STRENGTHENING OF SUBGRADE AND SUB-BASE OF BITUMINOUS PAVEMENT USING RBI GRADE 81

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DECLARATION

I, Abhishek Sehgal, hereby declare that this thesis entitled **"STRENGTHENING OF SUBGRADE AND SUB-BASE OF BITUMINOUS PAVEMENT USING RBI GRADE 81"** is an authentic record of my study carried out as requirements for the award of degree of **Master of Engineering** in **Civil Infrastructure Engineering** in the Civil Engineering Department, Thapar University, Patiala under the supervision of **Mr. Rajesh Pathak, Associate Professor and Mr. Tanuj Chopra, Assistant Professor,** Department of Civil Engineering, Thapar University, Patiala during July 2014 to July 2016 . This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

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CERTIFICATE

This is to certify that above statement made by the student concerned is correct and true to the best of my knowledge and belief.

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ABSTRACT

The accumulation of a variety of compounds such as lime, cement etc., into soils has been used for centuries all through the world. The present system of stabilization is less than 40 years old, but significant advances have been made in construction events during these past four decades. The new technique of stabilization which was improved as a result of the efforts of many engineers, contractors, and researchers.RBI grade 81 is a result of these efforts. RBI Grade 81(Road Building International Grade 81) is an exclusive and resourceful product that was developed for the stabilization of a broad range of soils in a proficient, least- cost manner.

The objective of this work is to determine the effectiveness of RBI Grade 81 for improvement in engineering properties of medium plasticity clayey soil.RBI Grade 81 was treated with collected soil sample at different dosages, Various samples have been made by mixing soil with 0% RBI grade 81; 2% RBI grade 81; 4% RBI grade 81; 6% RBI grade 81 and 8% RBI grade 81, method of soil replacement is opted for the preparation of samples. After studying the properties of soil sample light compaction test and California bearing ratio test was conducted under soaked and unsoaked conditions, Soaked CBR test results signify that the stabilizer can be used excellently with cohesive soils. Subsequently, unconfined compression test was done to determine the strength of clayey sample, the treated soil samples were cured for different periods 1 day, 7 day and ranging up to 28 days. From the study it was found that Soil can be stabilized with RBI grade 81 and then can be used in Sub grade and also as Sub base layer. The whole pavement can be constructed by using RBI grade 81 thus offering great cost-effectiveness.

Further design of pavement and cost analysis have been done from the results obtained from various test conducted. It was concluded that RBI grade 81 is very effective stabilizer and has great impact on weaker strata and good for high volume roads.

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LIST OF CONVERSIONS USED

Conversion	*Purpose of conversion*
1 Kg/cm^2 = 0.0980666 MPa	UCS test
1 Kg/cm^2=98.066 kPa	UCS test
1 kN/mm=101.97 kgf/mm	CBR test
1g/cm^3=9.8067 kN/m^3	Compaction TEST

ABBREVIATIONS

All symbols are explained where they occur first. Some of the symbols are,

CBR	California Bearing Ratio
CT/CTB	Cement Treated Base-Includes All Types of Cement/Cement Stabilized Bases
DBM	Dense Bitumen Macadam
E	Elastic Modulus of Cementitious Layer
GB	Granular Base
GSB	Granular Sub Base
IRC	Indian Road Congress
M_R	Resilient Modulus
msa	Million Standard Axle
MDD	Maximum Dry Density
N_f	Commulative No. of Repetitions for Fatigue Failure
N_R	Commulative No. of Repetitions for Rutting Failure
RBI 81	Road building international 81
UCS	Unconfined Compressive Strength
WBM	Wet Bound Macadam
WMM	Wet Mix Macadam
epZ	Vertical Subgrade Strain
epT	Horizontal tensile strain and stress
epR	Strain in Cementitious Layer
μ	Poisson's Ratio

CHAPTER 1

INTRODUCTION

In developing countries like India the biggest challenge is to provide a complete network of road system in the limited finances available by the conventional methods. Therefore there is a need to route to one of the suitable methods of low cost road construction to meet the growing needs of the road traffic. The construction cost can be considerably decreased by selecting local materials including local soils for the construction of the lower layers of the pavement such as the sub-base course. The uses of stabilizers are economical for road construction, upgrading of road, maintenance of unpaved roads, rehabilitation of failed roads, construction of roads, parking areas, air strips, and mass fills. Since the outset of the industrial revolution the greatest challenge before the processing and manufacturing industries is the disposal of the residual waste products. Waste products which are generally toxic, ignitable, corrosive or reactive pose serious health and environmental consequences. Thus disposal of industrial wastes is a major issue of the present generation. This measure issue requires an effective, economic and environment friend method to combat the disposal of the residual industrial waste products. One of the common and feasible ways to utilize these waste products is to go for construction of roads, highways and embankments. If these materials can be suitably utilized in construction of roads, highways and embankments then the pollution problem caused by the industrial wastes can be greatly reduced. Huge amount of soil is used in the construction of roads and highways but sufficient amount of soil of required quality is not available easily. For that reason large amount of trees are being cut which cause deforestation, soil erosion and loss of fertile soil which hampers in the agricultural productivity. Also, cost of extracting good quality of natural material is increasing. These industrial wastes which are used as a substitute for natural soil in the construction not only solve the problems of disposal and environmental pollution but also help to preserve the natural soil. The challenge for the present and future of road construction is the appropriate implementation of waste or industrial by-products as constructing materials. This will provide a number of significant benefits to the constructing industry as well as to the country as a whole by conservation of natural resources, by reduction of volume of waste to landfills, by lowering the cost of construction materials, by lowering waste disposal costs, and the last but not the least by promoting a “clean and green" image.

Soils could be stabilized by mechanical, chemical, electrical, or thermal means. Chemical stabilization includes the addition of RBI Grade 81, cement, lime, asphalt, chemical compounds, or a combination of those. RBI Grade 81(Road Building International Grade 81) is a unique and innovative product that was developed for the stabilization of a wide spectrum of soils in an efficient, least- cost manner. RBI Grade 81 is an environmentally friendly, inorganic, hydration activated powder based stabilizer that reacts with soil particles to create layers that are interconnected through a complex inter particle framework. RBI Grade 81 is a combination of naturally occurring compounds. Road can be opened to traffic within 24 hours of final compaction. It provides a dust free surface. If the nature of the soil changes for different depths, most of the methods for stabilization cannot be used. RBI Grade 81 has a wide range of response spectrum. Response spectrum is the range of soils for which a particular stabilizer can be used.

1.1 Soil Stabilization

Soil stabilization is the alteration of one or more soil properties to create an improved soil material possessing the desired engineering properties. There are three purposes for soil stabilization. These include increasing the shear strength of an existing ground condition to enhance its load-bearing capacity, achieve a desired improved permeability and enhance the durability of the soil to resistance to the process of weathering, and traffic usage among others. Some of the soil stabilization methods that are currently been used for improvement of highway sub-grade and sub-base can be grouped into three broad.

Categories

1) Mechanical stabilization
2) Use of geosynthetics for soil stabilization
3) Chemical admixture stabilization

Since the early 1940s, stabilization of soil with admixtures, such as cement, lime, bitumen, fly ash, etc. have been successfully investigated and used extensively for road and airport foundations in many countries. Addition of inorganic chemical stabilizers like cement and lime has two-fold effect on soil namely; acceleration of flocculation and promotion of chemical bonding. Due to flocculation, the clay particles are electrically attracted and aggregated with each other. This results in an increase in the effective size of the clay aggregations. The main advantages of liquid chemical stabilization is that only a small volume of stabilizing agent is generally required and the cost of stabilization is lower than that of other methods of stabilization. Chemical solutions are another of the major types of soil stabilization. All of these techniques rely on adding an additional material to the soil that will physically interact with it and change its properties. There are a number of different types of soil stabilization that rely on chemical additives of one sort or another; you will frequently encounter compounds that utilize cement, lime, fly ash, or kiln dust. Most of the reactions sought are either Cementitious or pozzolanic in nature, depending on the nature of the soil present at the particular site you are investigating.

The transformation of soil index properties by adding chemicals such as cement, fly ash, lime, or a combination of these, often alters the physical and chemical properties of the soil including the cementation of the soil particles. There are the two primary mechanisms by which chemicals alter the soil into a stable subgrade:

1. Increase in particle size by cementation, internal friction among the agglomerates, greater shear strength, reduction in the plasticity index, and reduced shrink/swell potential.
2. Absorption and chemical binding of moisture that will facilitate compaction

1.2 Stabilization with RBI Grade 81

RBI GRADE-81 is a cementitious material suitable for stabilization of every type of soil, base and subbase layers confirming to the required gradation as per IRC specifications. Stabilization with RBI GRADE-81 can be carried out for pavement layer, although its use in wearing course is restricted to special cases and on approval of technology suppliers.

1.3 Mechanism of RBI Grade 81

The use of RBI GRADE-81 in road projects is extremely effective method of converting poor quality soil into a strong and relatively water-resistant layer. It permits the construction of pavement layers, embankments and reinforced earth structures in areas where they were not previously workable, while saving significant construction material and time.

RBI 81 is calcium driven, inorganic soil additive patented worldwide. Its specific formulation allows stabilization of a wide variety of materials without compromising the value of the result.

The main mechanism that is used to relate RBI 81 is a sequence of inorganic hydration activated powders. It is composed of a particular type of cement, a lime, numerous pozzolonas, rate governing additives, and a special polypropylene fiber. The precise formation allows the uniqueness of the components to contribute to the reaction process, but also act holistically contributing of the stabilization process.

1.4 Benefits of RBI Grade 81

A. Engineering

RBI grade 81 Increases the California Bearing Ratio (CBR) manifolds and Unconfined Compressive Strength (UCS) considerably. It also Increases Modulus of Elasticity values, which results in reduction of pavement crust and also Reduces Plasticity Index (PI) value and Free Swelling Index (FSI) value.

B. General Benefits of RBI Grade 81

RBI grade 81 can strengthen the existing soil by 12 to 20 times the initial strength; it helps in replacing the conventional aggregate layers with soil stabilized layers, thus saving aggregate. It also reduces the quantity of bitumen in road construction. Since it reengineers any kind of soil and stabilizes it with increased strength; it eliminates removal and carriage of in-situ soil and replacing it with better soil suitable for construction. By using in-situ soil, it reduces the need to transport good soil & aggregate by about 40%-60%, thus reducing the carbon emission from the trucks. The treated areas are comparatively impermeable by water, thus preventing damage to the road foundation. Due to the reduced construction time, air pollution by heavy suspended particles is reduced considerably. Durability is increased thus the need for continuous maintenance is reduced. RBI Grade-81 technology is very simple and does not require skilled labor. RBI Grade-81 can also be used for cold recycling of existing pavement (flexible or rigid) layers, thus saving natural resources, as 90% of road material is being reused.

1.5 History of RBI Grade 81

Table 1.1: Timeline and material history of RBI Grade 81

Timeline	***Material History***
1999-2000	• RBI grade 81 goes through research and development, irreversibility and test for performance-over -time
2000-2004	• Holding company RBI marketing(Netherland) B.V Formalized and launches international patent on every content • Patent application went completely uncontested and approved as a" unique and novel concept"
2003-2004	• RBI marketing (Netherland) B.V sells its patent right to the technology in America, Africa, Australia to anyway solutions (www.anywaysolutions.com), who achieved a no. of key accolades in very short space of time, including • The approval of the product to the United Nations Development Program 'UNDP' • Approval of product by International Labour Organization 'ILO' • The PRIX D'excellence award in Africa 2007
2005-2006	• RBI marketing (Netherland) B.V licenses readers in United Kingdom, a division of Langley holding PLC ,a international engineering group, rated by HSBC as one of the UK top 250 company to produce RBI 81 • European investment bank confirms co-operation for implementation of RBI 81 In infrastructure projects
2008-2010	• RBI targets INDIA as the biggest Asian market, entry point given the regional potential and scope for use • Government 5 year budget plan of US 1trilllion for repair of existing infrastructure and new road projects • The technology is currently being manufactured under ISO:9001 • Repeatedly used by Indian army • First specification in government tender of Andhra Pardesh (2009)

1.6 RBI Grade 81: Next generation of soil stabilizing technology

Offer benefits over all methods of road construction which are limited in field use

- Conventional products are limited in applicability, highly expensive and costly
- RBI Grade 81 can be applied to all type of soils

Table 1.2: Comparison study of RBI Grade 81 with lime, cement and bitumen over different parameters

Type	***Cement***	***Lime***	***Bitumen***	***RBI Grade 81***
Used in following type of soil	Fine sand coarse sand	Fine clay coarse clay fine silt	Fine sand coarse sand	All soil types
Allows for use of in-situ soils	Rare: in situ soil needs to be replaced	Rare: in situ soil needs to be replaced	Yes: no need to replace in-situ soil	Yes: no need to replace in-situ soil
Exchange of soil required	Yes-High Cost	Yes-High Cost	No	No
Climate and environment impact	Negative	Negative	Negative	Offer environment and social benefit
Does Temperature Effect Stabilization	Yes	Yes	Yes	No
Required maintained over life of road	High	High	High	None

