches were successfully constructed with average saving of 50% of construction time by New Technology as compared to conventional technology

In base layers of all the stretches, except strengthening test section, the aggregate was totally replaced by the locally available soil i.e. no aggregate were used in construction of base layers. At an average of 84.35% of aggregate quantity and about 59.85% of bitumen quantity is saved in this project by RBI Grade-81 technology over Conventional technology.

The test sections and conventional sections were evaluated in three cycles by the hired agencies with all state of art equipment to satisfy all the parameter of road performance and durability.


Photo 4: National Highway Test Stretch Constructed with RBI Grade-81: Bus Bays at km 46 and 49, NH-206, Tumkur, Karnataka

Photo 5: Close up view of National Highway Test Stretch Constructed with RBI Grade-81: Bus Bays at km 46 & 49, NH-206, Tumkur, Karnataka

Photo 6: Temporary Diversion for Strengthening: Constructed with RBI Grade-81 km 9.30 to 9.80, NH-206, Tumkur, Karnataka

Photo 7: Temporary Diversion for Strengthening Constructed with RBI Grade-81 km 9.30 to 9.80, NH-206, Tumkur, Karnataka

Photo 8: Strengthening by Cold Recycling Technology with RBI Grade-81: km 9.30 to 9.80, NH-206, Tumkur, Karnataka

Photo 9: Strengthening by Cold Recycling Technology with RBI Grade-81: km 9.30 to 9.80, NH-206, Tumkur, Karnataka

Photo 10: Rural Road: NH-206 to Basaveshwara Temple, Mattigatta Village Constructed with RBI Grade-81, Gubbi, Tumkur, Karnataka

Photo 11: Rural Road: NH-206 to Basaveshwara Temple, Mattigatta Village Constructed with RBI Grade-81, Gubbi, Tumkur, Karnataka

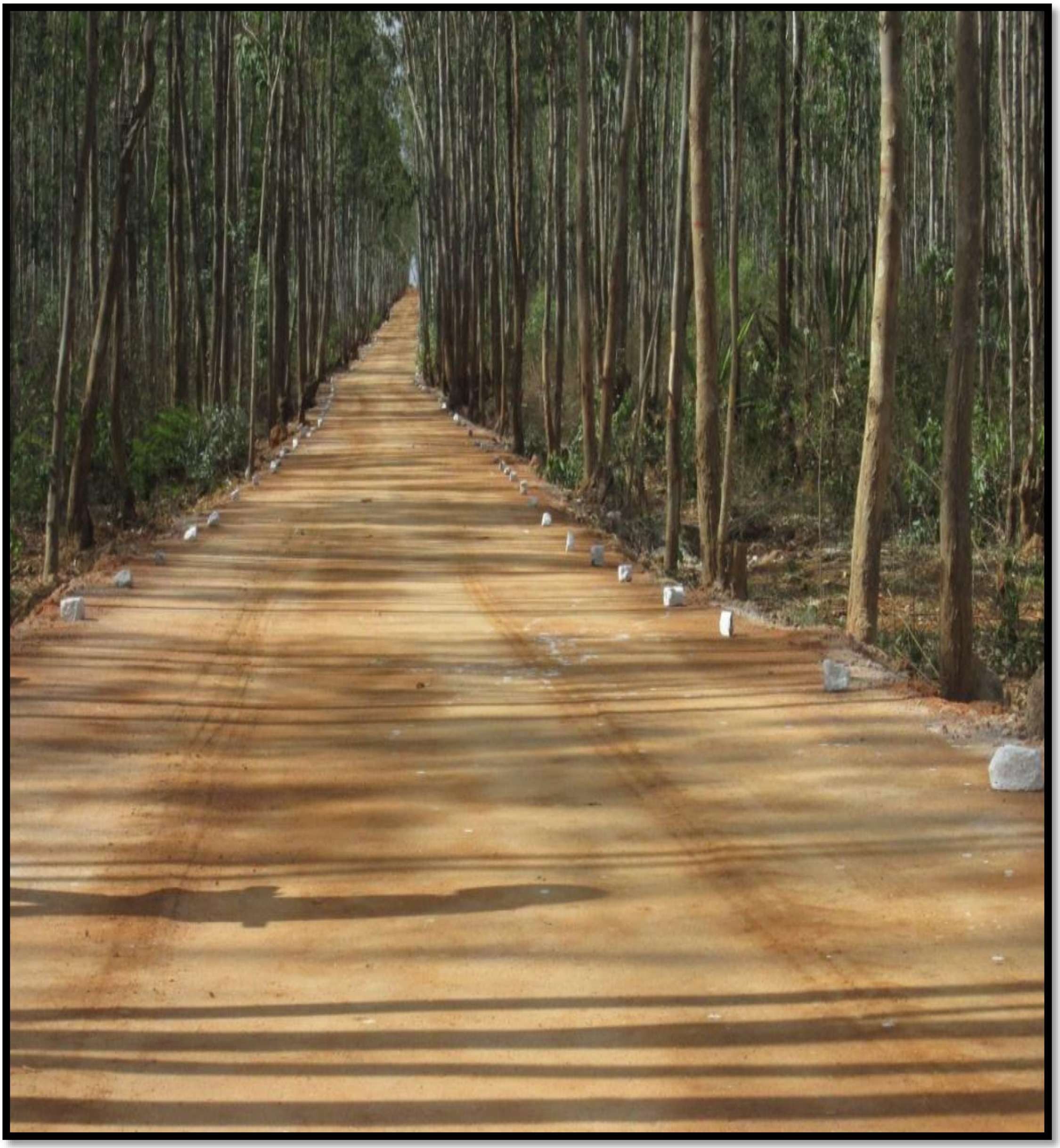

Photo 12: Unpaved Road Constructed with RBI Grade-81: Jarakabande forest Road B block near tree park area, Yelanka, Bengaluru

## RESULTS OF MONITORING OF TEST SECTIONS

A brief performance evaluation done by IISC, IRSM and BMS college of Engineering, are discussed in sub section below. The values obtained at last cycle of analysis are taken to see the performance of sections under prolonged traffic

### Deflection measurement

The summary of deflection measurement is shown in figure 2.

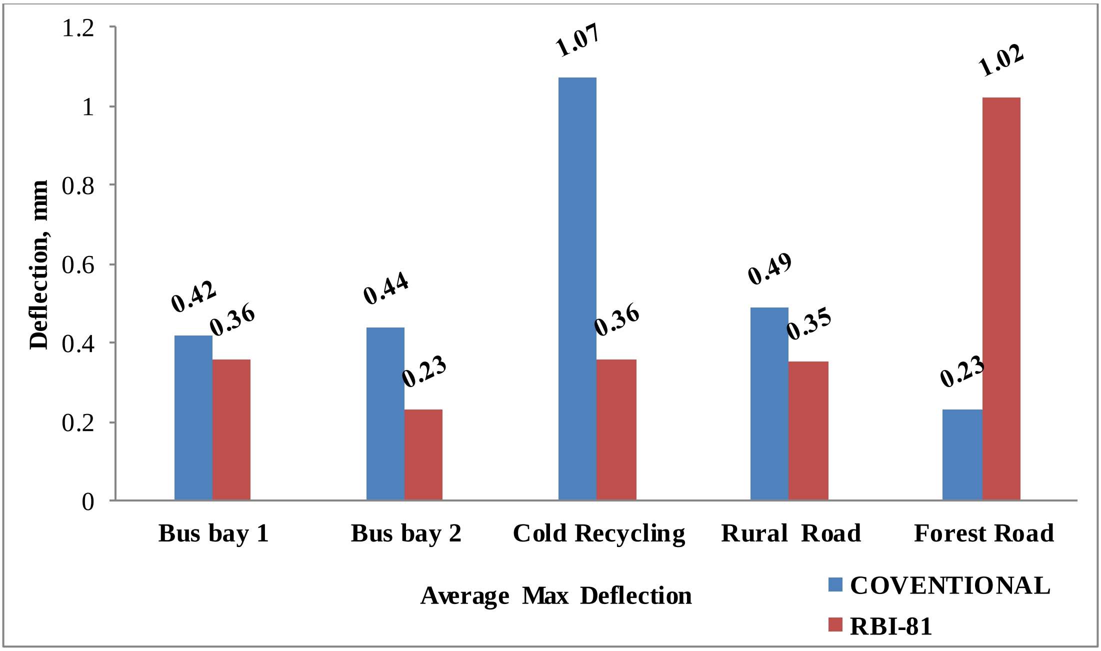


*Figure 2: Summary of Average Maximum Deflection*

As can be seen in the results above, the deflection values at the end of three cycles of evaluation is showing very good results in RBI-81 stabilized section. Only in case of unpaved forest road the deflection has gone marginally above 1mm. the forest road is an unpaved section, thus the higher value is expected

### Roughness Measurement

The summary of IRI results are given in table 2. The values used are of last cycle of evaluation

Photo 14: FWD Testing in Progress on Strengthening Stretch Constructed with RBI Grade-81

*Table 2: Summary of IRI Results*

| | IRSM | | BMSCE | |
|---|---|---|---|---|
| **Section Name** | **IRI Average conventional** | **IRI Average RBI-81** | **IRI Average conventional** | **IRI Average RBI-81** |
| Cold Recycling | 3.48 | 2.57 | 4.87 | 3.45 |
| Rural Road | 2.77 | 2.51 | - | - |
| Bus bay 1 Part 1 | - | 5.56 | 3.75 | 3.18 |
| Bus bay1 Part 2 | - | 5.25 | - | - |
| Bus bay 2 Part 1 | - | 6.67 | 4.11 | 3.33 |
| Bus bay 2 Part 2 | - | 4.23 | - | - |


Photo 15: Network Survey Vehicle Collecting data on RBI Grade81 Stretch

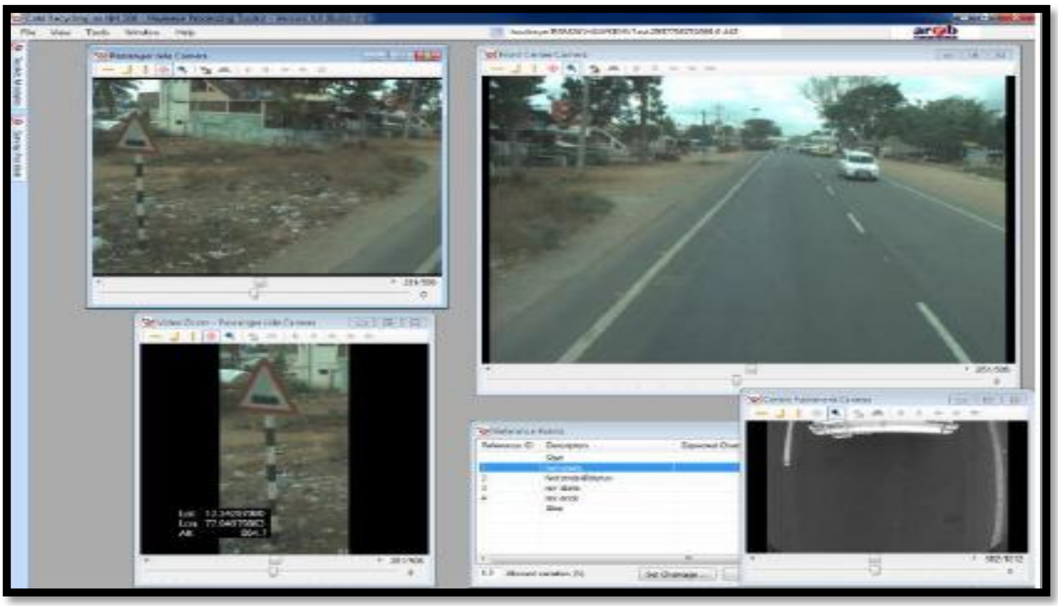

Photo 16: NSV Data Collection Monitor

**Rutting Measurement**

The rutting results as per final cycle of evaluation are given in table 3.