1.7 Benefits of Technology: Environment burden reduction

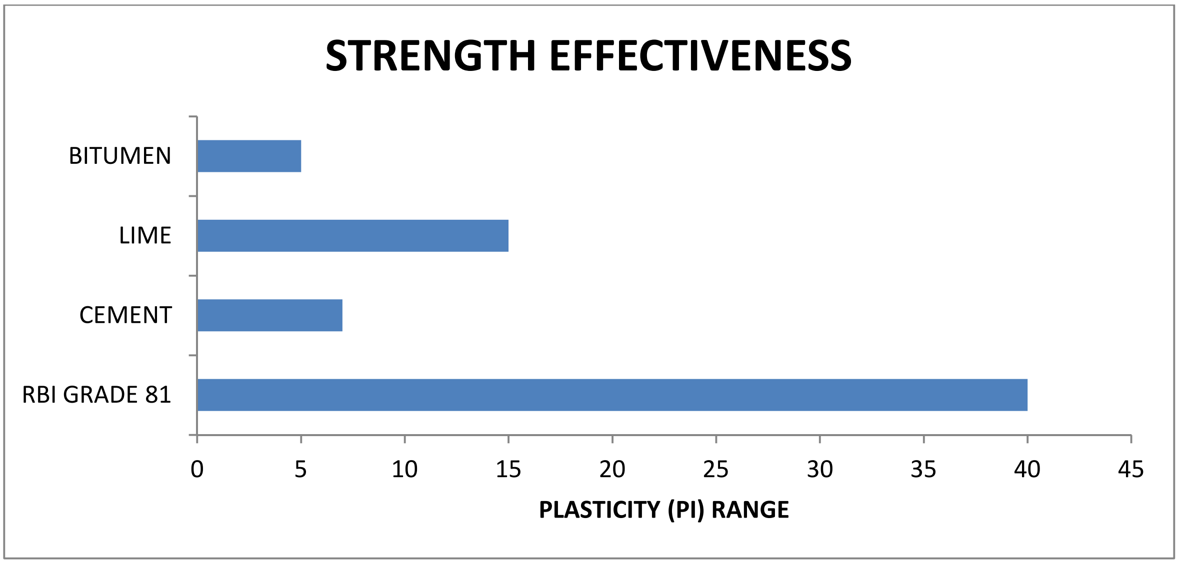
Environments benefits attributable to the use of RBI Grade 81

- The environment and social benefits of using RBI 81 are significant
- RBI Grade 81 is certified under BS EN ISO 9001:2000

Table 1.3: Benefit of RBI Grade 81 in different phases of construction

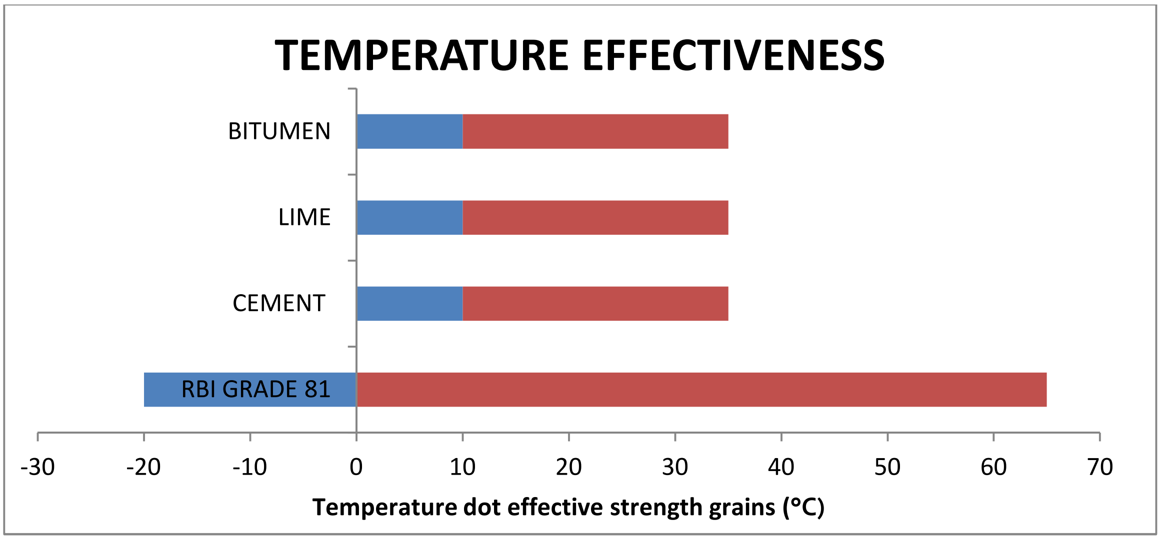
Construction Stage	***Specific Saving***
Pre-Construction Phase	• RBI grade 81 facilitates the use of in-situ material, avoiding the conventional need for sourcing quarry material • Reduction in raw material requirements in terms of stabilization material ,labor and construction time • No requirement for prospecting and the creation of new burrow pits
Construction Phase	• Reduction in requirement for non-renewable in energy consumptions and soil materials • Minimizing the energy consumption in construction phase • Waste material from steel works and coal fired power plants component of RBI grade 81 • Complete elimination of waste dumping to landfill, RBI grade 81 facilitates the use of recycled waste material • Allows for the recycling of asphalt, stabilizing the sub layer of soil
Use in Road	• Eliminates leaching of bitumen and harmful chemicals due to integrity of sub-layer with RBI 81 • Prevention of soil erosion • Minimizing the dustiness of gravel roads avoiding the contamination of vegetation of crops

1.8 RBI Grade 81: Superior performance on various measures



Graph 1.1: Comparison study of RBI Grade 81 with lime, cement and bitumen on the basis of strength effectiveness

- From the graph 1.1 we conclude that a superior strength gain achieved by using RBI Grade 81 and it improves the engineering properties of soil.



Graph 1.2: Comparison study of RBI Grade 81 with lime, cement and bitumen on the basis of temperature effectiveness

- From the graph 1.2 we conclude that RBI Grade 81 offers versatility across temperature ranges.

1.9 OUTLINE OF THESIS:

The thesis has been divided into six chapters:

- I st chapter is about the general introduction of RBI Grade 81 and its benefits.
- 2nd chapter is the literature review of the research work conducted with the use of RBI Grade 81 for improving the strength of subgrade soil.
- 3rd chapter deals with the experimental program wherein all test procedures are explained in detail.
- 4th chapter deals with the results and discussions where findings of experimental programmes are discussed.
- 5th chapter includes the methodology and design of flexible pavement using RBI Grade 81.
- 6th chapter consists of conclusion of the dissertation

CHAPTER- 02
LITERATURE REVIEW

2.1 Literature Review on Road Building International 81(RBI Grade 81):

B. M. Patil, K. A. Patil (2013) initiate that the geotechnical properties of clayey soil are improved significantly, if pond ash added with RBI Grade 81. The geotechnical properties like Maximum Dry Density, Optimum Moisture Content, Unconfined Compressive Strength, CBR value are tested in the laboratory for different mixes of soil, pond ash and RBI Grade 81 for different proportions. The optimum mix suggested for subgrade is soil: pond ash: RBI Grade 81 in magnitude of 76:20:4The soaked CBR value of subgrade clayey soil and grade-III material enhanced by adding up of pond ash and RBI Grade 81and therefore it is likely to decrease the thickness of road. The best possible mixed obtained for subgrade soil is 76:20:04 and for base course 77:20:03.

Table 2.1: Effect of RBI Grade 81 on base course grade-III material

S.No	*proportion*	*% soaked CBR value*
1	Untreated GRADE -III	34.71
2	Grade – III + 3% RBI Grade 81	81.32
3	Grade – III + 4% RBI Grade 81	93.85

The soaked CBR value of grade-III material treat amid 4% RBI Grade 81 is improved by 170.38%, as compare to untreated grade-III material. The RBI Grade 81 help to bind the complete grade-III materials collectively and it help to enhance the CBR value. The geotechnical properties of clayey soil improve extensively due to addition of RBI Grade 81

Table 2.2: Effect of RBI Grade 81 on OMC and MDD of soil

Soil mix	*OMC (%)*	*MDD (g/cc)*
Soil	25.80	*1.45*
Soil + 2% RBI	*26.16*	*1.47*
Soil + 4% RBI	*26.67*	*1.48*

B.M.Patil and K.A.Patil (2013) found that the stabilizer like RBI Grade 81 is used to improve the properties of subgrade soil. According to the study the cost of construction of road increases, if only RBI Grade 81 is used as a stabilizer. The CBR value of subgrade soil can be improved by using moorum with RBI Grade 81 and cost of construction can be reduced to certain extent. From CBR test, it is found that the soaked CBR value of soil is improved by 476.56% i.e. 2.56% to 14.76% by stabilizing soil with 20% moorum and 4% RBI Grade 81. The various mixes of soil: moorum: RBI Grade 81 for the different proportions were tested for maximum dry density (MDD), optimum moisture content (OMC) and soaked CBR value.

Table 2.3: Effect of RBI Grade 81 on OMC and MDD of soil

Soil mix	*OMC (%)*	*MDD (g/cc)*	*Soaked CBR value*
Soil	25.80	*1.43*	*2.56*
Soil + 2% RBI	*26.16*	*1.45*	*4.89*
Soil + 4% RBI	*26.67*	*1.46*	*8.79*

***B. M. Patil and K. A. Patil (2013*)** deal with improvement of swelling characteristics of clayey soil by adding industrial waste and RBI Grade 81. The construction of road in clayey soil is challenging due to its more swelling and more shrinkage characteristics.

To prevail over this problem there are two solutions one is substitute the clayey soil by good quality granular material. The second is stabilizing the subgrade clayey soil by means of various industrial wastes. The swelling and shrinkage characteristics of clayey soil are considerably improved if it treated with industrial wastes and RBI Grade 81.

The important outcome of the study was that these industrialized wastes in construction of roads reduces pollution of environment and solves the trouble of dumping of these wastes up to a assured amount.

Tejinder Singh and Navjot Riar (2013) studied that Soil can be stabilized with RBI grade 81 and then can be used in Sub grade and also as Sub base and base Layers. The entire Pavement can be constructed by means of RBI grade 81 thus reducing energy consumed and insertion of unbound granular material (WBM/WMM) without compromising on Strength and durability. Various samples have been made by captivating soil with 0% RBI Grade-81 content; 2% RBI Grade-81 content; 4% RBI Grade-81 content; 6% RBI Grade-81 content; 8% RBI Grade-81. The CBR sample is prepared by 7 days curing and 4 days soaked period. The evaluation of the strength results with or without RBI Grade 81 has been done. It has been found that RBI Grade 81 is a exclusive and landmark material which results in cutback the additional cost of the pavement.

Table 2.4: Effect of RBI Grade 81 on OMC and MDD of soil

Soil mix	*OMC (%)*	*MDD (g/cc)*
Soil	9.4	*1.93*
Soil + 2% RBI	*8.95*	*1.92*
Soil + 4% RBI	*9.67*	*1.90*
Soil + 6% RBI	*11*	*1.88*
Soil + 8% RBI	*12.05*	*1.87*

OMC increased and MDD decreased with addition of RBI Grade 81. MDD is decreasing with addition of RBI Grade 81 but there is increase in soaked CBR value with increased the addition of RBI Grade 81.

K.V. Madurwar, P.P. Dahale, and A.N.Burile (2013) transformed engineering properties of black cotton soils from Nagpur region, Maharashtra, India by using RBI Grade 81 and sodium silicate. Atterbergs limit, light Compaction, California Bearing Ratio, Unconfined Compressive Strength tests were carried out on the samples of soil and soil with stabilizers. RBI Grade 81 added to the soil in dry state in percentage (by weight) varying from 2% to 6% Initially UCS and CBR (SOAKED) of stabilized soils using RBI 81 increased tend to improve properties of soft soil

There is decrease in MDD values and increase in OMC values, results from work has been shown in Table below.

Table 2.5: Test results with RBI 81

S.No	*Particulars*	*Soil*	*Soil + 2% RBI 81*	*Soil + 4% RBI 81*	*Soil + 6% RBI 81*
1	Optimum Moisture Content (O.M.C.) (%)	20	24.25	25.09	26.40
2	Maximum Dry Density (MDD) (g/cc)	1.63	1.575	1.565	1.563
3	California Bearing Ratio (C.B.R.) (%)-7days	2.33	8.03	16.24	19.76
4	Unconfined Compressive Strength (U.C.S.) (Kg/cm²)-7 days	2.69	2.97	3.96	4.73

Dr. R. M. Damgir, Ahmed. Naseem .A .K and S. L. Hake. (2014) initiate that Liquid limit, plastic Limit, Plasticity Index, OMC, MDD, CBR improved within increase with the blend of fly ash and RBI Grade 81. From cost-effective analysis it was found that fly ash up to 30 % and 4% RBI Grade 81 consumption can be used in strengthening of the sub grade of Black cotton soil in flexible pavements to reduce the Cost of Construction.

Lekha B.M. And A.U. Ravi Shankar (2014) studied the enhancement in engineering properties of Black Cotton soil. The composed soil samples were treated with RBI 81 in a blend of ratio. Consequently, the treated soil samples were cured for altered period ranging from four hours to twenty eight days. The engineering properties obtained for altered mix Proportions of soil and the stabilizer are studied. The results of UCS, CBR obtained for altered mix proportions of soil and stabilizer, for diverse curing periods under soaked and unsoaked conditions have been studied and discussed. Tests were also conducted to establish chemical composition of untreated and treated soils to understand the mechanism of stabilization. Soaked CBR test results indicate that the stabilizer used works well with cohesive soils (such as BC soils).

From the results of CBR test, it is marked that BC soil treated with 6% stabilizer offers fine improvement .There is decrease in MDD values and increase in OMC values, results from work has been shown in Table below.

Table 2.6 OMC, MDD AND CBR test results with RBI 81

Soil mix	*OMC (%)*	*MDD (kN/m³)*	*CBR (%)*
Soil	17.46	*20*	*0.3*
Soil + 2% RBI	*17.80*	*21*	*4.5*
Soil + 4% RBI	*17.60*	*18*	*9.3*
Soil + 6% RBI	*17.20*	*16*	*12.5*

Mamta and Mallikarjun.Honna (2014) Used RBI grade 81 for relative study of BC soil and lateritic soil .Atterbergs limit, CBR, UCS tests has been carried out on the samples of soil and soil with stabilizers. Curing of samples is done for 0, 3, days. RBI Grade 81 will be added to the soil in dry state in percentage (by weight) varying from 1% to 2% and the tests has been carried out for lateritic and BC soil. BC soil and lateritic soil are such that they symbolize a broad range of discrepancy in their properties.

Table 2.7 CBR test results with RBI 81

DAYS	*CBR(%)with varying RBI-81 for BC soil*		*CBR(%)with varying RBI-81 for lateritic soil*	
	1%	2%	1%	2%
0(unsoaked)	5.7	7.1	11.4	12.3
3(soaked)	7	`10	13	15

Parijat Jain and H S Goliya (2014) deals with the upgrading in various properties of Black Cotton soil for pavement sub-grade by using soil stabilizer. The stabilizer like RBI Grade 81 is used to improve the properties of Black Cotton soil for pavement sub-grade purpose. From CBR test, it is found that the soaked CBR value of soil is improved by 745.54% i.e. 2.02% to

15.06% by stabilizing soil 4% RBI Grade 81. The various mixes of Black Cotton soil: RBI Grade 81 for the different proportions was tested for Atterbergs limit, Shrinkage limit, Free Swelling Index, Compaction (OMC & MDD) and 4 day's soaked CBR value. Liquid limit decreasing by adding 4% RBI GRADE 81 & further addition of admixtures soil tends to non plastic. But in the case of plastic limit, its increase up to addition of 4% RBI GRADE 81& further addition of admixtures soil tends to non plastic.

Design the road treated with 4% RBI GRADE 81which having15% CBR respectively found that reduction in sub-base layer by 56.5% and reduction in DBM layer by 53.84% respectively in contrast to pavement design on Untreated BC. Design pavement on treated BC soil with 4% RBI GRADE 81, pavement thickness reduce by 37.50% to the pavement design on untreated BC soil and the outlay of the pavement reduced by 18.50% to the original cost of pavement cost of untreated BC soil.

R.Annadurai et al. (2014) tried to improve the strength and to soothe the challenging soil by the utilize of chemical stabilizer, RBI grade 81. Complete experimental investigation including unconfined compression tests were conceded out to know the effectiveness of addition of RBI grade 81 to advance the geotechnical engineering properties.

Treated soil specimen at various stabilizer quantities (2, 4 and 6%) were tested for UCS after curing period of 3 days and 7 days. It was observed that the UCS of the soil sample A1 and A2 increased by 475% and 430% with addition of 6% stabilizer after 7 days curing.

Table 2.8: UCS test results with RBI 81

Soil + % RBI	*UCS Value (kPa)*			
	Sample A1		*Sample A2*	
	3 days	*7 days*	*3 days*	*7 days*
Soil + 0% RBI	138		122	
Soil + 2% RBI	209	217	130	148
Soil + 4% RBI	365	436	277	348
Soil + 6% RBI	742	794	514	541

Venugopal G et al. (2014) studied the effect of new stabilization product, RBI Grade-81 on black cotton soil to advance the properties of subgrade soil. Atterbergs limit, Light Compaction, California Bearing Ratio, Unconfined Compressive Strength were carried out on the samples of soil and soil with stabilizers. Various samples have been made by taking soil with altered percentage 2%, 4%, 6% and 8% of RBI Grade-81.The evaluation of the strength results with or without RBI Grade-81 have been done. The subgrade soil can be improved by using RBI Grade-81 and cost of construction can be reduced to certain extent.

MDD decreased and OMC improved slightly due to the adding of RBI Grade-81 when compared with virgin soil. There was a well-built change in soaked CBR of treated soil.RBI 81 addition makes the UCS value increase significantly.

A.U.R Shankar et al. (2015) attempted to get better physical and geotechnical properties of red soil, to utilize of it in pavement layers over subgrade. For this reason, Road Building International Grade 81 (RBI 81) was used as a stabilizer with different dosage of 2, 4, 6 and 8 % by dry weight of soil. Compaction and CBR were carried out on red soil with different dosages of RBI 81 in order to observe its influence. The best possible amount of RBI 81 was dogged as 6%, based on potency and economical grounds. The laboratory results obtained indicated a decrease in OMC and increase MDD, with the introduction of RBI 81. CBR values showed a considerable progress for treated soil with increase in curing days. The response time was observed to be an important constraint where strength improved with increase in time.

With the objective of using stabilized red soil for superior layers, 12mm down size aggregates were added with optimum RBI 81 – soil mix 30 and 50% of dry weight of soil, and CBR test was conducted for this soil – aggregate mixture. KENPAVE software was used for stress strain and damage analysis of both natural and stabilized soils and put in order pavement design sections. For natural soil, analysis was carried out for CBR 8% and traffic 2 million standard axles, using the standard design thickness as per IRC-37:2012 guidelines. Trial and error method was adopted to determine thickness for treated soil aggregate mixture, by keeping the stress strain value within permissible limits. For stabilized soil, rutting and fatigue life and damage ratio were also observed to be significantly improved. From the results of the experimental research and KENPAVE analysis, it has been observed that red soil can be effectively stabilized with aggregates and RBI 81.

They also concluded that as the magnitude of the stabilizer increase, reaction has taken place and boost in OMC and MDD is observed. Method of stabilization was observed from chemical investigation of treated and untreated soil samples. The investigation indicated that the RBI 81 aggregate stabilized soil can be used as base layer for high volume roads, which reduce the aggregate quantity and outlay of construction

B. Vishnuvardhan Kumar, M. Teja and G. Kalyan Kumar (2015) studied that through the adding up low dosages of RBI 81 the volume stability of the soil is increased considerably. The reaction of RBI 81 with soil particles produces an inter-particle matrix that bind soil particles together into a firm mass. This binding of the soil particle through both chemical bonds and frictional forces serves to limit the pore volume of the produced firm stabilised soil system. An noticeable increase in the values of UCS and CBR are observed with the addition of Road Building International grade 81 materials compared to the Ground Granulated Blast Furnace Slag material and it is considered more appropriate for sub grade soil stabilization.

CHAPTER-3

EXPERIMENTAL PROGRAMME

3.1 Materials Used:-

A brief description of the materials and methods used in this investigation is given as following.

3.1.1 Soil

Soil taken was collected from Ambala region, Haryana (India). The investigation of Soil is done by Indian Standard code. The index properties of soil such as Liquid limit, Plastic limit, and Plastic index were determined.

Table 3.1: Geotechnical properties of collected sample

S.No	***Properties***	***Description***	***Relevant IS Codes***
1	Fines (%)	53.7	IS 2720 Part IV
2	Sand (%)	46.3	IS 2720 Part IV
3	MDD (kN/m^3)	18.5	IS 2720 Part VIII
4	OMC (%)	14.7%	IS 2720 Part VIII
5	Liquid Limit (%)	32.5	IS 2720 Part V
6	Plastic Limit (%)	20	IS 2720 Part V
7	Plasticity Index (%)	12.5	IS 2720 Part V
8	Flow Index	29	IS 2720 Part V
9	Toughness Index	0.68	IS 2720 Part V
10	Soaked California Bearing Ratio (C.B.R.)	3.2%	IS 2720 Part XVI
11	Unconfined Compressive Strength (U.C.S.) at 14.7 % OMC on day 1 in kPa	193	IS 2720 Part X

3.1.2 Road Building International 81

RBI Grade-81 is an Inorganic Soil Stabilizer & Pavement Material which saves road construction time and natural resources. The roads so constructed are more durable than road constructed with conventional method

Table: 3.2 Chemical composition of RBI Grade 81

S.No	***Properties***	***Description***
1	Calcium Oxide (CaO)	50-60 %
2	Silicon dioxide (SiO2)	15-20%
3	Sodium oxide(SO 2)	10-15%
4	Aluminium trioxide (Al2 O3)	5-10%
5	Iron trioxide (Fe2 O3)	0-2%
6	Magnesium Oxide (Mg O)	0-1%
7	Fibers (Poly propylene)	0-1%
8	Additives	0-4%

Table 3.3 Physical properties of RBI Grade 81

S.No	***Properties***	***Description***	***S.No***	***Properties***	***Description***
1	Appearance	Beige powder	**6**	Flammability	Inflammable.
2	Odor	Odorless.	**7**	Specific Gravity	2.5
3	pH	12.5 (saturated paste)	**8**	Solubility	In water 0.2pts/10Opts.
4	Vapour Pressure	Not measurable	**9**	Shelf Life	12 month (Dry Storage)
5	Flammability	Inflammable.	**10**	Bulk Density	700 kg/ m3

Plate 3.1: RBI Grade 81 sample

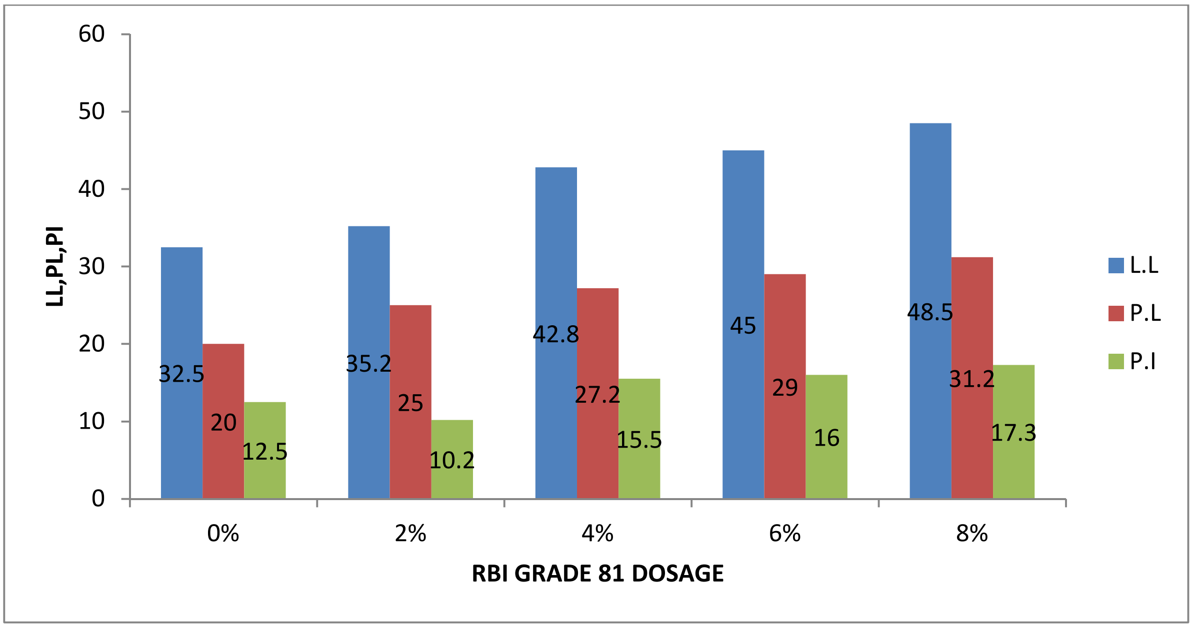
3.2 Atterbergs Limit Test

This test is done for determination of the liquid limit, plastic limit and plasticity index of soil. Reference Standard: IS: 2720(Part 5)-1985- Methods of test for soils: Determination of liquid and plastic limit

The soil sample was treated with RBI grade 81 dosage 2%, 4%, 6% and 8% for characterization of soil with respect to virgin soil sample. At 2% RBI grade 81 there was decrease in plasticity index but with further increase in RBI grade 81 dosages increase in plasticity index was observed.

Table 3.4: Effect of RBI grade 81 on plasticity index

Soil: RBI grade 81	*Liquid limit (%)*	*Plastic limit (%)*	*Plasticity index (%)*
100.0	32.5	20	12.5
98:2	35.2	25	10.2
96:4	42.8	27.2	15.5
94:6	45	29	16
92:8	48.5	31.2	17.3



Graph 3.1: RBI Grade 81 Vs LL, PL & PI

3.3 Compaction Test

This test is done to determine the maximum dry density and the optimum moisture content of soil using by proctor test as per IS: 2720-Part viii (1995).

Compaction is the process of densification of soil mass by reducing air voids. The degree of compaction of a soil is measured in terms of its dry density. For a given compaction energy every soil attains the maximum dry density at a particular water content which is known as optimum moisture content.