*Table 3: Summary of Rutting Results*

| | IRSM | | BMSCE | |
|---|---|---|---|---|
| **Section Name** | **Rutting Average conventional** | **Rutting Average RBI-81** | **Rutting Average conventional** | **Rutting Average RBI-81** |
| Cold Recycling | 2.66 | 2.83 | 2 to 5 | 3 |
| Rural Road | 3.05 | 2.31 | Not Available | NIL |
| Bus bay 1 Part 1 | Not Available | 4.53 | 9 | 8 |
| Bus bay 1 part 2 | Not Available | 4.43 | Not Available | NIL |
| Bus bay 2 Part 1 | Not Available | 5.61 | 10 | NIL |
| Bus bay 2 part 2 | Not Available | 4.8 | Not Available | NIL |

There is negligible rutting observed in RBI-81 experimental sections. None of the values are close to 20 mm allowable rut. The performance thus far is satisfactory.

**GPR Study**

The study done by IISC using, 800 MHz GPR antennas and subsequently obtained radargram's have helped evaluate the pavement characteristics. The summary of evaluated stretches is given below in table 4.

The outcome shared shows that RBI-81 layers are homogeneous and intact, with no signs of functional / structural failure.

*Table 4: Summary of GPR Study*

| Sr. No. | Location | Layer Behavior | | | | Remarks |
|---|---|---|---|---|---|---|
| | | **Uniform** | **Homogenous** | **cracks** | **Intact** | |
| 1 | Bus Bay 1 | YES | YES | NO | YES | Existing are not Uniform |
| | Adjacent Conventional stretches | NO | NO | - | YES | non uniform at the edge ,uniform at the middle |
| 2 | Forest Road | YES | YES | YES | YES | Separation within RBI-81 Layer, minor cracks at the Edge |
| 3 | Cold Recycling | YES | YES | NO | YES | Cracks At the Junction |
| | Adjacent Conventional road | NO | NO | YES | YES | Alligator cracking on more than 70% of area |
| 4 | Bus Bay 2 | YES | YES | NO | YES | - |
| | Adjacent Conventional Section | NO | NO | NO | YES | |
| 5 | Rural Road | YES | YES | NO | YES | Subsurface below 200 are not Homogenous |
| | Adjacent Conventional road | NO | NO | NO | YES | |

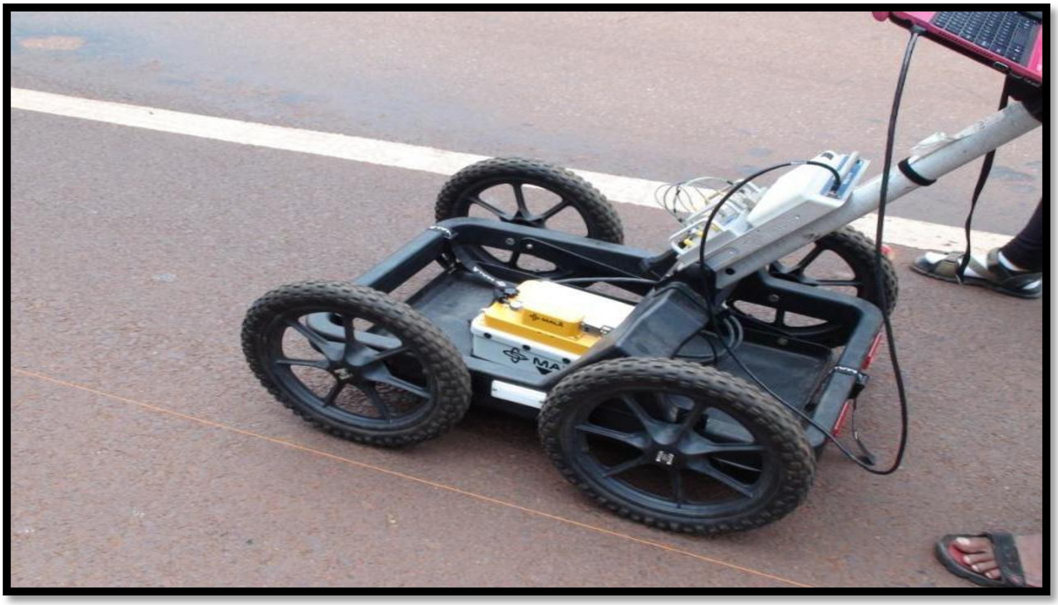

Photo 17: GPR Testing in Progress at Bus Bay Constructed with RBI Grade-81 at 46 km, NH-206

**Elastic Modulus**

Elastic modulus is calculated through back calculation of values obtained through FWD. The summary of results obtained in final cycle of evaluation is shown in figure 3

In addition to the study done under this project, a five year old section constructed with RBI-81 technology was also studied to compare its performance with conventional section under the instructions & guidance of PMC.

The pavement Mean modulus of conventional section was found out to be 240 MPa compared to 428 MPa of RBI Grade-81 stabilized section. It is seen that even at reduced thickness of pavement at 225 mm from conventional 375mm, RBI-81 section is structurally more stable. The following are the observations:

- Conventional section was strengthened in the year 2012 even then RBI Grade-81 pavement shows less deflection than conventional section.
- Strength gain over period of time can be observed in modulus data.

- There is no sign of cracks in stabilized base as the deflection is decreased and modulus is increased over time.
- It has been proven beyond doubt the RBI-81 constructed roads are far more stronger and durable than the conventionally constructed roads

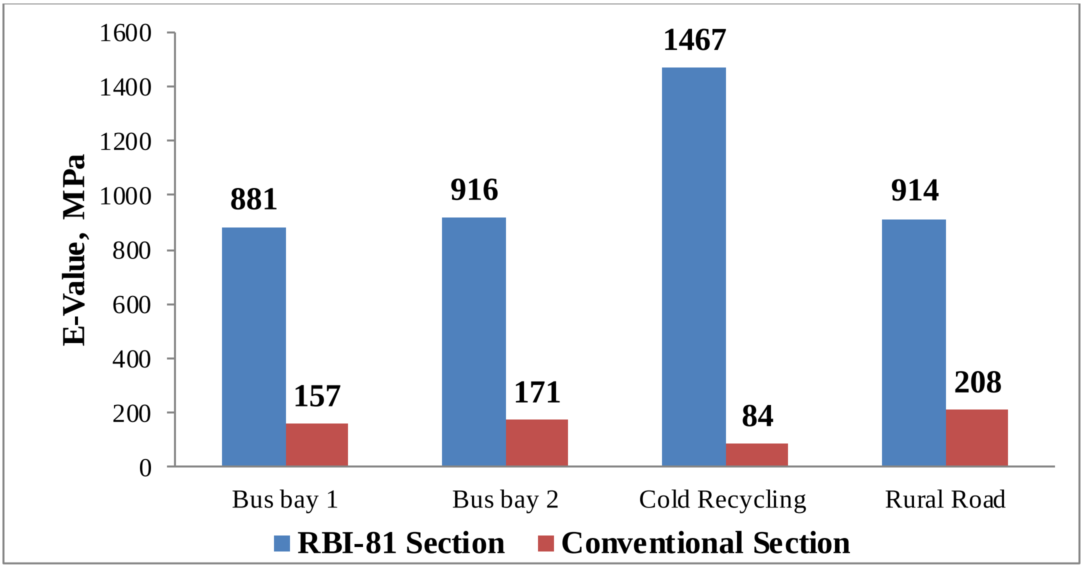


*Figure 3: Summary of Elastic Modulus Value of Base Layers*

## ECONOMIC BENEFITS OF NEW TECHNOLOGY

It has been established that the construction of the roads using the new technology RBI Grade-81 is economical than conventional method

For cost benefit analysis of the RBI Grade-81 technology of roads construction following factors has been taken into consideration:

**a)** Construction Cost

**b)** Material Savings

**c)** Time Savings

**Construction Cost**

As per the actuals, the construction cost of RBI Grade-81 test tracks are considered and for conventional construction cost of similar geometrics is calculated on the basis of latest State Schedule Of Rates of the region. The comparative table for construction cost is shown in figure 4:

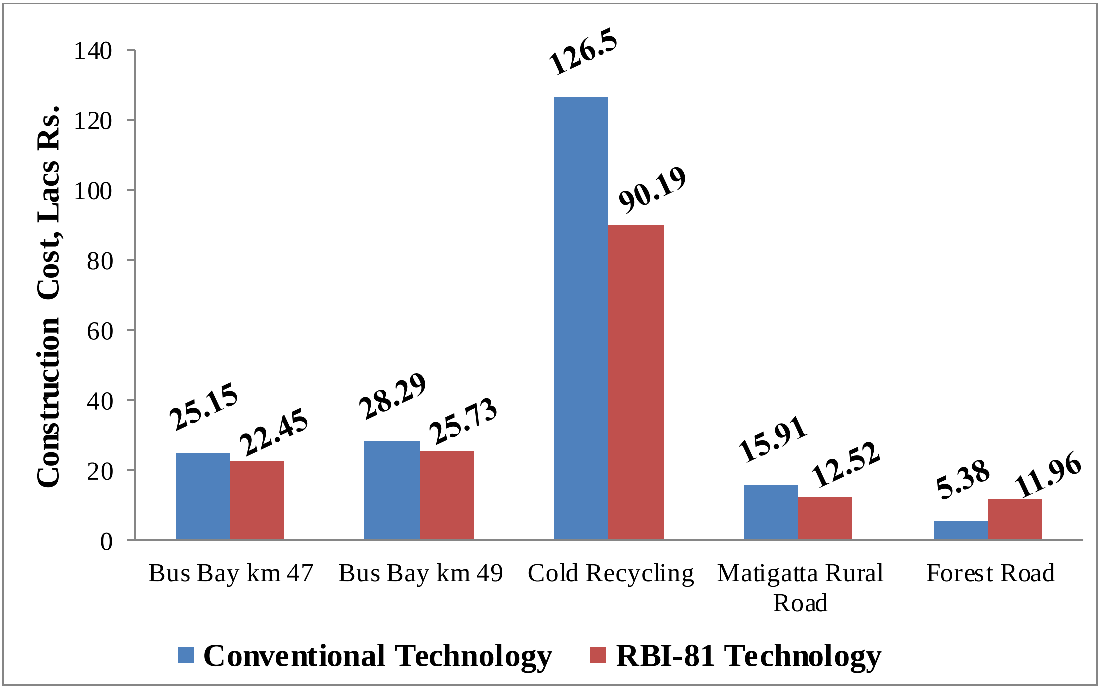


*Figure 4: Construction Cost of Test Stretches*

**Material Savings**

With RBI Grade-81 technology, maximum use of locally available material was done. Even in base layers of pavement only soil was used and at cold recycling stretch existing material with extra material for losses was used for construction of base layer. The comparative table of material consumption for the conventional and RBI Grade-81 technology is shown in figure 5.