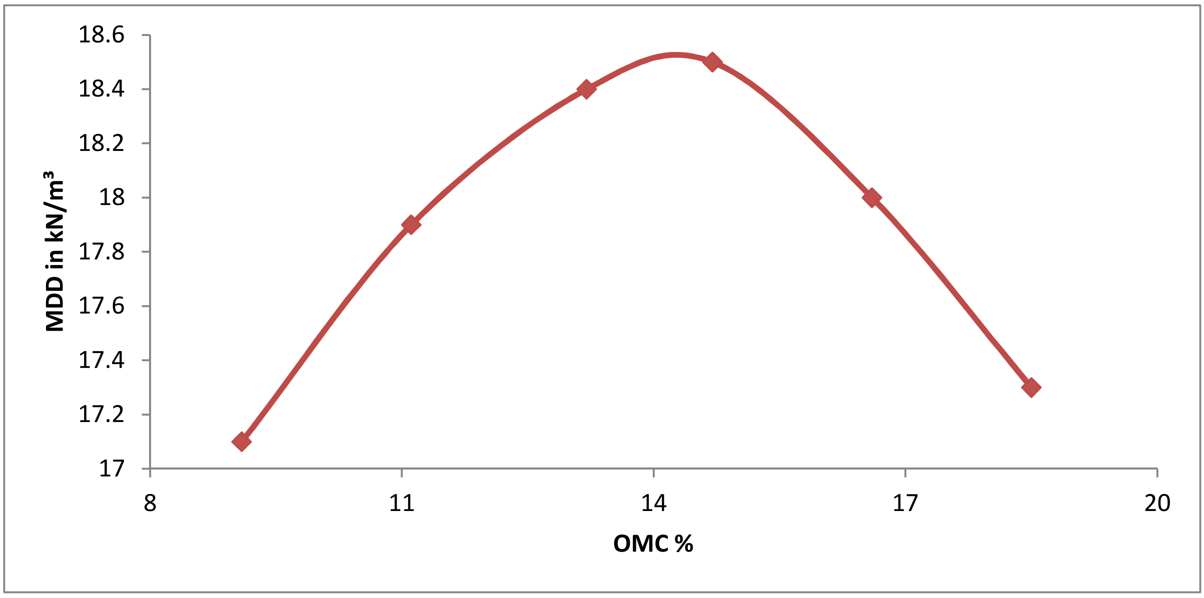
The Standard proctor test was conducted on untreated soil, the values of MDD and OMC were found to be 18.5 kN/m^3 and 14.7 % respectively. The results of the MDD and OMC for untreated soil and soil treated with different percentage of RBI Grade 81 are mentioned below; there is decrease in MDD of treated soil with increase in dosage of RBI Grade 81 in comparison to untreated soil. The OMC of soil treated with 2% RBI Grade 81 shows a slight decrease but for 4%, 6% RBI Grade 81 dosage there is gradual increase in OMC and further slightly falling at 8%RBI Grade 81.The RBI Grade 81 reacts chemically with soil particles and binds them together and reduces the pore spaces and help to increase the MDD of soil, but also The RBI Grade 81 contains fibers due to which the increase in MDD is less and if the percentage of RBI Grade 81 increases the MDD of soil reduces.

Plate 3.2: compacted sample in mould

Plate 3.3: automatic compactor

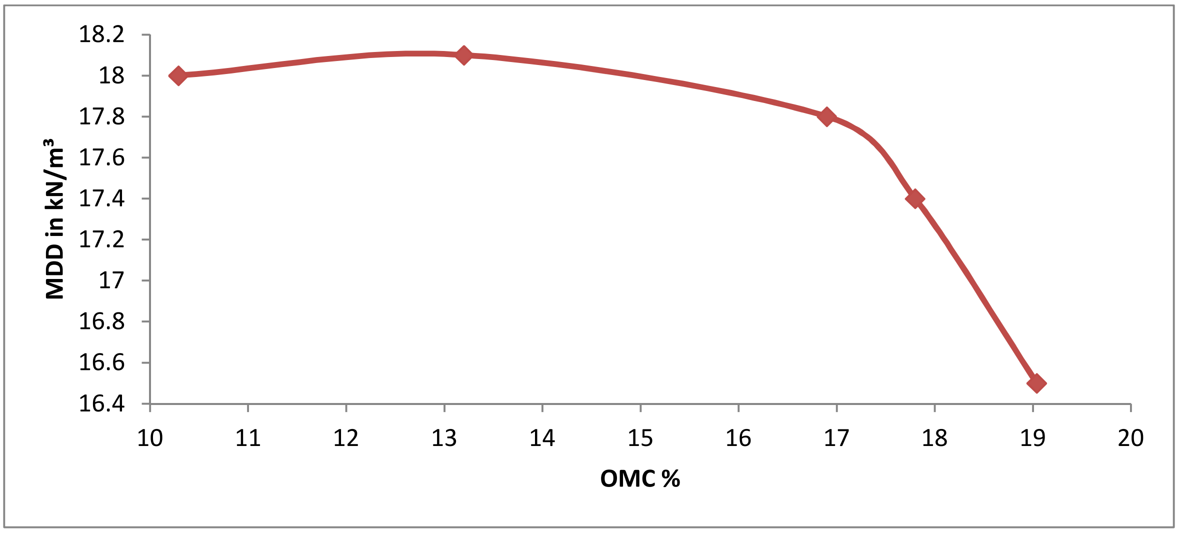
3.3.1 Graphs and results of compaction test

1. In Graph 3.2 calculations and observation of light compaction test at 0% RBI Grade 81 dosage is shown. While performing the test a mould of 1000cc weighing 4320 gm is taken, total 25 no of blows were blown in 3 layers. We have achieved the 14.7% OMC and 18.5 kN/m³ MDD from the results.



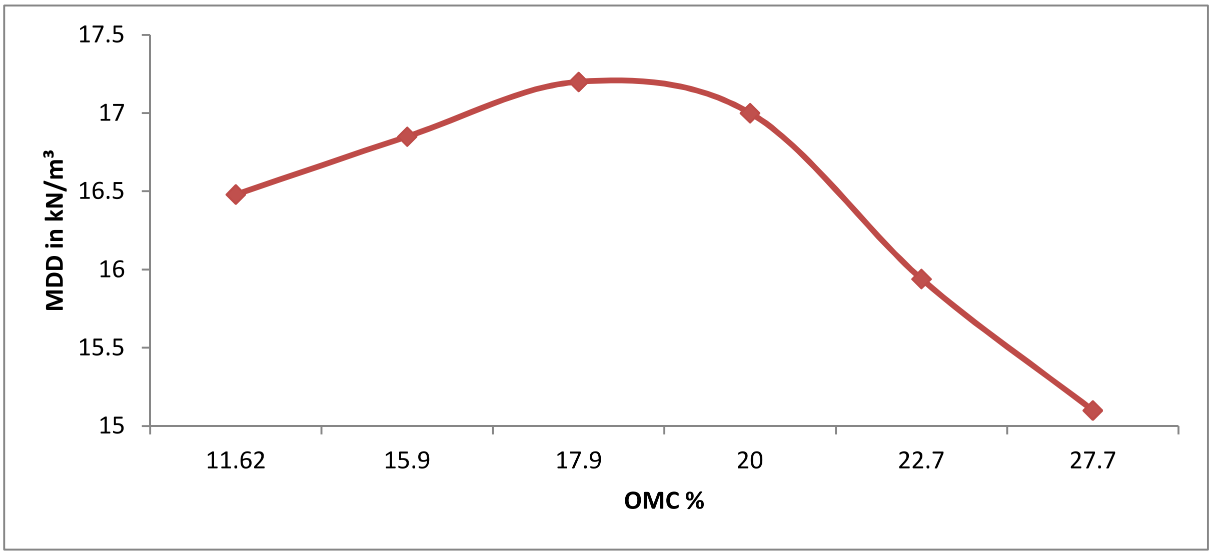
Graph 3.2: Effect of RBI grade 81 on OMC and MDD at 0%

2. In Graph 3.3 calculations and observation of light compaction test at 2% RBI Grade 81 dosage is shown. While performing the test a mould of 1000cc weighing 4320 gm is taken, total 25 no of blows were blown in 3 layers. We have achieved the 13.2% OMC and 18.1 kN/m³ MDD from the result.



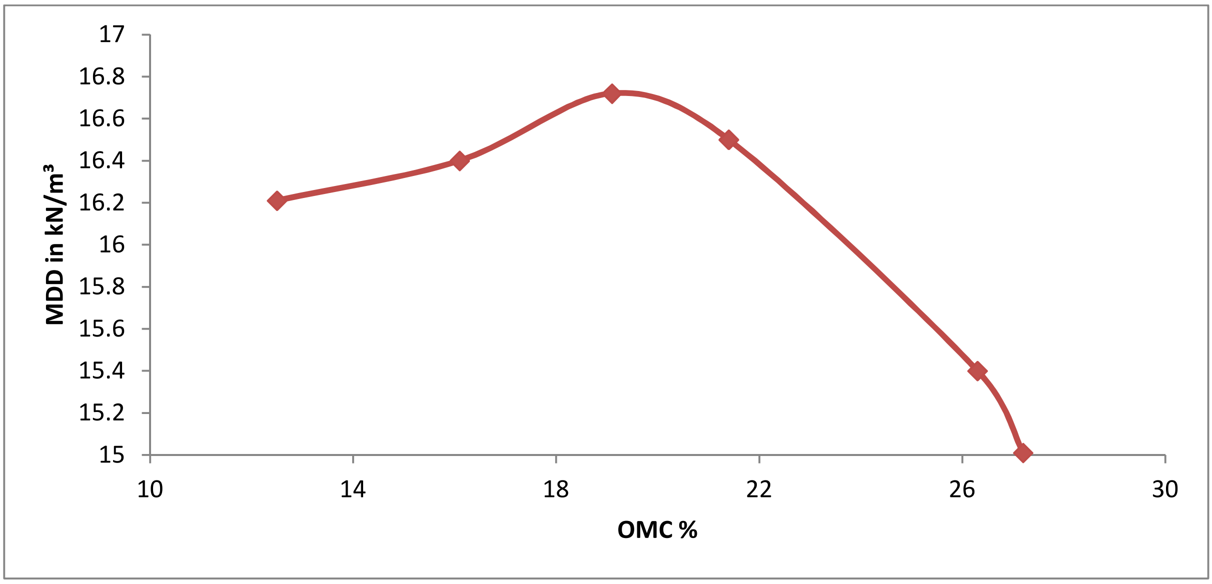
Graph 3.3: Effect of RBI grade 81 on OMC and MDD at 2%

3. In Graph 3.4 calculations and observation of light compaction test at 4% RBI Grade 81 dosage is shown. While performing the test a mould of 1000cc weighing 4320 gm is taken, total 25 no of blows were blown in 3 layers. We have achieved the 17.9% OMC and 17.2kN/m³ MDD from the results.



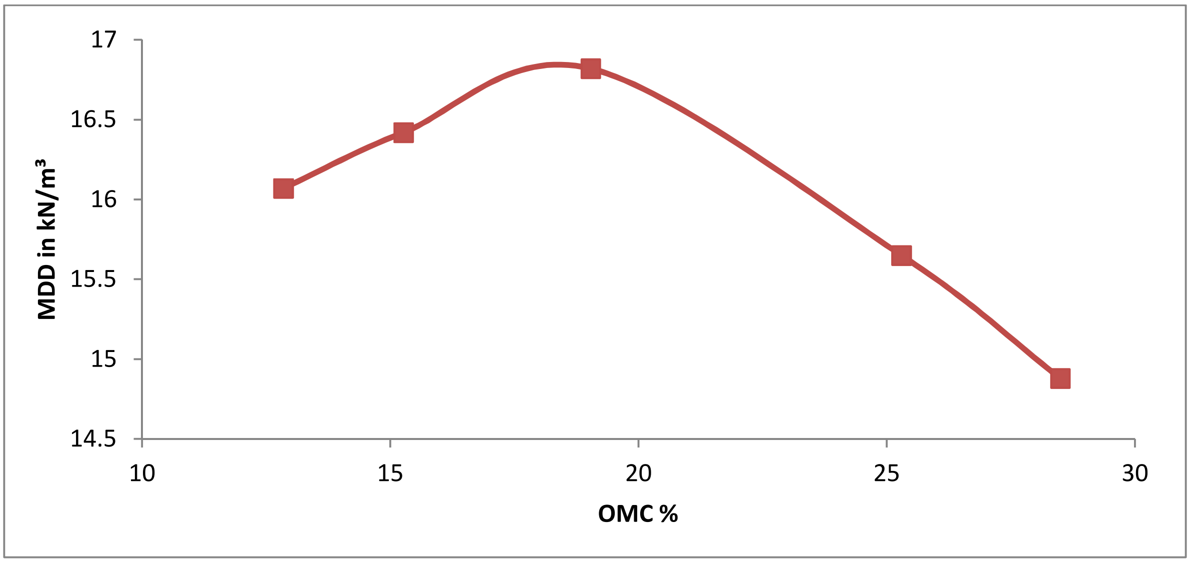
Graph 3.4: Effect of RBI grade 81 on OMC and MDD at 4%

4. In Graph 3.5 calculations and observation of light compaction test at 6% RBI Grade 81 dosage is shown. While performing the test a mould of 1000cc weighing 4320 gm is taken, total 25 no of blows were blown in 3 layers. We have achieved the 19.1% OMC and 16.72 kN/m^3 MDD from the result



Graph 3.5: Effect of RBI Grade 81 on OMC and MDD at 6%

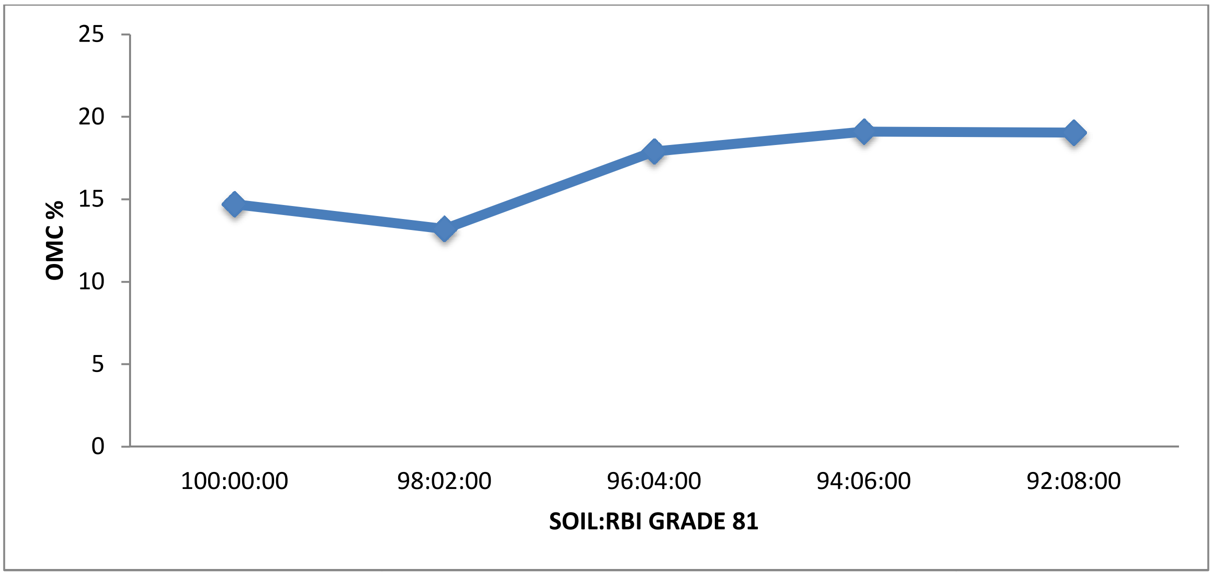
5. In Graph 3.6 calculations and observation of light compaction test at 8% RBI Grade 81 dosage is shown. While performing the test a mould of 1000cc weighing 4320 gm is taken, total 25 no of blows were blown in 3 layers. We have achieved the 19.04% OMC and 16.8kN/m^3 MDD from the result.



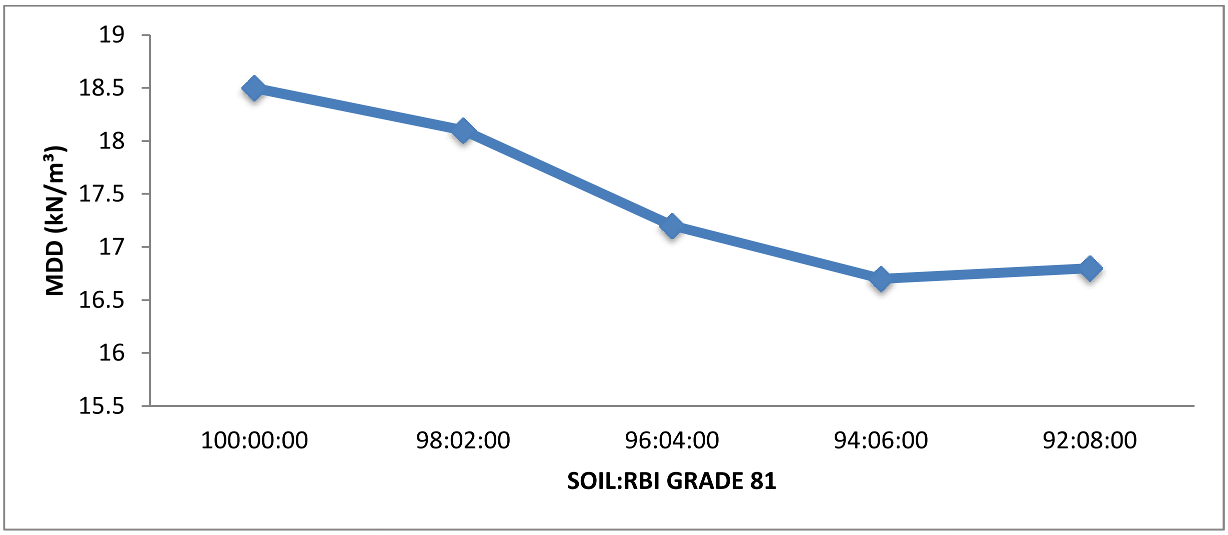
Graph 3.6: Effect of RBI Grade 81 on OMC and MDD at 8%

Table 3.5-Light compaction test calculation and observations at different RBI Grade 81: Soil

SOIL:RBI 81	MDD in kN/m^3	OMC in %
100:0	18.5	14.7
98:2	18.1	13.2
96:4	17.2	17.9
94:6	16.7	19.1
92:8	16.8	19.04



Graph 3.7: Effect of RBI grade 81 on OMC



Graph 3.8: Effect of RBI Grade 81 on MDD

3.4 California Bearing Ratio Test

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. IS 2720- Part xvi (2002) is used for this test.

$$\text{C.B.R.} = \frac{Test\ Load\ (kg)}{Standard\ Load(kg)} \times 100$$

The following Table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%

Table 3.6: Standard Loads adopted for different Penetrations

Penetration of Plunger (mm)	*Standard Load (kgf)*
2.5	1370
5	2055
7.5	2630
10	3180
12.5	3600

The test may be performed on undisturbed specimens and on remolded specimens who may be compacted either statically or dynamically. This test is done to determine the California bearing ratio by conducting a load penetration test in the laboratory. The California bearing ratio test is penetration test meant for the evaluation of sub grade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

Plate 3.4: Compacted Sample at RBI Grade81: Soil in a Mould

3.5 Unconfined Compression Test

An Unconfined compression test is also known as uniaxial compression tests, is special case of a triaxial test, where confining pressure is zero. UCS test does not require the sophisticated triaxial setup and is simpler and quicker test to perform as compared to triaxial test. In this test, a cylinder of soil without lateral support is tested to failure in simple compression, at a constant rate of strain. The compressive load per unit area required to fail the specimen as called unconfined compressive strength of the soil

It is not always possible to conduct the bearing capacity test in the field. Sometimes it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also to choose the best material for the embankment, one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the unconfined compression test on undisturbed and remoulded soil sample.


Plate 3.5: Soil: RBI Grade 81 Mixture


Plate 3.6: Compacted Soil


Plate 3.7 Extraction of Sample


Plate 3.8: Extracted Samples


Plate 3.9: Testing Of Samples

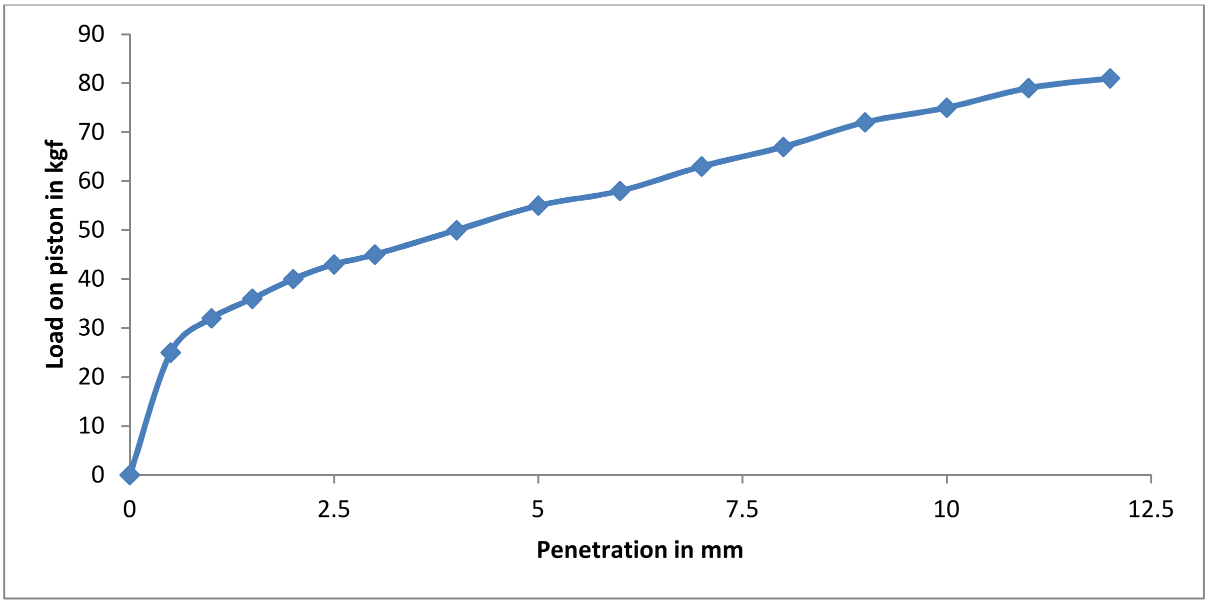

Plate 3.10: Failed Sample

CHAPTER-4
RESULT AND DISCUSSIONS

4.1 Effect of RBI Grade 81 on Soaked CBR Value of Soil

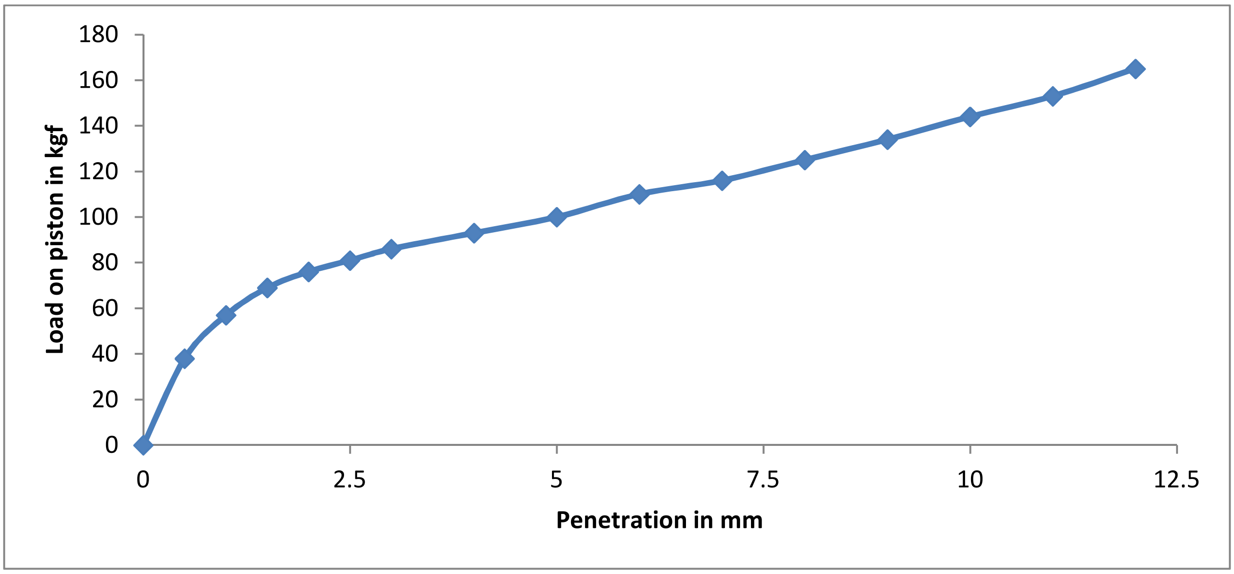
The CBR tests were performed on soaked specimens for modified proctor densities. Since the soaked values of CBR are used for pavement designs generally, the moist cured samples were soaked for four days before testing. The results presented in Tables and graphs, indicate that the strength of the soil has improved considerably and it has more resistance to penetration after stabilization. Addition of RBI 81 to the untreated soil has caused better cementation in the soil matrix which made it resistant against penetration. The CBR test is conducted in the laboratory on soil, RBI Grade 81 for various proportions. The obtained results are given in Table 4.1.The modified soil obtained by mixing soil: RBI Grade 81 in the proportion of 98:2, 96:4, 94:6 and 92:8.Results from the graphs is mentioned below

1. In Graph 4.1 observations from the results obtained are shown, from the Load Vs Penetration graph at 0% RBI Grade 81 dosage shows that we have achieved CBR value of 3.2 % at 2.5mm penetration and CBR value of 2.7% at 5mm penetration, we have taken CBR value of 3.2% as our design value.



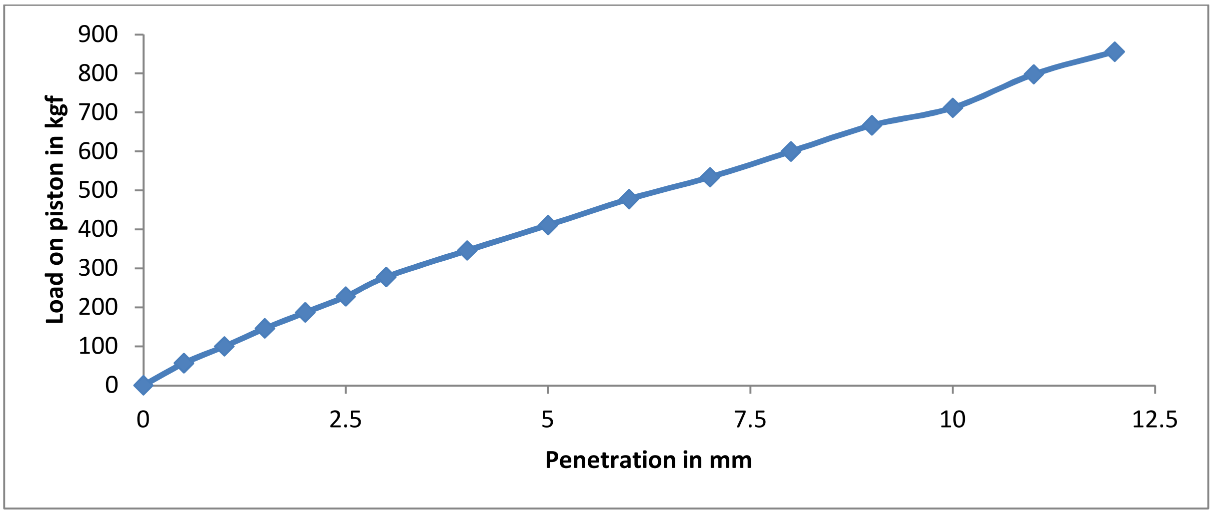
Graph 4.1: Load Vs Penetration graph at 0% RBI Grade 81 dosage

2. In Graph 4.2 observations from the results obtained are shown, from the Load Vs Penetration graph at 2% RBI Grade 81 dosage shows that we have achieved CBR value of 6.2 % at 2.5mm penetration and CBR value of 4.96% at 5mm penetration, we have taken CBR value of 6.2% as our design value.