**Time Savings**

The construction time required for conventional technology with similar geometrics is calculated on the basis of the capacities of the machinery given in Standard Data book of Ministry (MOSRTH). The actual time taken by RBI Grade-81 is considered for the comparison. The comparison of time consumed is given in figure 6.

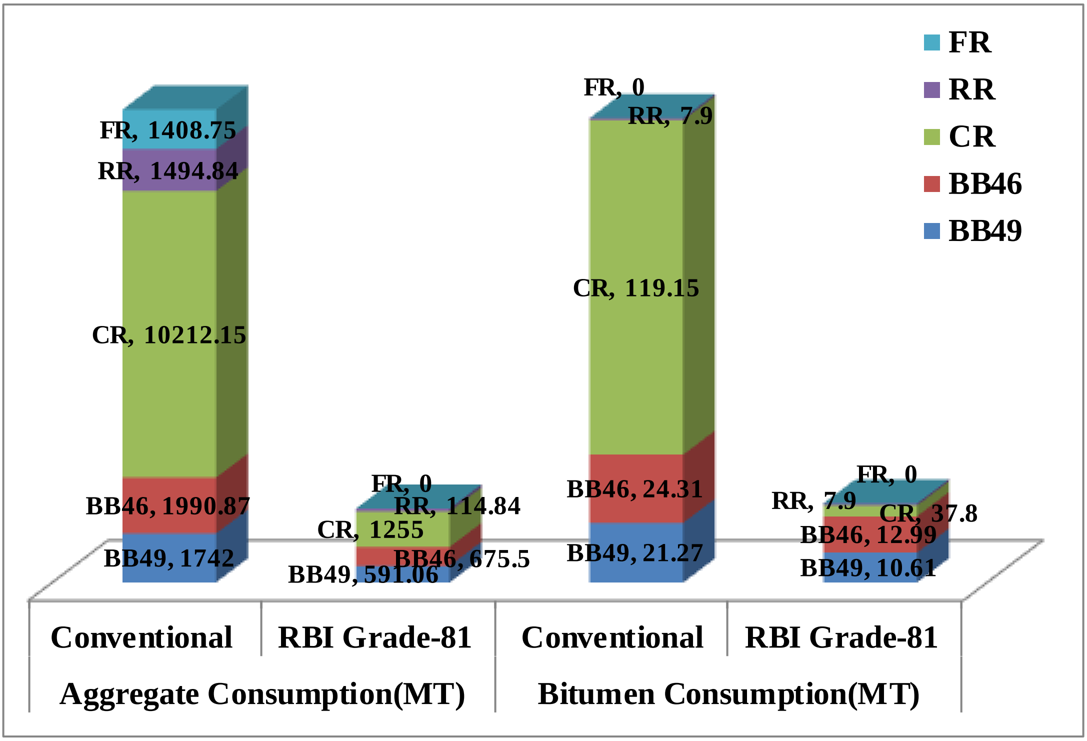


*Figure 5: Comparison of Material Consumption*

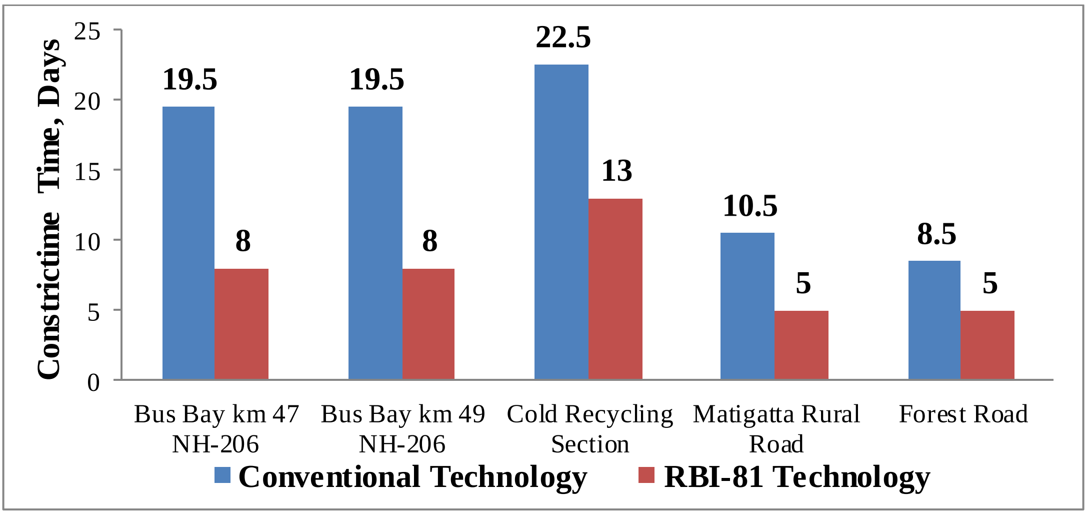


*Figure 6: Comparison of Construction Time*

**Cost Benefit Analysis**

- At an average, 19**%** of construction cost is saved by RBI Grade-81 technology over Conventional technology. That means approx. 123 km length can be constructed by RBI Grade-81 within the cost of 100 km by conventional technology.
- At an average, 84.35**%** of aggregate quantity is saved by RBI Grade-81 technology over Conventional technology. That means approx. 600 km length can be constructed by RBI Grade-81 within the quantity of aggregate required to construct 100 km by conventional technology.
- At an average, 59.85**%** of bitumen quantity is saved by RBI Grade-81 technology over conventional technology. That means approx. 240 km length can be constructed by RBI Grade-81 within the quantity of bitumen required to construct 100 km by conventional technology.
- At an average 50**%,** of construction time is saved by RBI Grade-81 technology over conventional technology. That means approx. 200 km length can be constructed by RBI Grade-81 within the time required to construct 100 km by conventional technology.

**LIFE CYCLE ANALYSIS OF NEW TECHNOLOGY**

Life Cycle Assessment analysis comprises the complete life cycle of a product, process or activity, including the production of raw materials, manufacturing, transport and distribution, usage, re-usage, maintenance, recycling of materials and final disposal or destruction. The aim of life cycle analysis is to assess and compare the different structural solutions, including all actions necessary over their entire service life.

A life cycle assessment also analyses the environmental impact from a system, taking into account ecological effects, effects on health and the consumption of resources. At present the choice of materials and techniques in road construction is dictated by structural requirements and economical aspects. Ecological factors have gained importance due to environmental considerations in politics and society. To evaluate the environmental impact of motorways, a life cycle assessment (LCA) according to ISO 14040 was carried out. In this project the structural requirements and the economic aspects have not been compromised while taking into account the ecological factors. To fulfill the requirements of a proper life cycle assessment of the RBI Grade 81 technology proper care has been taken to consider the usage of raw material, the transportation of raw material the construction process monitoring of the constructed road, evaluating the structural integrity of the road and a comparison of the alternate technology with the existing for all parameters. Even the suspension of solid particles in air, the traffic details and the leachability of the product have also been studied.

The aim of life cycle analysis was to assess and compare the different structural solutions, including all actions necessary over their entire service life. The design model was intended to take account of environmental impacts as well as the traffic effects of alternative constructions. The environmental impacts were assessed on the basis of the data generated in this study.

The purpose of pavement design was to identify the most economic design, with sufficient structural capacity, for the particular design situation. Various alternative designs are initially identified, considering the availability of materials, structural capacity demand of the actual traffic spectrum, and the service level of the facility. Ultimate selection of a particular design, however, depends on an economic analysis of the design options over the full life-cycle of the facility. The strategy for some of the design alternatives may call for more capital investment for the initial construction to ensure a longer structural design period, while others may have a bigger demand for maintenance funds. Refer to pavement design section of this report; by RBI-81 technology there is an average reduction of crust thickness by about 48.6% as shown in figure 7.

It is important, therefore, not just to design and build a road, but to have a strategy as to how to retain the structural bearing capacity with time, i.e., a life cycle strategy that includes maintenance. The deterioration of the riding quality and skid resistance with time defines when maintenance is required. Two approaches to the maintenance strategy are possible. The design strategy and economic analysis of the full life-cycle of the facility require an understanding of the behavior of different pavement types, and the type and timing of maintenance and rehabilitation expected during the life cycle. An understanding of material and pavement behavior is therefore critically important.