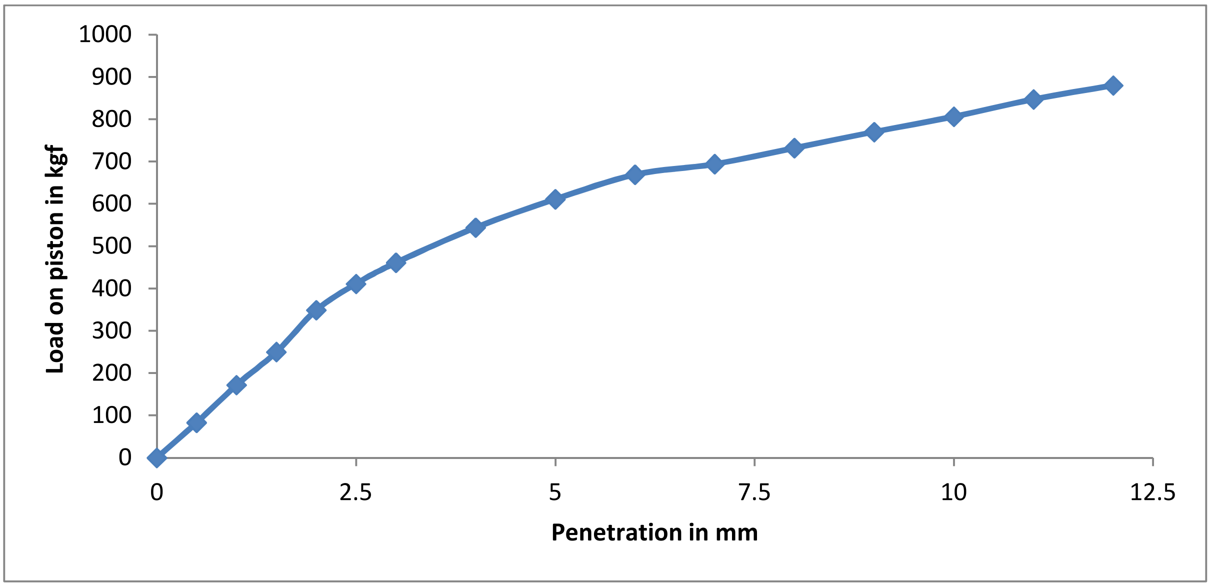
Graph 4.2: Load Vs Penetration graph at 2% RBI Grade 81 dosage

3. In Graph 4.3 observations from the results obtained are shown, from the Load Vs Penetration graph at 4% RBI Grade 81 dosage shows that we have achieved CBR value of 16.9 % at 2.5mm penetration and CBR value of 20.39% at 5mm penetration, we have taken CBR value of 20.39% as our design value.



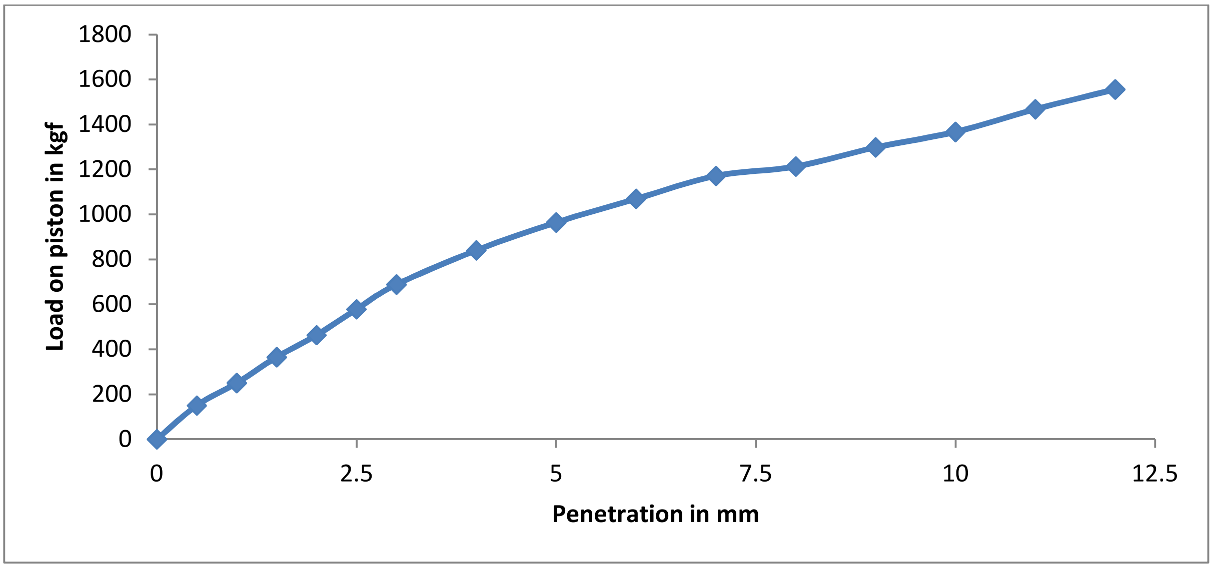
Graph 4.3: Load Vs Penetration graph at 4% RBI Grade 81 dosage

4. In Graph 4.4 observations from the results obtained are shown, from the Load Vs Penetration graph at 6% RBI Grade 81 dosage shows that we have achieved CBR value of 30.51 % at 2.5mm penetration and CBR value of 30.33% at 5mm penetration, we have taken CBR value of 30.51% as our design value.



Graph 4.4: Load Vs Penetration graph at 6% RBI Grade 81 dosage

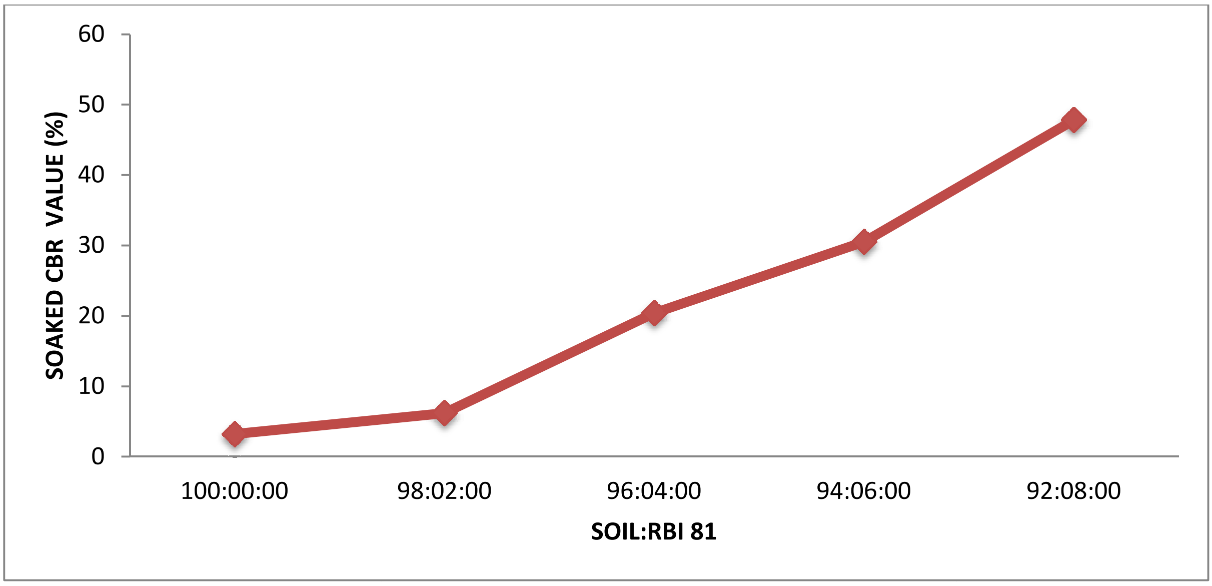
5. In Graph 4.5 observations from the results obtained are shown, from the Load Vs Penetration graph at 8% RBI grade 81 dosage shows that we have achieved CBR value of 43 % at 2.5mm penetration and CBR value of 47.83% at 5mm penetration, we have taken CBR value of 47.83% as our design value.



Graph 4.5: Load Vs Penetration graph at 8% RBI Grade 81 dosage

Table 4.1: Effect of RBI Grade 81 on soil at different ratios and % increase in CBR value

CBR VALUES AFTER 4 DAY SOAKING PERIOD					
SOIL:RBI81	100:0	98:2	96:4	94:6	92:8
OMC	14.7	13.2	17.9	19.1	19.04
CBR VALUE(%)	3.2	6.2	20.39	30.51	47.83
% INCREASE IN CBR VALUES	–	93.75	537.18	853.4	1394.6



Graph 4.6: RBI Grade 81 Vs Soaked CBR at different ratios.

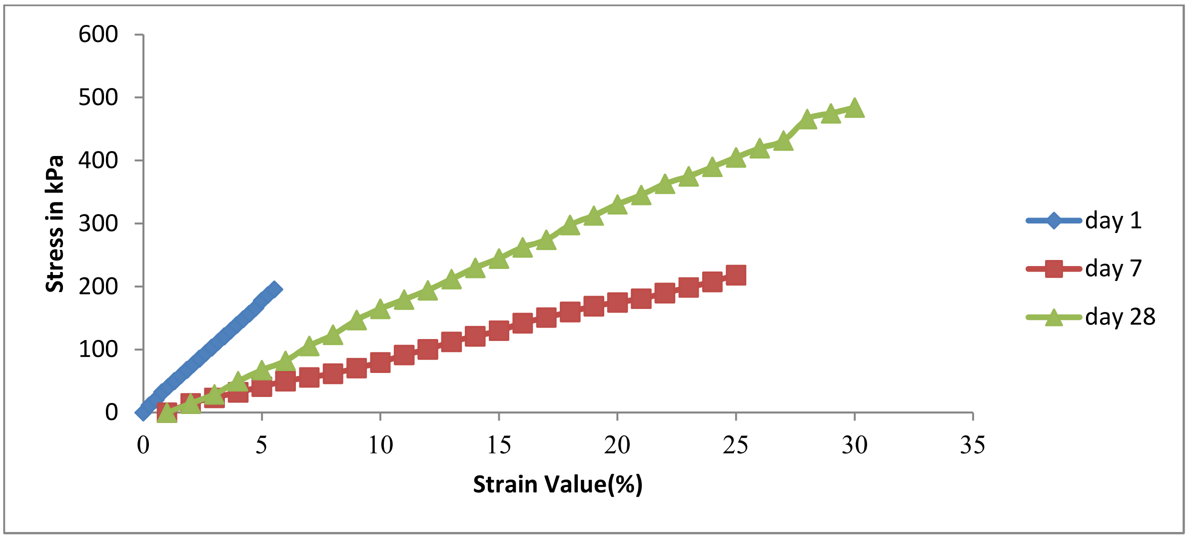
4.2 Effect of RBI Grade 81 on UCS

Unconfined compression test was conducted on prepared sample of 38 mm diameter and 76 mm height at various dosages of RBI 81 and the samples were cured for a period of 1 days, 7days and 28 days before testing. The UCS values reveal an increasing trend with the increase in percentage stabilizer and curing period. This experimental work was conducted to investigate the influence of curing period and percentage addition of RBI Grade 81 on the unconfined compressive strength of soils. For curing period day 1(unsoaked condition) there is not much variation in trend of strength of UCS samples .Further increase in curing period has shown increase in strength with respect to virgin soil sample . Results from graph and tables are shown below.

1. From the Graph 4.7 and Table 4.2 it is accomplished that samples at day 1 failed at strain value of 5%, while samples at day 7 and day 28 are failing at strain value of 25% and 32 % and stress taking capability is improved with curing period.

Table 4.2: UCS results at 0% RBI Grade 81-OMC 14.7 %

UCS results at 0% RBI 81-OMC 14.7 %	
CURING PERIOD	UCS VALUE IN kPa (Avg. of 3 samples)
1 day	193
7 days	213
28 days	491

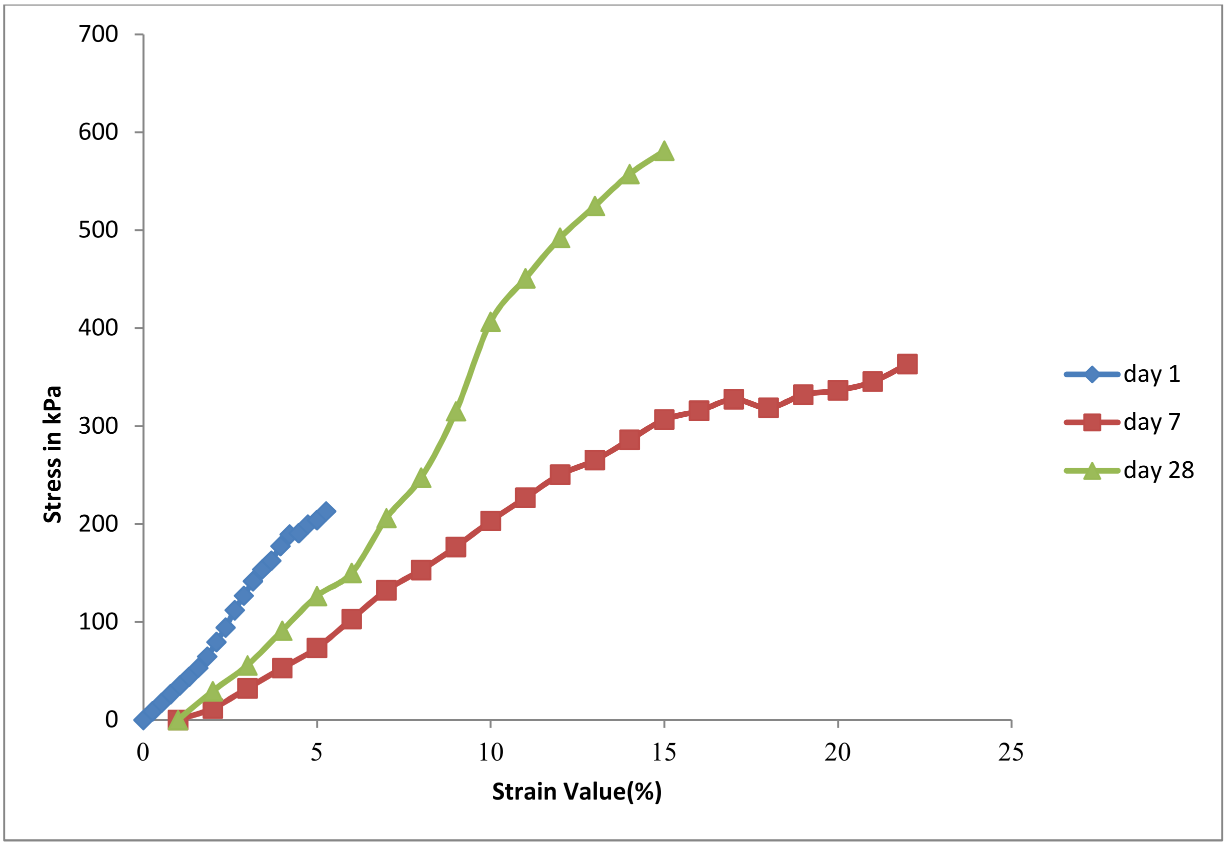


Graph 4.7: Stress Vs Strain Graph at different curing period for 0% RBI Grade 81

2. From the Graph 4.8 and Table 4.3 it is accomplished that samples at day 1 failed at strain value of 5%, while samples at day 7 and day 28 are failing at strain value of 23% and 17 % and stress taking capability is improved with curing period.

Table 4.3: UCS results at 2% RBI Grade 81-OMC 13.2 %

UCS results at 2% RBI 81-OMC 13.2 %	
CURING PERIOD	UCS value in kPa (Avg. of 3 samples)
1 day	207
7 days	363
28 days	584

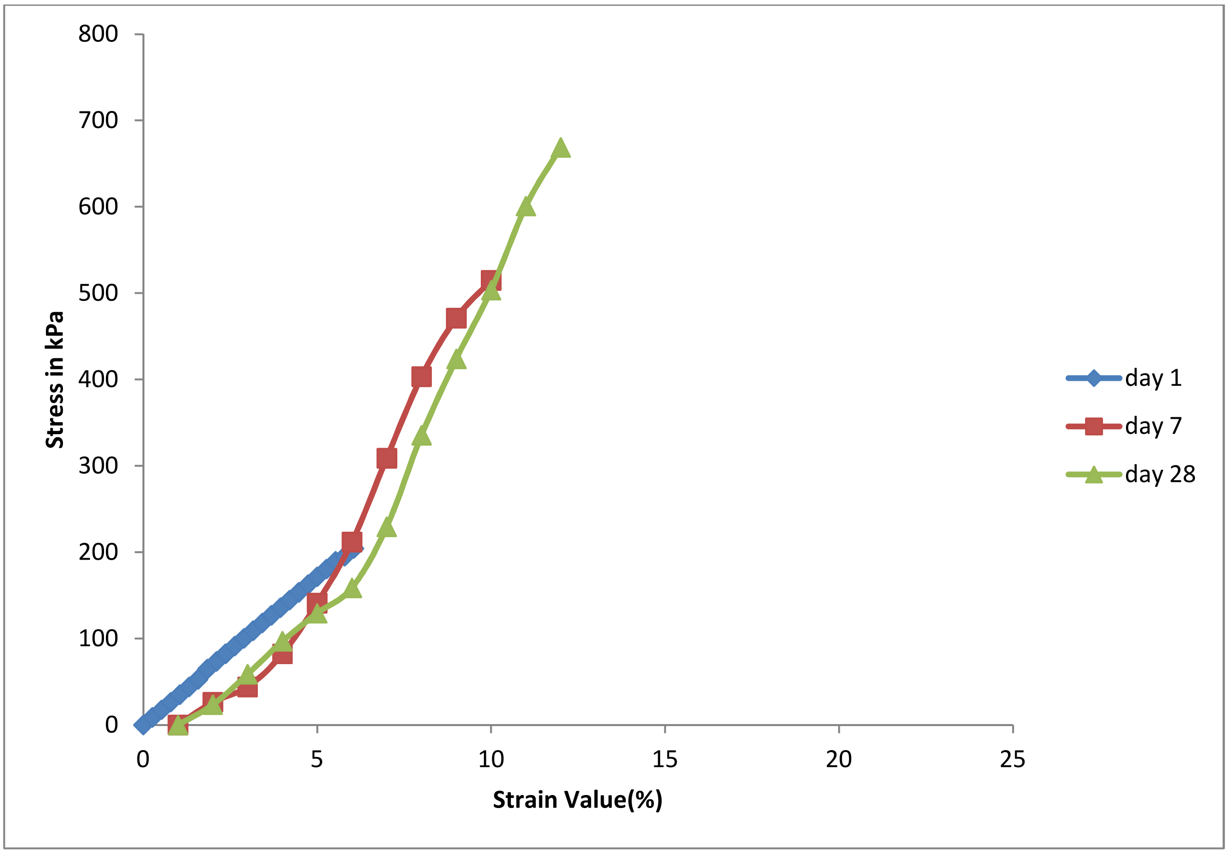


Graph 4.8: Stress Vs Strain Graph at Different Curing Period for 2% RBI Grade 81

3. From the Graph 4.9 and Table 4.4 it is accomplished that samples at day 1 failed at strain value of 6%, while samples at day 7 and day 28 are failing at strain value of 10% and 13 % and stress taking capability is improved with curing period.

Table 4.4: UCS results at 4% RBI Grade81-OMC 17.9 %

UCS results at 4% RBI 81-OMC 17.9 %	
CURING PERIOD	UCS value in kPa (Avg. of 3 samples)
1 day	199
7 days	515
28 days	683

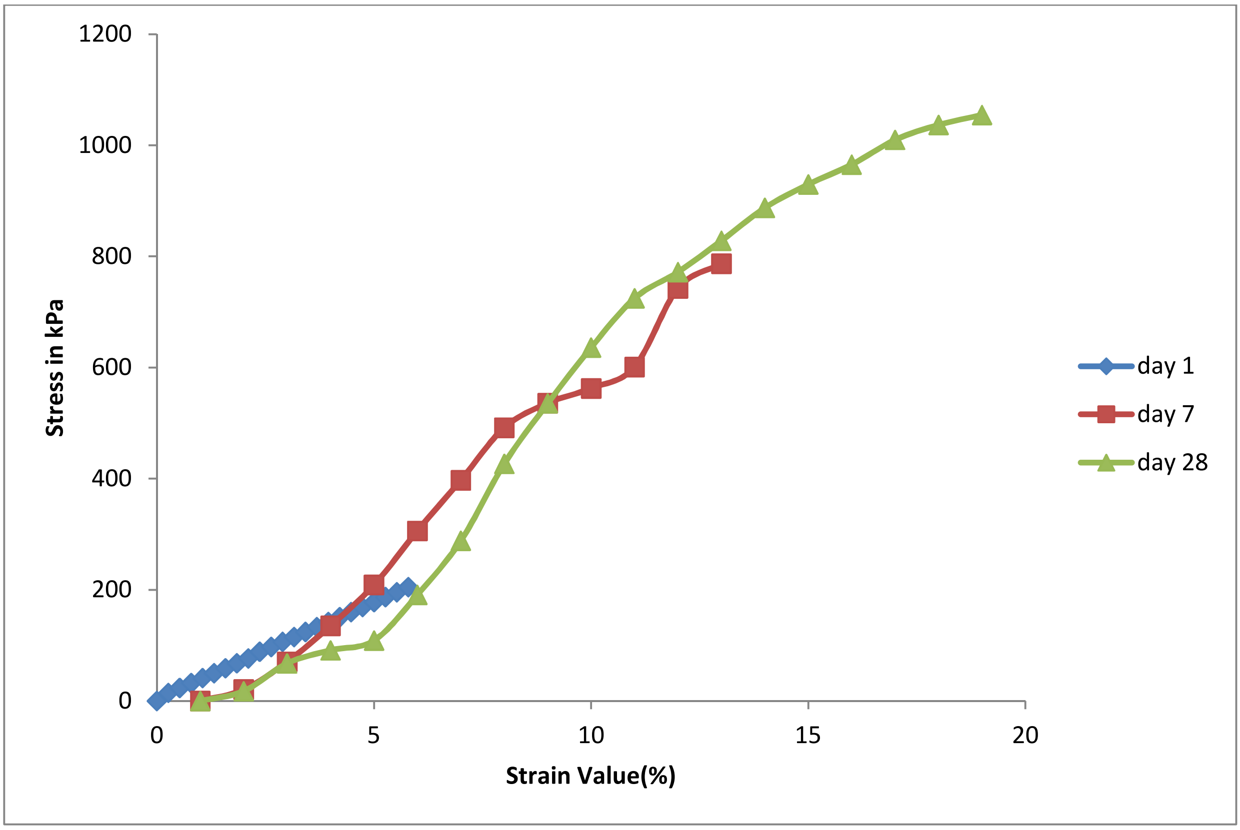


Graph 4.9: Stress Vs Strain Graph at different curing period for 4% RBI Grade 81

4. From the Graph 4.10 and Table 4.5 it is accomplished that samples at day 1 failed at strain value of 6%, while samples at day 7 and day 28 are failing at strain value of 14% and 20 % and stress taking capability is improved with curing period.

Table 4.5: UCS results at 6% RBI Grade 81-OMC 19.1 %

UCS results at 6% RBI 81-OMC 19.1 %	
CURING PERIOD	UCS value in kPa (Avg. of 3 samples)
1 day	204
7 days	639
28 days	1003

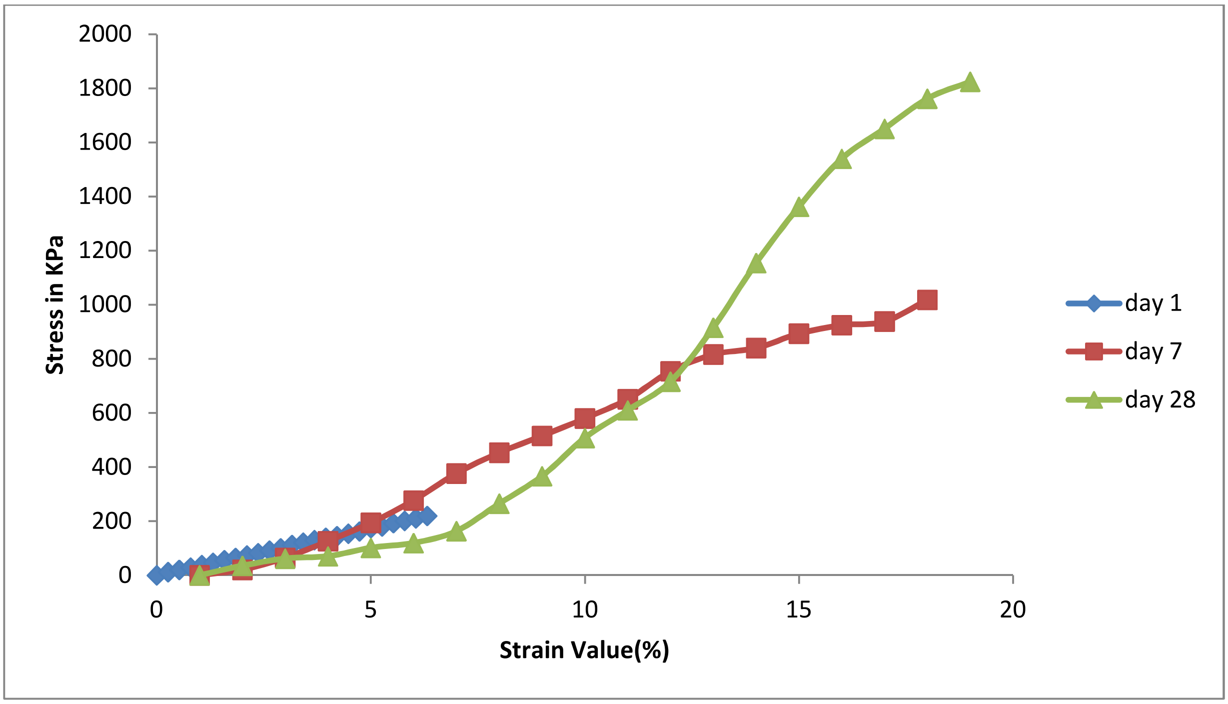


Graph 4.10: Stress Vs Strain Graph at different curing period for 6% RBI 81

5. From the Graph 4.11 and Table 4.6 it is accomplished that samples at day 1 failed at strain value of 7%, while samples at day 7 and day 28 are failing at strain value of 17% and 20 % and stress taking capability is improved with curing period.