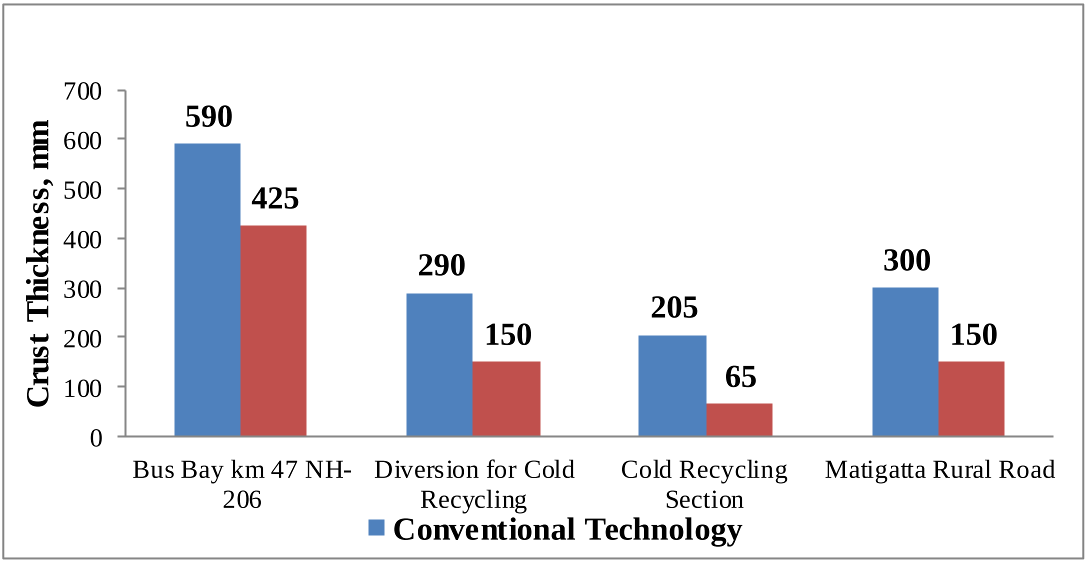


*Figure 7: Reduction in Crust Thickness*

*Table 5: Summary of Strength Testing with Soil*

| Sr. No. | Test Stretch | CBR of Stabilized Soil with RBI Grade-81 | UCS of Stabilized Soil with RBI Grade-81 |
|---|---|---|---|
| **1** | Bus Bay km 47 NH-206 | 158.00% | 6.87 MPa |
| **2** | Bus Bay km 49 NH-206 | 130.00% | 6.89 MPa |
| **3** | Cold Recycling Section NH-206 (Diversion) | 138.00% | 5.61 MPa |
| **4** | Cold Recycling Section NH-206 | 590 KPa (ITS) | 7.25 MPa |
| **5** | Matigatta Rural Road | 100.00% | 5.60 MPa |
| **6** | Unpaved Forest Road | 150.00% | 6.97 MPa |

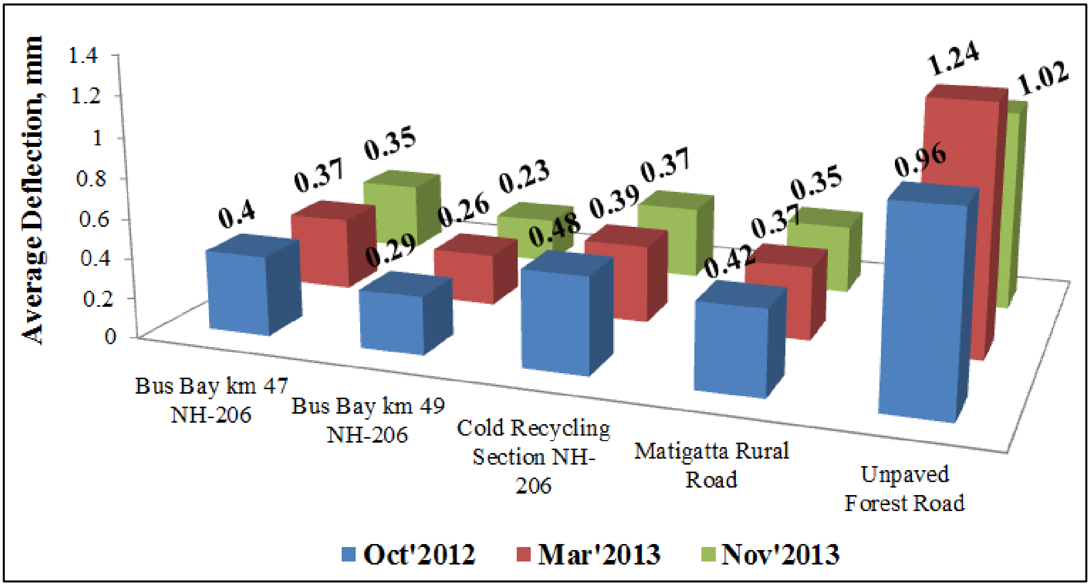


*Figure 8: The summary of collected deflection data on test tracks*

*Table 6: The summary of functional performance data on test tracks*

| Sr. No. | Test Stretch | Cracking, % | Rutting, % | Ravelling, % | Patching, % | Potholes, No. | Upheaval, m | Bleeding, % | Roughness, IRI |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Bus Bay km 47 NH-206 | Nil | 4.43 | Nil | Nil | Nil | Nil | 1.6 | 3.18 |
| **2** | Bus Bay km 49 NH-206 | Nil | 4.80 | Nil | Nil | Nil | 1 | 2 | 3.33 |
| **3** | Cold Recycling Section NH-206 | 2 | 2.68 | Nil | 2 | Nil | Nil | 2 | 3.45 |
| **4** | Matigatta Rural Road | Nil | Nil | Nil | Nil | Nil | Nil | Nil | 2.51 |
| **5** | Forest Road | Nil | 2.31 | 19 | Nil | Nil | Nil | Nil | NA |

The comparative study was carried out between conventional and RBI Grade-81 section. It was found that the RBI Grade-81 base layers are relatively uniform and homogeneous than that of unbound conventional layers. There is no evidence of premature cracking in the RBI Grade-81 stabilized base layers. There are some cracks on bituminous surface at cold recycling stretch but those are limited to only bituminous layer.

The construction, operation and maintenance of roads in many cases, from an environmental point of view, been regarded as less significant compared to the impact of vehicles using the road during its lifetime. This study is an attempt to acquire knowledge about the importance of road maintenance, seen from a life cycle perspective.

This work is a preliminary study where the road system has been studied in terms of life cycle assessment methodology. The complete life cycle of a road has been studied including the extraction of raw materials, construction products, construction process, maintenance and operation of the road and finally the disposal/reuse of the road at the end of the life cycle (end of the analyzed time period). The contribution from traffic during the same time period is included in the study. As a brief comparison, the contribution from the traffic has been calculated and compared with the road system.

Daily traffic data has been gathered after construction and important parameters were monitored. The constructed road has been evaluated over a period of 18 month period from construction and studies were carried out about the health of the pavement in three separate cycles immediately after construction and after the first monsoon .

Functional requirements are defined for a road over a period known as the analysis period. This usually extends over 20 to 30 years and sometimes longer. Structural considerations define the life of a road in terms of its structural bearing capacity, which will be shorter than the analysis period. In short, the structural capacity is normally defined as the number of equivalent single axle loads that the pavement can support before it reaches a defined terminal condition. The period in which this takes place is termed the structural design period.

In road construction the use of mass raw materials, land use and the possible release of pollutants into the soil have greater significance than in most other applications of life cycle assessment. The testing for leaching and toxicity is independently handled by Indian Institute of Toxicology Research Lucknow.

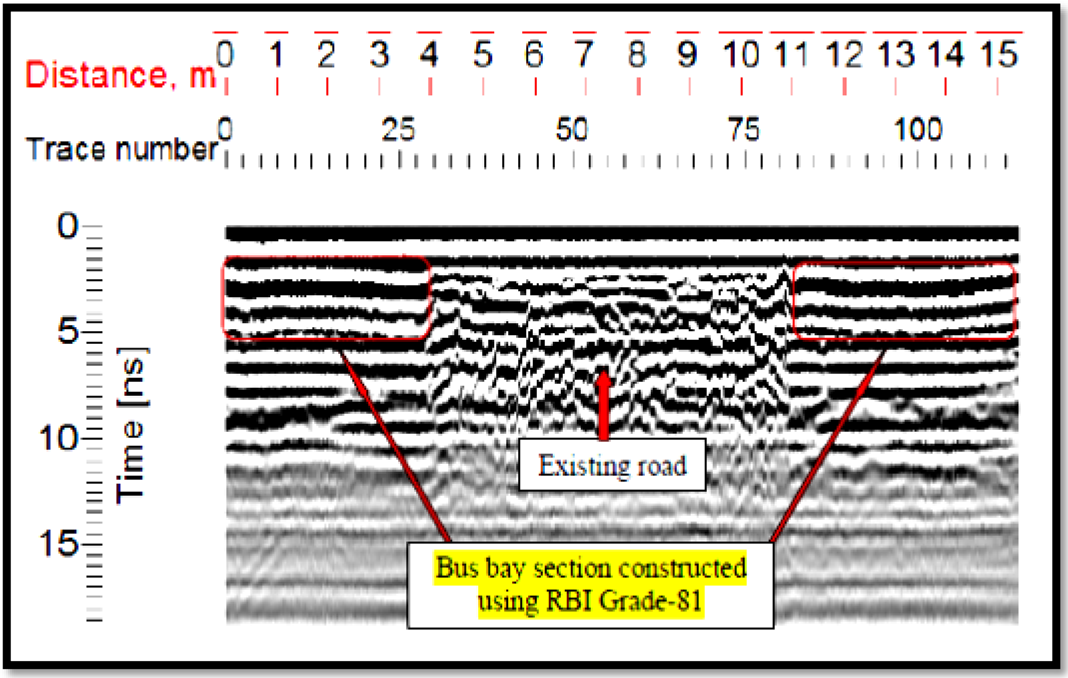


*Figure 9: GPR radargram for section Bus bay - existing road - Bus bay after 11 month of construction*

The first phase of the life cycle of a road is the projection and construction phase. In this phase, the road and any related peripheral equipment is constructed. It includes several heavy work elements such as excavation in order to obtain the desired routing of the road, foundation reinforcement work and other efforts. These elements do not normally reoccur at a later stage in the lifetime of a road. After the construction phase the road moves on to a usage phase, which contains the operation and maintenance phases.

A road is different from many other products where production methods, materials consumption etc. vary significantly both between and within different construction projects. For example, geo-technical conditions may vary and the geographic

location of the road may be different. Due to the varying conditions, it has not been possible to use a static life cycle assessment model.
Since roads are of different types, traffic loads and construction activities have been taken into consideration.

- Widening of an existing highway by constructing bus bays
- New construction of a rural road
- New construction of a an unpaved forest road
- Full depth reclamation or recycling of an existing distressed highway

Besides that functional characteristics of materials and structures used in roads have been studied. Substitute materials are also being presented for use in road and earth constructions. It is possible to design alternative constructions using these substitute materials.
All constructions must meet the functional requirements specified by the Ministry of Road Transport & Highways. In selecting materials and structures it is also necessary to take the economics and environmental impact into consideration. In modern design, emphasis is also given on the Environmental factors which affects comparative costs analysis between the conventional sections and the new technology. Life cycle impacts are being used as a selection criterion for products and materials both in industry and in other activities. Assessment and calculation methods have developed since the early days of LCA, and the scope of its application has grown enormously. Assessment of total environmental impacts of activities and products reliably and in such a way that alternatives can be compared is a different task. The "cradle-to-grave" life cycle always involves numerous stages and activities that give rise to a number of different environmental loadings. In order to keep the amount of work within reasonable bounds, the assessments must always be limited and efforts must be made to identify the critical stages of the life cycle and those factors responsible for environmental loadings. This requires not only adherence to the basic principles of life cycle analysis but also information of the product or activity in question.
The special features of the construction sector are the large volumes of materials used, the long service lives of the finished products, the need to examine construction as a whole rather than comparing alternative materials, and the

significant effect of the construction's longevity and need to repair during their life cycle environmental loadings. The development of models for the environmental impact assessment of materials and constructions and for their comparison on an ecological basis is regarded as important.

Keeping the varied requirements of the life cycle assessment techniques, it may be claimed that, a diligent attempt has been made to correlate the various aspects of design, acceptance, material, consumption, construction, compatibility, traffic impact, environment, pollution, carbon emission during construction, effect of monsoon, and performance of the pavement. The results have been collated and presented in this report. Most of the materials used in road construction are naturally occurring mineral aggregates and soils. Because the need for materials is large, depletion of the best materials, the needs for resource conservation and transportation of construction material have compelled the need to introduce substitute materials for natural sand and gravel. Refer to this report evaluation section; the summary of environmental benefits is given in table 7:

*Table 7: Environment Benefits in Construction of Test Section (Total Length of about 2 Km)*

| Sr. No. | Test Stretch | Aggregate MT | Bitumen MT | Fuel ($tCO_{2\ eq.}$) | Carbon Emission ($tCO_{2\ eq.}$) |
|---|---|---|---|---|---|
| **1** | Conventional Technology | 16849.00 | 172.63 | 307.85 | 586.00 |
| **2** | RBI Grade-81 Technology | 2636.00 | 69.30 | 201.27 | 324.00 |
| **3** | Savings by RBI Grade-81 Technology | **84.35%** | **59.85%** | **34.62%** | **44.70%** |

## ENVIRONMENTAL BENEFITS OF NEW TECHNOLOGY

### Toxicity and Leaching

Environment is one of the important factors to consider when venturing into any new project. This is particularly relevant when soil stabilization is considered, as a foreign substance, the stabilizer, is added to a medium in which the potential for leaching is high. Chemical reactivity and leaching are not the only environmental issues to consider, as road construction requires large amounts of earthworks and the potential for environmental impacts on a physical level are therefore high. It is for these physical and chemical reasons that should place a very high level of commitment on ensuring that the stabilizer is not a threat to the environment under any foreseeable circumstance while minimizing the potential for physical impacts. There are two types of environmental impacts; chemical and physical. Chemical impacts include the addition of chemical, whether it is solid or liquid, natural or synthesized, which affects the environment at micro and macro level.

Chemical mobility and toxicity assessment are important in determining its fate in the environment. Physical impacts revolve around those aspects in which application or construction affects the natural landscape. This can be as simple as walking through a fragile ecosystem or as intensive as clear cutting a forest, or in the case of road construction, removal and disposal of undesirable soil types. There is a link between chemical and physical impacts; however their relationship is such that each aspect can be dealt with individually without compromising the understanding of the related subject.

Toxicity study was performed by Indian Institute of Toxicology Research Lucknow – The only out of the prestigious laboratory in India to carry out these tests. The study report was directly submitted to the Ministry of Environment, Forests and Climate Change, New Delhi.

The objective of the study was to assess the leaching of selected heavy metals from the soil when it was molded with RBI Grade-81 at 2% and 4% w/w ratio. This assumes the importance as this material is intended to be used for binding and stabilizing the soil.

The study was conducted according to the USEPA guidelines (1311 of July 1992) for Toxicity Characteristics Leaching Procedure (TCLP). TCLP is a soil sample extraction method for chemical analysis. When a material is disposed in landfills, hazardous substances contained in them may enter the environment. To examine if the addition of RBI Grade-81 to the soil results in the leaching of any toxic metal in the environment, simulated methods have to be applied to test this possibility and compare the values with the permitted levels as per TCLP guidelines.

All the leaching studies were done in triplicate and the mean results are given in table 8.

*Table 8: Metal levels in leachates generated as per TCLP (ug/ml)(USEPA method 1311)*

| Sr. No. | Sample Code | Sample Description | Metal levels in leachates generated from soil (ug/ml) | | | |
|---|---|---|---|---|---|---|
| | | | Cr | Pb | Cu | Ni |
| 1 | CS-NS | Control soil without spiking | 0.016 | 0.0889 | 0.0138 | 0.0414 |
| 2 | CS-WS | Control soil with spiking | 0.0245 | 0.106 | 0.0175 | 0.067 |
| 3 | RBI-S-4-I | Soil with 4% RBI Grade-81 and Spiking | 0.0435 | 0.1387 | 0.0245 | 0.0692 |
| 4 | RBI-S-4-II | Soil with 4% RBI Grade-81 and Spiking | 0.047 | 0.1321 | 0.0234 | 0.0713 |
| 5 | RBI-S-2-I | Soil with 2% RBI Grade-81 and Spiking | 0.0336 | 0.1162 | 0.0176 | 0.0651 |
| 6 | RBI-S-2-II | Soil with 2% RBI Grade-81 and Spiking | 0.0365 | 0.1109 | 0.0166 | 0.0683 |
| 7 | RBI-4-I | Soil with 4% RBI Grade-81 and No Spiking | 0.0488 | 0.1312 | 0.0204 | 0.0732 |
| 8 | RBI-4-II | Soil with 4% RBI Grade-81 and No Spiking | 0.0428 | 0.1372 | 0.0208 | 0.0685 |
| 9 | RBI-2-I | Soil with 4% RBI Grade-81 and No Spiking | 0.038 | 0.1256 | 0.0214 | 0.0621 |
| 10 | RBI-2-II | Soil with 4% RBI Grade-81 and No Spiking | 0.0356 | 0.1230 | 0.0194 | 0.0642 |

**Pollution Abatement**

Clean air is important for both human health and the health of the environment. Deteriorating air quality is still a matter of great concern for the Country.

Emissions to the atmosphere from construction sites include suspended particulate matters that include dust, motor vehicle emissions, smoke and odor. Such emissions have adverse impacts on the environment.

Emissions can occur from any of the construction activities, but on different sites to varying degrees and with different durations and frequencies. For example, road dust generated from vehicular movements within the site may occur at regular intervals. Other activities may only occur at certain stage of the construction process, e.g. earthmoving, demolition, grit and sand blasting or spray painting.

The major air emission expected from construction activities is dust, that is, particulates. This is not only of potential nuisance to adjacent or nearby occupants but in some instances also poses a potential health risk.

Photo 18: Air Sample Collection in Progress

Health studies have established a relationship between fine particulates and respiratory problems, especially for people within 'high-risk' groups such as children, asthmatics and the elderly. However, it is usually the local amenity or nuisance impacts that are of concern to nearby premises.

Other emissions from construction sites include those generated from the diesel engines operating vehicles and machinery.

Fare Labs Pvt. Ltd., Gurgaon has carried out field tests during construction on NH-58 with RBI Grade-81 and conventional construction. The findings are given in table 10.

**Conservation of Natural Resources**

With RBI Grade-81 technology, maximum use of locally available material was made. Even in base layers of pavement only soil was used and at cold recycling stretch existing material with extra material for losses was used for construction of base layer. The comparative table of material consumption for the conventional and RBI Grade-81 technology is given in table 9:

*Table 9: Comparison of Material Consumption*

| Sr. No. | Test Stretch | Aggregate Consumption (in MT) | | Bitumen Consumption (in MT) | |
|---|---|---|---|---|---|
| | | Conventional Technology | RBI Grade-81 Technology | Conventional Technology | RBI Grade-81 Technology |
| **1** | Bus Bay km 47 | 1742.00 | 591.06 | 21.27 | 10.61 |
| **2** | Bus Bay km 49 | 1990.87 | 675.50 | 24.31 | 12.99 |
| **3** | Cold Recycling Section including diversion | 10212.15 | 1255.00 | 119.15 | 37.80 |
| **4** | Rural Road | 1494.84 | 114.84 | 7.90 | 7.90 |
| **5** | Forest Road | 1408.75 | 0.00 | 0.00 | 0.00 |

| Table 10: Suspended Particulate and Air Quality During and After Construction | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **NGL** | **During GSB** | **During WMM** | **During DBM** | **During BC** | **During Stabilized Sub-Base** | **During Stabilized Base** | **After Construction of Conventional Road** | **After Construction of Stabilized Section** |
| 1 | Particulate matter ($PM_{2}$,s), µg./$m^3$ | 39.38 | 44.51 | 43.12 | 40.89 | 40.81 | 42.38 | 40.31 | 32.47 | 29.6 |
| 2 | Particulate matter ($PM_{10}$,s), µg/$m^3$ | 88.45 | 88.38 | 87.54 | 85.21 | 88.54 | 86.42 | 86.87 | 83.87 | 80.57 |
| 3 | Sulphur Dioxide (as $SO_2$), µg/$m^3$ | 32 | 32 | 31 | 28 | 29 | 29 | 28 | 35 | 30 |
| 4 | Oxides of Nitrogen (as $No_x$),µg/$m^3$ | 12.34 | 10.1 | 10.2 | 8.5 | 10.2 | 9.1 | 9.4 | 10.25 | 8.6 |
| 5 | Ammonia (as $NH_3$), µg/$m^3$ | 292.35 | 299 | 289 | 274 | 290 | 275 | 266 | 270 | 264 |
| 6 | Ozone (as $O_3$), µg/$m^3$ | 50 | 54 | 50 | 48 | 52 | 52 | 51 | 52 | 49 |
| 7 | Carbon Monoxide (as CO), µg/$m^3$ | 183 | 210 | 201 | 195 | 200 | 195 | 199 | 192 | 181 |
| 8 | Nickel (as Ni), ng/$m^3$ | ND, [DL-10] | ND, [DL-10] | ND, [DL-10] | ND, [DL-10] | ND, [DL-10] | ND, [DL-10] | ND, [DL-10] | ND, [DL-10] | ND, [DL-10] |
| 9 | Arsenic (as As), ng/$m^3$ | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] |
| 10 | Benzene (as $C_6H_6$),µg/$m^3$ | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] | ND, [DL-2] |
| 11 | Benzo (a) pyrene (as BAP), ng/$m^3$ | ND, [DL-0.5] | ND, [DL-0.5] | ND, [DL-0.5] | ND, [DL-0.5] | ND, [DL-0.5] | ND, [DL-0.5] | ND, [DL-0.5] | ND, [DL-0.5] | ND, [DL-0.5] |
| 12 | Carbon Di-oxide (as $CO_2$), ppm | 350 | 354 | 356 | 350 | 360 | 345 | 325 | 345 | 324 |

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**Carbon Footprints Study**

There is large amount of Greenhouse gas emission takes places during road construction. Today Carbon footprint Reduction is one the main challenges faced by road construction industry. As saving of environment is our primary concern, it is very important to reduce carbon footprint in road construction without compromising on strength and durability. Lot of Research work have been done in improving the pavement design, construction and maintenance process and strategies but very less attention has been given in the field of reducing the carbon footprint in road construction.

The Calculation of Carbon Footprint was done using International Road Federation (IRF) CHANGER software.

CHANGER Software is developed by International Road Federation (IRF) for the calculation and modeling of Greenhouse Gas Emissions (GHG) from road construction projects.

The main objectives of the CHANGER are to achieve tangible, long term benefits for the global environment and to contribute proactively to the shaping of dynamic sustainable road development policies going forward. It is user friendly and fully compatible with Intergovernmental Panel on Climatic Change (IPCC) guidelines.

The goals of software are detailed environmental analysis of road projects, authoritative basis for comparative study analysis of various road- building techniques and materials and enable detailed estimation of GHG emissions specifically attributable to the road construction industry. CHANGER adopts a comprehensive "input-output" modeling approach. It comprises of two main modules

- Pre- construction module which includes Clearing and piling, cut export and fill import transport.
- Pavement module which includes on-site impacts, construction materials, materials transport and construction machines.

In CHANGER software GHG emissions generated throughout the road construction process are converted to carbon dioxide equivalents which are commonly expressed as "million metric tons of carbon dioxide equivalent (MMT$CO_2$ Eq)".

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Data related to usage of materials, machinery and fuel during various construction activities like clearing and piling, cut/fill transport, procuring, transporting, laying and compaction of various pavement layers during Road construction for both RBI Grade-81 method and conventional method are collected by Alchemist Touchnology Limited during site execution work. This construction site data forms an input for CHANGER software.

As RBI Grade-81 is not present in the list of material of CHANGER Software, carbon footprint during per tonne production of RBI Grade-81 is calculated separately. The calculation of carbon footprint per tonne of RBI Grade-81 is done by considering the following Aspects

- Greenhouse gas emission during production of various raw materials used in RBI Grade-81
- Greenhouse gas emission during Production of RBI Grade-81

*Table 11: Carbon Emission Comparison between different Stabilizers*

| **Soil Stabilizers** | **tCO2 per tonne of Stabilizer** |
|---|---|
| Lime | 2.04 |
| Cement | 1.06 |
| Hydraulic Road Binders | 0.44 |
| **RBI Grade-81** | **0.31** |
| Granulated Blast Furnace Slag | 0.13 |
| Fly Ash | 0.001 |

The detailed results of carbon footprint by both conventional and RBI Grade-81 methods of all the five tests stretches are given Annexure 10.1 - 10.4. The Summary of Carbon Footprint of both conventional and RBI Grade-81 methods for all the test stretches is shown in figure 10,11,12,13 and 14.

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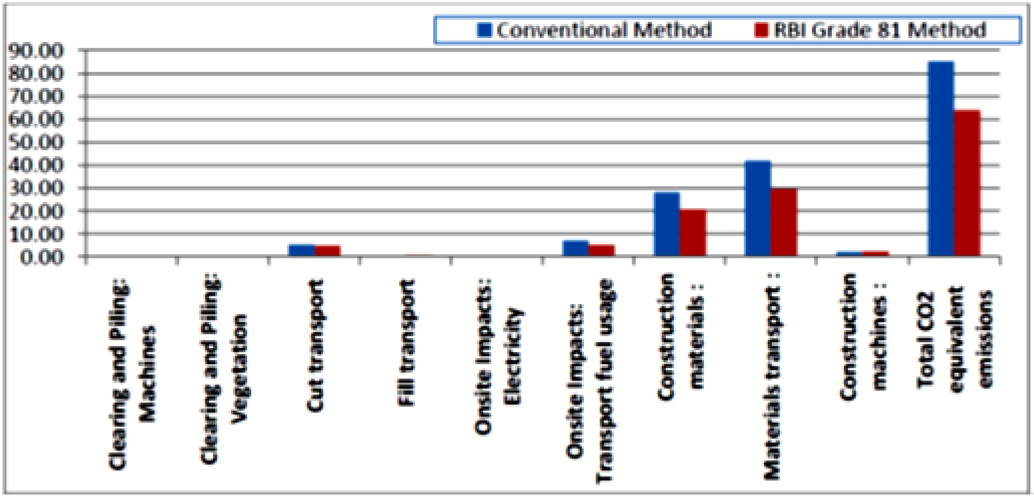


*Figure 10: Carbon Footprint – Km 46 Bus Bay, NH-206*

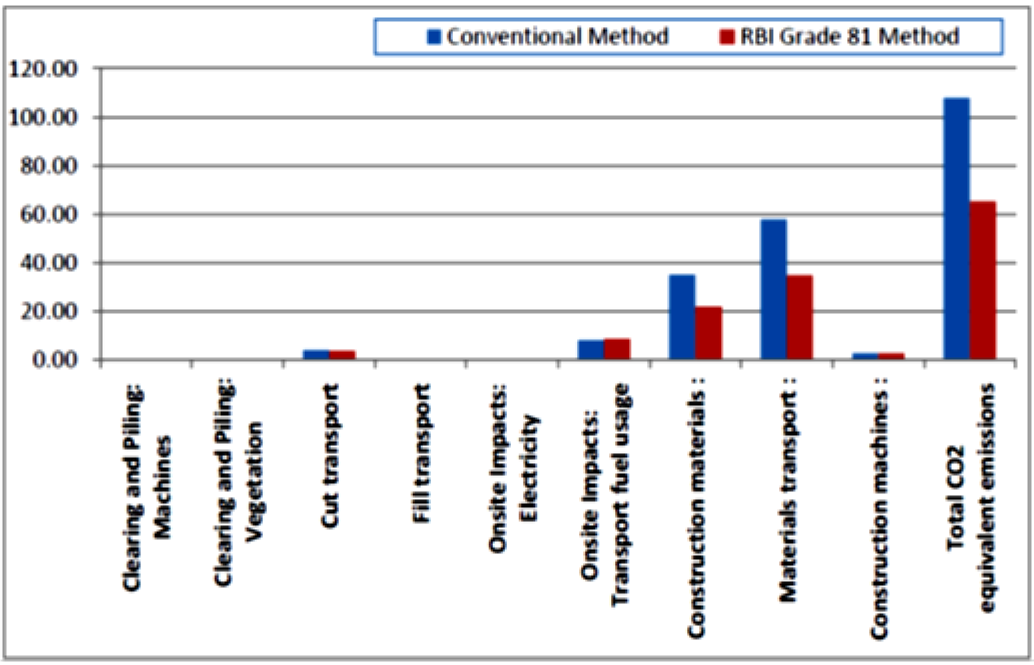


*Figure 11: Carbon Footprint – Km 49 Bus Bay, NH-206*

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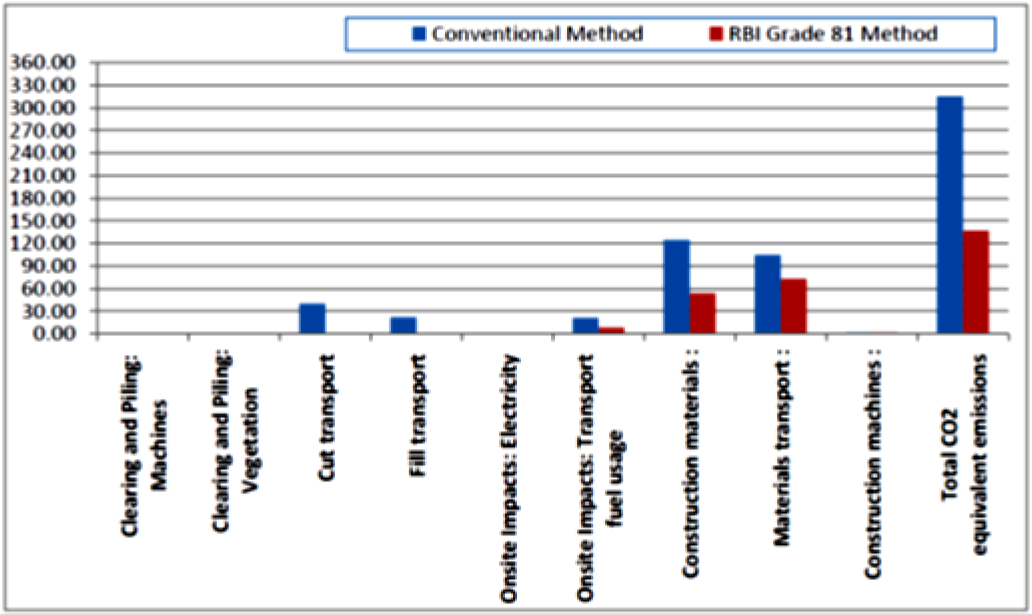


*Figure 12: Carbon Footprint – Cold Recycling, NH-206*

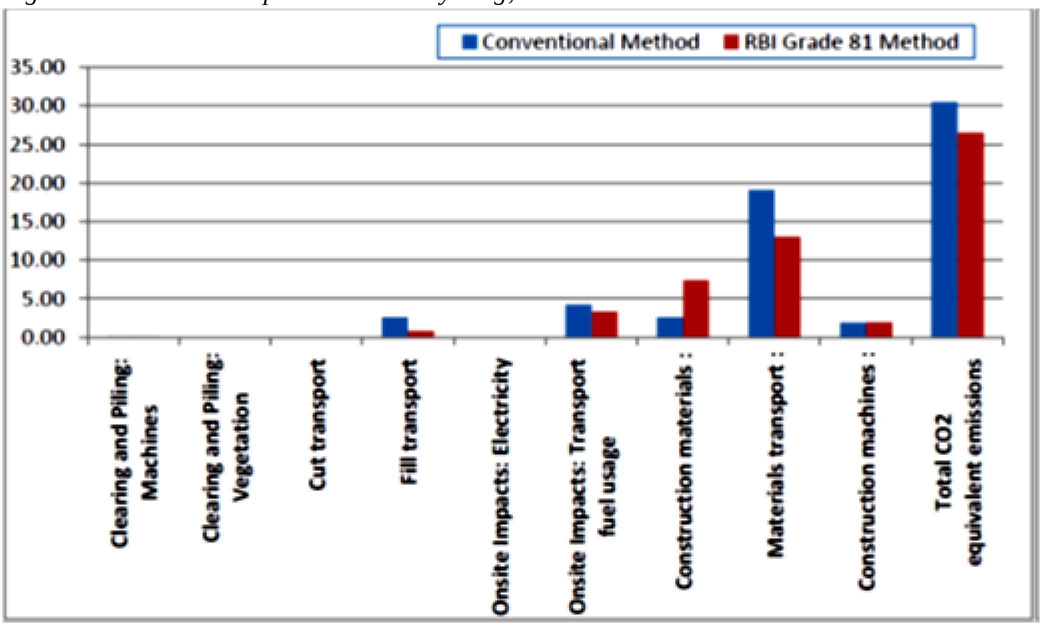


*Figure 13: Carbon Footprint – Forest Road*

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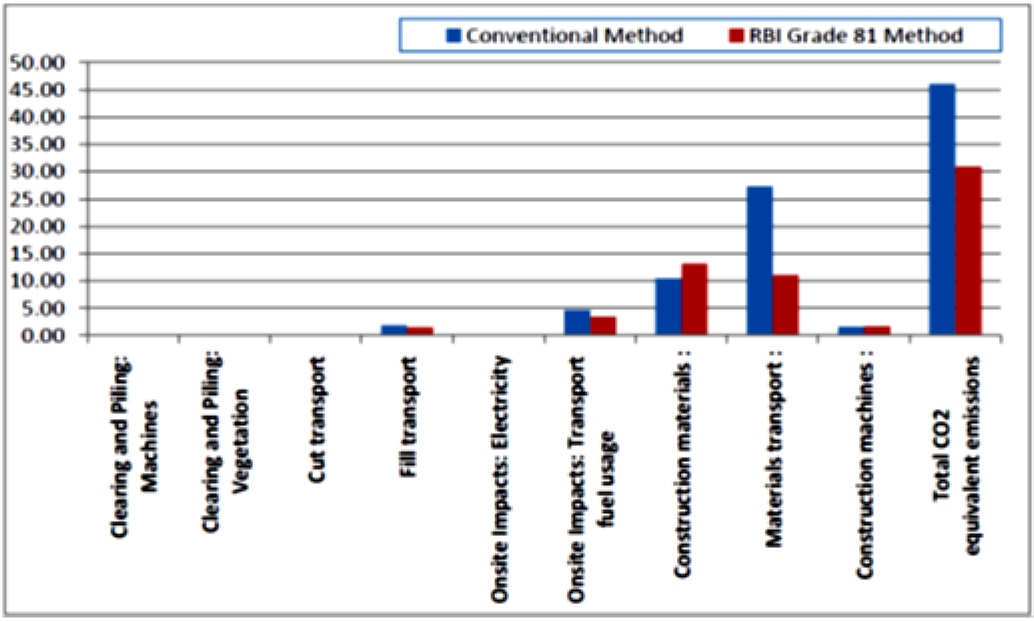


*Figure 14: Carbon Footprint – Rural Road*

**Environmental Benefits of New Technology:**

- It appears from the leaching studies that RBI Grade-81 has the affinity to bind the metals from the soil as the values in spiked soil plus RBI Grade-81 and non-spiked soil plus RBI Grade-81 are in close proximity.
- The affinity of RBI Grade-81 to bind the metals from the soil varies from metal to metal.
- There is no likelihood of contamination of ground water by leaching from the soil bound with either 2 or 4% of RBI Grade-81 as the metal levels were well within the allowable range.
- During construction of stabilized sub base and base layers the suspended particulate are lesser with better air quality as compared during the conventional base and sub base construction
- After construction also stabilized pavement shows better air quality than the conventional section.

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- Final Results of Total $CO_2$ equivalent emission for all the five road stretches for both the conventional and RBI Grade-81 method with percentage reduction are shown in figure 15.

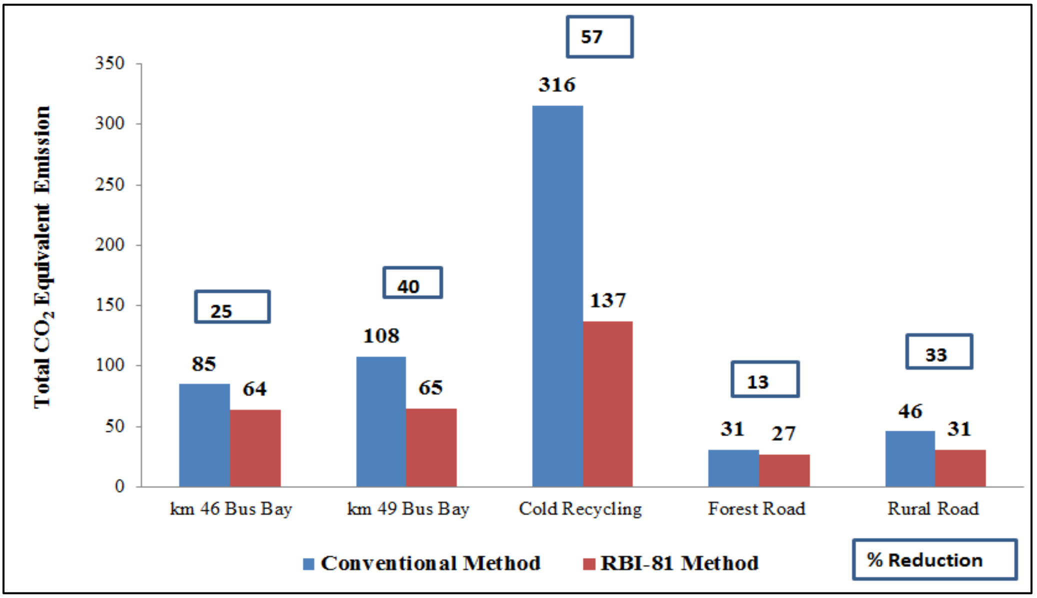


*Figure 15: Comparison of Carbon Emission*

- It can be concluded from the results of equivalent Tonne Carbon Dioxide ($tCO_2$) emission of various activities during construction of the test stretches that procurement of construction materials and material transport are the two activities that produce highest Greenhouse gas emission.
- From the results of Carbon Footprint during construction as shown in this report, it can be concluded that for national highway stretches, conventional method Greenhouse gas emission is huge for material transport and procurement of construction materials activities in comparison to RBI Grade-81. Whereas for forest road and rural road greenhouse gas emission is huge in conventional method in comparison to RBI Grade-81. The comparisons of these activities for all the five stretches are given in table 12.

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*Table 12: Comparison of Carbon Emission in Various Activities of Road Construction*

| Road | Construction Activity | Total $CO_2$ equivalent Emission | |
|---|---|---|---|
| | | Conventional Method | RBI Grade-81 Method |
| **NH 206 km 46 Bus Bay** | *Procuring Construction Material* | **28** | **21** |
| | *Material Transport* | **42** | **30** |
| **NH 206 km 49 Bus Bay** | *Procuring Construction Material* | **35** | **22** |
| | *Material Transport* | **58** | **35** |
| **Cold Recycling Stretch** | *Procuring Construction Material* | **125** | **54** |
| | *Material Transport* | **105** | **73** |
| **Forest Road Stretch** | *Procuring Construction Material* | **3** | **7** |
| | *Material Transport* | **19** | **13** |
| **Rural Road Stretch** | *Procuring Construction Material* | **10** | **13** |
| | *Material Transport* | **27** | **11** |

## DESIGN METHODOLOGY

Indian Road Congress (IRC) had published various codes of specifications for design of pavement for different category of roads. For highways, IRC: 37-2012 was recently published and does have guidelines for "Bituminous pavements with cemented base and cemented Sub base having 100 mm of aggregate interlayer for crack relief or with SAMI at the interface of base and the bituminous layer". The Interlayer is must for cemented layer, but with RBI Grade-81, the crack relief layer is not mandatory as justified by the Ground Penetrating Radar study on homogeneity of stabilized layers because inherent constituent materials of RBI Grade-81 prevent the

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formation of cracks due to shrinkage unlike that of cement. There are number of codes of specification referring to stabilization of pavement layers.

Considering, all the relevant codes of specifications and manuals a design manual specifically for the pavement with RBI Grade-81 is developed. The design philosophy is based on IRC: 37-2012 for highways and IRC: SP: 72-2007 for rural roads.

**TESTING MANUAL**

The main aim of these laboratory tests is to establish, firstly, the type and engineering properties of the natural material (Soil) which is to be treated with RBI Grade 81, for the necessary improvement thereof in order to meet the specified requirements for its intended usage and secondly to achieve, by treating the natural material (Soil) with RBI Grade 81, an acceptable strength gain or degree of hardness which will give an adequate acceptance in bearing strength (CBR) compressive strength (UCS) and durability. This will in turn prove the overall efficacy of the product.

Testing manual is developed considering all the testing guidelines referring to Bureau of Indian Standards (IS Codes), Indian Road Congress (IRC Codes) and other International Standards.

**CONSTRUCTION MANUAL**

This manual covers the stabilization of materials used in the construction of the roadbed, fill and pavement layers by the addition of RBI Grade 81 stabilizer. It includes the preparation of the base, application of stabilizer, compaction and curing of the stabilized layer. Stabilization with RBI Grade 81 stabilizer improves the engineering properties of substandard, readily available material, where such stabilizations is a better alternative to the procurement of materials complying with the relevant specifications, or where layers with substantial higher tensile strength are required to withstand the onslaught of the expected high increase in heavy traffic and environment. The success of the stabilization requires technical input and engineering and not merely equipment and powder. A good technique used

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successfully will guarantee a high degree of stabilization success even in extreme conditions.

Construction manual is developed considering all the specification and methodology provided by Ministry of Road Transport and Highways in "Specifications for Road and Bridge Works".

**CONCLUSIONS**

- Five types of road sections that include bus bay at km 47 and 50, Diversion for cold recycling section, Cold recycling section, Rural road and Forest road are successfully constructed with RBI Grade-81 technology and are performing well after 3 monsoons
- A total of 34.62% of fuel was saved using RBI Grade-81 technology when compared with conventional technology. At the same time the bitumen consumption was also reduced by 59.85%.
- Using the CHANGER Software the saving calculated for fuel and Carbon emission for project roads when compared with conventional section is 34.62% and 44.70% respectively.
- The field study done for suspended particles and air pollution done on NH-58, in the state of Uttarakhand, has shown results that clearly indicated that RBI Grade-81 is more environment friendly than conventional technology.
- The average CBR obtained across all the stabilized layer is 100% at 3% RBI grade-81 dosage, going up to 158% with 4% RBI Grade-81.
- The average UCS Value obtained is ranging from 5.6 MPa to 6.97 MPa, which is well above the minimum requirement of 4.5 MPa for stabilized base course as per IRC: 37-2012.
- The UCS results with varying moisture content for RBI Grade-81 stabilized layer showed very little variation, implying low susceptibility to water.
- The permeability results obtained in laboratory and field have indicated that the RBI Grade-81 layers are relatively impermeable, ensuring no leaching taking place.

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- The decrease in deflection values over three cycles using FWD shows, there is no cracking in the pavement and the modulus is also gradually improving.
- The comparative deflection study done on conventional and RBI Grade-81 section shows the results are in favor of RBI Grade-81 pavement.
- The deflection study done by CRRI and IRSM on 5 year old BBH Mines road supports the statement that "stabilized pavements are more durable" as the deflection values are in favor of RBI Grade-81 stabilized section even when the conventional section is strengthened during these 5 years.
- RBI-81 pavement technology has given following clear environment benefits over conventional methodology
    - Aggregate Saving = 84.35%
    - Bitumen Saving = 59.85%
    - Fuel Saving = 34.62%
    - Carbon Emission Saving = 44.70 %.
- By the toxicity and leaching studies, it is concluded that mixing of RBI Grade-81 with soil does not contribute to contamination of water. It can also effectively bind other hazardous material and use in road construction
- In addition to the above savings, the technology has also reduced the construction time by 50% and provided clear cost benefits over life cycle cost( based on current comparative deflection values )
- At an average of 19% of construction cost is saved in this project by RBI Grade-81 technology over Conventional technology. That means approx. 123 km length can be constructed by RBI Grade-81 within the cost of 100 km by conventional technology.
- At an average of 84.35% of aggregate quantity is saved in this project by RBI Grade-81 technology over Conventional technology. That means approx. 600 km length can be constructed by RBI Grade-81 within the quantity of aggregate required to construct 100 km by conventional technology.
- At an average of 59.85% of bitumen quantity is saved in this project by RBI Grade-81 technology over Conventional technology. That means approx. 240 km

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length can be constructed by RBI Grade-81 within the quantity of bitumen required to construct 100 km by conventional technology.

- At an average of 50% of construction time is saved in this project by RBI Grade-81 technology over Conventional technology. That means approx. 200 km length can be constructed by RBI Grade-81 within the time required to construct 100 km by conventional technology.
- By the strength and functional evaluation it can be observed that the RBI Grade-81 pavements are more durable and stronger than Conventional Pavements.
- The results obtained with RBI Grade-81 stabilized layers are satisfying the specified codal requirements used in various international practices.
- By RBI Grade-81 technology of road construction, construction cost, time, depleting natural material like good soil and aggregates can be saved with more stronger and durable pavements.
- It has been established and proven beyond doubt that use of RBI Grade-81 technology will result in conservation of natural resources use marginal material and provide more durable roads for Indian conditions at a lower cost.
- An incentive to build green roads should be given to promote environment friendly and sustainable roads

**RECOMMENDATIONS and WAY FOREWORD**

The conclusion of the project clearly shows that the roads constructed using RBI Grade-81 have performed well and have taken the traffic. It is our view that further research and study needs to be done in the following areas.

- To further improve the performance of stabilized pavement instead of using SDBC and PMC as wearing courses there is a need to look at alternate bitumen surfacing like Surface dressing or Chip and Spray or Slurry seal over stabilized base course.
- Now that RBI Grade-81 has been successfully used in the base course of different types of roads a study should be carried out for strengthening sub grades and use of all in situ soil so that borrow pit material can be eliminated and poor and marginal soil can be used successfully.

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- Since studies till now have shown that RBI Grade-81 stabilized layers are not cracking. Separate fatigue equations and Modulus of Rupture for RBI Grade-81 to be developed to study the difference between cement.
- Specific design charts to be developed based on the results of this study and the separate fatigue equations
- Cores to be extracted to examine the performance of the stabilized layer.
- Separate code to be developed by IRC for different types of roads based on the results of this study and other available data on RBI Grade-81
- Separate code to be developed by IRC on full depth reclamation of existing distressed pavements based on the success of this study
- Ministry of Environment and Forests and Ministry of Road Transport and Highways to provide incentives for environment friendly green roads.
- Now that the study has established the performance of the roads constructed using less aggregate and bitumen Ministry of Environment and Forests and Ministry of Road Transport and Highways to use suitable guidelines to the road construction industry to commence reduction in the use of aggregates and bitumen from all new roads which are to be constructed.
- To benefit from the results of this study it is recommended that the Ministry of Environment and Forests and Ministry of Road Transport and Highways move forward to allocate a percentage of roads in each category to be constructed using this technology.
- The successful use of only soil as a base course without aggregates should be guideline for areas where aggregates cannot be found or where expensive and guidelines issued to adopt the new technology.
- Ministry of Environment and Forests through its independent and direct study of the material through the Indian Institute of Toxicology Research Lucknow has revealed that even when toxic material is added to the soil and stabilized with RBI Grade-81 prevents leaching of harmful substance. The benefit of this result should be used to utilize other waste material in road construction with RBI Grade-81 for binding so that leaching of the bitumen from top can also stopped through the structure.

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- The suitability of using waste material like demolition waste, all types of slag, marble, granite, stone dust, fly ash, etc. to be stabilized with this technology along with soil and used in road construction.
- The characteristics of im-permeability and non- leaching of this technology should be taken benefit of by using in roads in high rainfall areas and also riverbanks which have to be protected from sewage and other pollutants leaching on to the rivers
- As the study has established that there can be reduction in construction time and also in the construction cost both the Ministry of Environment and Forests and the Ministry of Road Transport and Highways should ensure that this benefit is derived from all future road construction projects

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## PROJECT TEAM

Ministry of Environment and Forests appointed Alchemist Touchnology Limited, New Delhi for the implementation of all the test sections using RBI Grade-81. Under the guidance of Maj. Gen. Anil Oberoi, Vice Chairman, Alchemist group, following team was deputed for the work.

| Sr. No. | Name | Project's Designation |
|---|---|---|
| 1. | Dr. Sunil Bose | Pavement Expert |
| 2. | Mr. Mohit Verma | Project In-charge |
| 3. | Mr. Jitendra Diwan | Finance Controller |
| 4. | Mr. Vikas Verma | Documentation Engineer |
| 5. | Mr. Lalit Kushwah | Material, QS and Billing Engineer |
| 6. | Mr. Shiv Pratap Singh | Engineer In-Charge<br>Rural Road and Bus Bay Stretch |
| 7. | Mr. Lalit Kushwah | Engineer In-Charge<br>Strengthening Stretch |
| 8. | Mr. Nirdesh Kushwah | Engineer In-Charge<br>Unpaved Forest Road |
| 9. | Mr. Sudhir Dixit | Lab. and Field Testing In-charge |
| 10. | Mr. Deepti Ranajan | Lab Assistant |
| 11. | Mr. Vinod Patel | Lab Helper |
| 12. | Mr. Arvind Dixit | Lab Helper |
| 13. | Mr. Hari Shetty | Local Administration |
| 14. | Mr. Vasant Shetty | Local Administration |
| 15. | Mr. Padmanabh | Local Administration |
| 16. | Mr. Anukul Saxena | Independent Consultant |

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## PROJECT MONITORING COMMITTEE

Ministry of Environment, Forests and Climate Change constituted a Project Monitoring Committee (PMC) to monitor the project. Prof. A. Veeraragavan, Transportation Engineering Division, Department of Civil Engineering, Indian Institute of Technology Madras, Chennai was appointed as the Chairman of the PMC. The Committee comprising of various experts to represent from Environment, Road Sector, Central Pollution Control Board, Toxicology Research Institute, Highways sector, MoRTH, IRC and an Independent Project Investigator. As per this, following Committee was constituted:-

| Sr. No. | Name | Organization | Designation |
|---|---|---|---|
| 1. | Prof. A. Veeraragavan | Professor, IIT Madras, Chennai | Chairman |
| 2. | Prof. L. Kannan | Former VC, Tiruvalluvar University | Member |
| 3. | Prof. B.B. Pandey | Professor, IIT, Khargpur | Member |
| 4. | Mr. K. Sitaram Anjanyelu | Head, Pavement Evaluation, CRRI | Member |
| 5. | Chief Engineer(SandR)/Road | Ministry of Road Transport and Highways | Member |
| 6. | Secretary General/Nominee | Indian Roads Congress, New Delhi | Member |
| 7. | Member Secretary/Nominee | Central Pollution Control Board, New Delhi | Member |
| 8. | Director/Nominee | Indian Toxicology Research Institute, Lucknow. | Member |
| 9. | Mr. Mithra Dewars | Independent Consultant | Project Investigator |
| 10. | Dr. (Ms.) Manju Raina | Director (SF), MoEF&CC | Member Secretary |

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The terms of reference of PMC are as follows

1. Evaluate the environmental benefits like reduction in aggregate quantities, reduction in fuel consumption, emission in greenhouse gases, estimation of suspended particulate matters and air pollution in totality in comparison to the existing technology.
2. Toxicity study of the RBI Grade-81 technology.
3. Strength of soils stabilized with RBI Grade-81, viz., California Bearing Ratio, Unconfined Compressive Strength etc.
4. Moisture sensitivity studies of the soils stabilized with nature soil stabilizer RBI Grade-81.
5. Studies on impermeability to water and prevent leaching of harmful substances into the soil.
6. Comparison of aggregate consumption for typical roads constructed by conventional method and with RBI Grade-81 stabilized layers.
7. Comparison of pavement thickness designs with and without RBI Grade-81 technology with best international practices.
8. Cost benefits analysis of the RBI Grade-81 technology.
9. Structural evaluation of the pavement sections constructed with RBI Grade-81 using Falling Weight Deflectometer and estimation of remaining service life.
10. Functional performance of the pavement sections constructed with RBI Grade-81 stabilizer in terms of cracking, patching, rutting, roughness etc.
11. Evaluation of the pavement sections constructed with RBI Grade-81 stabilizer, using Ground Penetration Radar equipment.
12. Life cycle assessment of pavement sections constructed with RBI Grade-81 technology and comparison with conventional method of pavement design as per IRC.

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*Project Monitoring Committee Members interacting with local villagers about the performance of rural road*

*Project Monitoring Committee Members at Unpaved Forest Section constructed with RBI Grade -81*

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*Final Project Monitoring Committee Meeting at Bengaluru*


Strengthening of Existing Highway Using Reclaimed Material from Deteriorated Pavement Layers with RBI Grade-81 Technology, Location Km 9.30, NH-206, Tumkur, Karnataka, India

# RBI Grade-81

*Pavement Material & A Natural Soil Stabilizer*