Table 4.6: UCS results at 8% RBI Grade 81-OMC 19.04 %

UCS results at 8% RBI 81-OMC 19.04 %	
CURING PERIOD	UCS value in kPa (Avg. of 3 samples)
1 day	222
7 days	964
28 days	1819

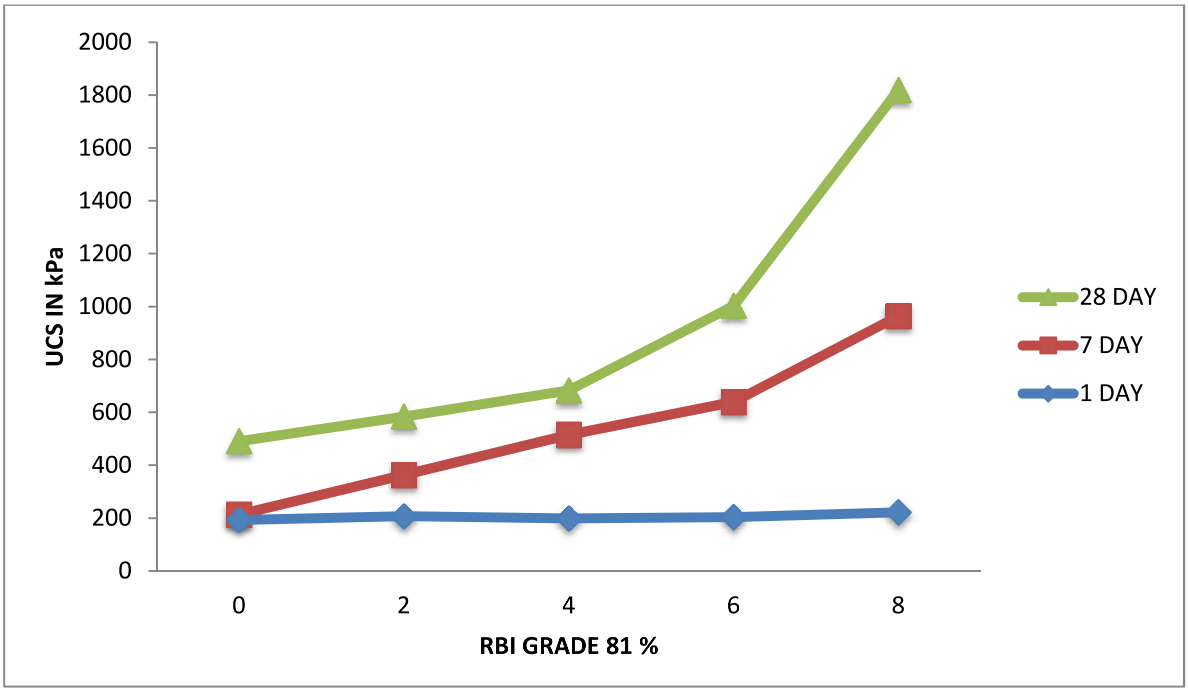


Graph 4.11: Stress Vs Strain Graph at different curing period for 8%RBI Grade 81

Conclusion from Graphs and Tables: From the graphs of Stress Vs Strain for different curing period and different dosage of RBI grade 81 recommended that with increase in RBI grade 81 dosages, strain values at which samples are failing have decreased with respect to the sample failed at different curing period at 0% RBI grade dosage but stress taking capability has been increased throughout.

Table 4.7: UCS results at different curing period

RBI 81 % dosage	**UCS (kPa)**		
	CURING PERIOD		
	1 DAY	**7 DAYS**	**28 DAYS**
0	**193**	**213**	**491**
2	**207**	**363**	**584**
4	**199**	**515**	**683**
6	**204**	**639**	**1003**
8	**222**	**964**	**1819**



Graph 4.12: UCS Vs RBI GRADE 81at different curing period

CHAPTER 5

DESIGN OF FLEXIBLE PAVEMENT USING RBI GRADE 81

5.1 Analysis of pavement section with Granular Base and Granular Subbase.

The pavement structure is a linear elastic Possion ratio multli layered system and the stress-strain solution of the material is characterized by the E value and μ values. Each layer has a finite thickness H1, H2 etc, except the subgrade layer. In pavement analysis, when the wheel loads is applied on the top surface of the pavement structure it can produced two types of strains:

1. Tensile strain, ε_t, at the bottom of the bituminous layer
2. Vertical strain, ε_v, on the top of the subgrade layer.

These are the two parameters for the pavement design so as to limit cracking and rutting in the bituminous layer. If the critical horizontal tensile strain ($\varepsilon_{t,}$) value is more than the allowable strain value, cracking will occur on the top surface of the bituminous layer and the pavement may distresses due to fatigue. If the vertical compressive strain (ε_v) is exceed than the allowable strain value, permanent deformation (rutting) will occur on the surface in the pavement structure, due to the overloading of subgrade and the pavement may distresses due to rutting. *(CI 10.1 IRC 37:2012)*

5.1.2 Fatigue Model:-

According to the IRC: 37-2012, the two equations for fatigue model at 80% and 90% reliability are given below:

$N_f = 2.21 * 10_{-04} \times [1/\varepsilon_t]^{3.89} * [1/M_R]^{0.854}$ (80 percent reliability)………….. (5.1)

$N_f = 2.021 * 10\text{-}04 \times [1/\varepsilon_t]^{3.89} * [1/M_R]^{0.854}$ (90 percent reliability)…. (5.2)

N_f = fatigue life, ε_t = Tensile strain at the bottom of the bituminous layer M_R = resilient modulus of the bituminous layer

= 3000 MPa, for VG40 bitumen at 35^0C in 90% reliability.

= 1700 MPa, for VG30 bitumen at 35^0C in 80% reliability.

Equations 5.1 gives, fatigue life for 20 percent cracked area of the bituminous layer at a reliability level of 80 percent respectively at the end of the design period.

In equation 5.2, only ten percent of the area may have 20 per cent cracks, if 90 percent reliability is used for high volume highways. To avoid frequent maintenance, a reliability level of 90 per cent is recommended for highways having a design traffic exceeding 30 msa.

5.1.3 Rutting model:-

The two equations for rutting model at 80% and 90% reliability are given below:-

$N = 4.1656 \times 10^{-08} [1/\varepsilon_v]^{4.5337}$ (80 percent reliability)………. (5.3)

$N = 1.41 \times 10^{-8} \times [1/\varepsilon_v]^{4.5337}$ (90 percent reliability …………. (5.4)

Where, N = Number of standard axles, and

ε_v = Vertical strain in the subgrade

The limiting rutting is recommended as 20 mm in 20% of the length for design traffic up to 30 msa and 10% of the length for the design traffic beyond.

5.14 Basic summary for design through granular base and granular subbase

According to the results obtained from Light compaction test and CBR test, we can design our pavement in the course of granular base and sub-base i.e. for CBR value of 3.2 % at 0% RBI grade 81 and 6.2 % at 2% RBI grade 81. Pavement is designed for 50msa, 100 msa and 150 msa studying the different situations. Values taken for determining the thickness for different layers of pavement has been taken from PLATE 1(CBR 3%) and PLATE 4(CBR 6%) of IRC37:2012, allowable vertical and horizontal strain values are checked at 90% reliability with respect to strain values output from IITPAVE

Table 5.1: Horizontal and vertical Strain values for 50 msa, 100 msa and 150 msa

Traffic	Horizontal Tensile Strain in Bituminous Layer	Vertical Compressive Strain on Subgrade
	Allowable	Allowable
50 msa	2.07 E-04	3.71 E-04
100 msa	1.73 E-04	3.18 E-04
150 msa	1.56 E-04	2.91 E-04

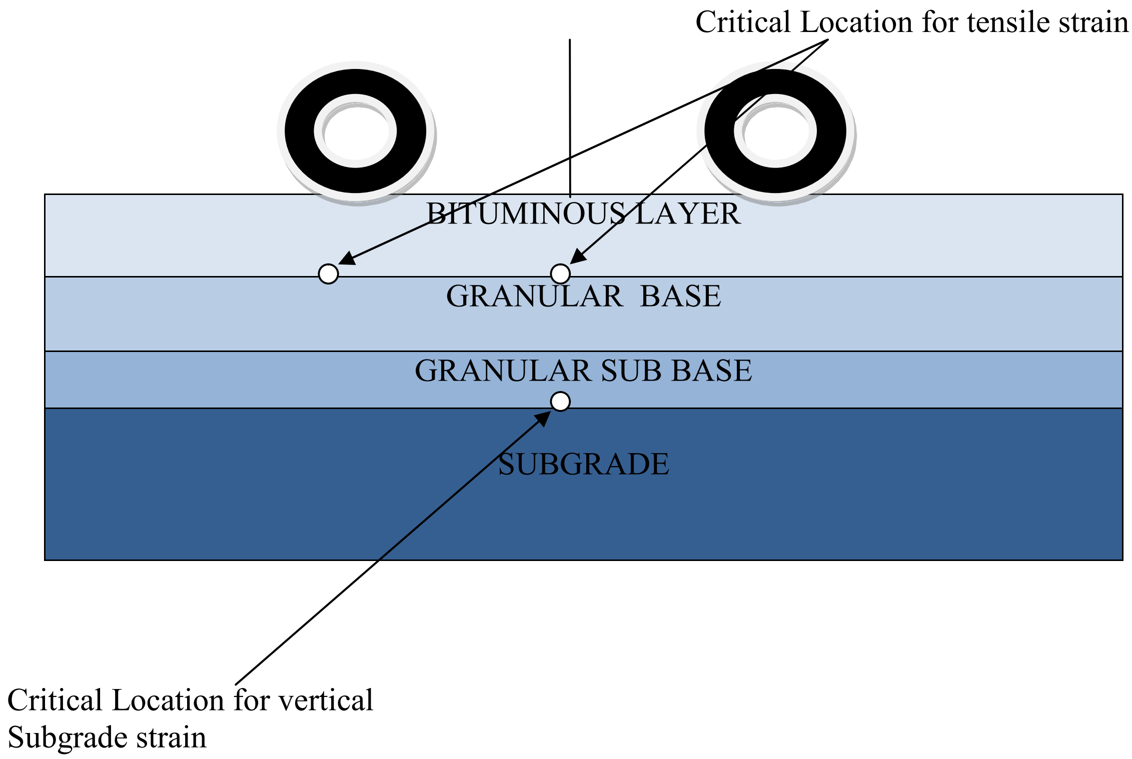


Figure 5.1: Bituminous surfacing with granular base and sub-base

5.2 Analysis of the pavement section with Cementitious Base and RBI treated Subbase with aggregate interlayer.

It consist of five layer elastic structure consisting of bituminous surfacing, aggregate interlayer layer, cemented base, cemented subbase and the subgrade. Material properties such as modulus and Poisson's ratio are the input parameters apart from loads and geometry of the pavement for the IITPAVE software. For traffic greater than 30 msa, minimum thickness of bituminous layer consisting of DBM and BC layers is taken as 100 mm (AASHTO-1993) even though the thickness requirement may be less from structural consideration. Residual life of the bituminous layer against fatigue cracking is not considered since it cracks faster after the fracture of the cemented base. *(CI 10.2 IRC37:2012)*

Rutting model and fatigue model is same as Granular Base and Granular Subbase. (CI 10.1) but there is addition of parameter i.e. Strain analysis for the RBI treated subbase

5.2.1 Strain analysis for the RBI treated subbase

Thickness of the cemented layer is firstly evaluated from fatigue consideration in terms of standard axles the computation of stresses due to the individual wheel load is done by the IITPAVE program.

The design requirement is that the cumulative damage of all wheel loads should be less than 1 during the design life of a pavement. If it is greater than 1, the section has to be changed and iteration done again.

Fatigue Life in Terms of Standard Axles

$$N = RF\left[\frac{(11300/E)^{\cdot 0\ 804} + 191}{e_t}\right]^{12} \ldots\ldots (5.5)$$

Where,

RF = Reliability factor for Cementitious materials for failure against fatigue.

= 1 for Expressways, National Highways and other heavy volume roads.

N = Fatigue life of the Cementitious material.

E = Elastic modulus of Cementitious material.

e_t= tensile strain in the Cementitious layer, micro strain.

5.2.2 Basic summary for design through Cementitious Base and RBI treated Subbase

According to the results achieved at 4%, 6% and 8% dosages of RBI grade 81 i.e. CBR 20.39%, CBR 30.51% and CBR 47.83% we are using second combination for 50 msa, 100 msa and 150 msa i.e. replacing granular sub-base with RBI 81 treated sub-base and granular base with cemented base. Values taken for determining the thickness of different layers for pavement has been taken from PLATE 9(CBR 3%) and PLATE 10(CBR 5%) from IRC 37:2012, further trial and error method was applied for assuming pavement thickness Allowable strain values and strain values from IITPAVE are checked on all the three parameters.

Table 5.2: Horizontal, vertical and tensile Strain values for 50 msa, 100 msa and 150 msa

Traffic	Horizontal Tensile Strain in Bituminous Layer	Vertical Compressive Strain on Subgrade	Tensile Strain in RBI 81 treated Layer
	Allowable	Allowable	Allowable
50 msa	2.07 E-04	3.71 E-04	1.579 E-04
100 msa	1.73 E-04	3.18 E-04	1.491 E-04
150 msa	1.56 E-04	2.91 E-04	1.441 E-04

5.3 Analysis of flexible pavement as per IRC 37:2012 &IITPAVE

A flexible pavement has been modeled as an elastic multilayer structure. Stresses and strains at critical locations are computed using a linear layered elastic model. The Stress analysis software IITPAVE (modified version of FPAVE) has been used for the computation of stresses and strains in flexible pavements.

- **Input data:** Laboratory CBR value of the subgrade soil sample collected.
- **Design traffic** :Design is made out for fix MSA i.e. 50,100,150
- **Output data :**Strain checking and its results(Allowable and Actual) **,**Layer thickness for BC, DBM, WMM and GSB

Table 5.3 – SOIL: RBI 81 relation with OMC, CBR and its E value

CBR VALUES AFTER 4 DAY SOAKING PERIOD					
SOIL:RBI81	100:0	98:2	96:4	95:6	92:8
OMC	14.7	13.2	17.9	19.1	19.04
CBR VALUE (%)	3.2	6.2	20.39	30.51	47.83
E VALUE (MPa)	32	56.50	121.20	156.80	209.10
% INCREASE IN CBR VALUES	_	93.75	537.18	853.5	1394.6

5.3.1 Pavement design analysis for granular base and granular sub-base for subgrade CBR value of 3.2%:

It is considered as a three layer elastic structure consisting of bituminous surfacing, granular Base, granular subbase and subgrade. The granular layers are treated as a single layer. Strain and stresses are required only for three layer elastic system. The critical strains locations are shown in the figure. Pavement thickness for CBR 3.2 % is mentioned in table 5.4 for various layers at different assumed traffic.

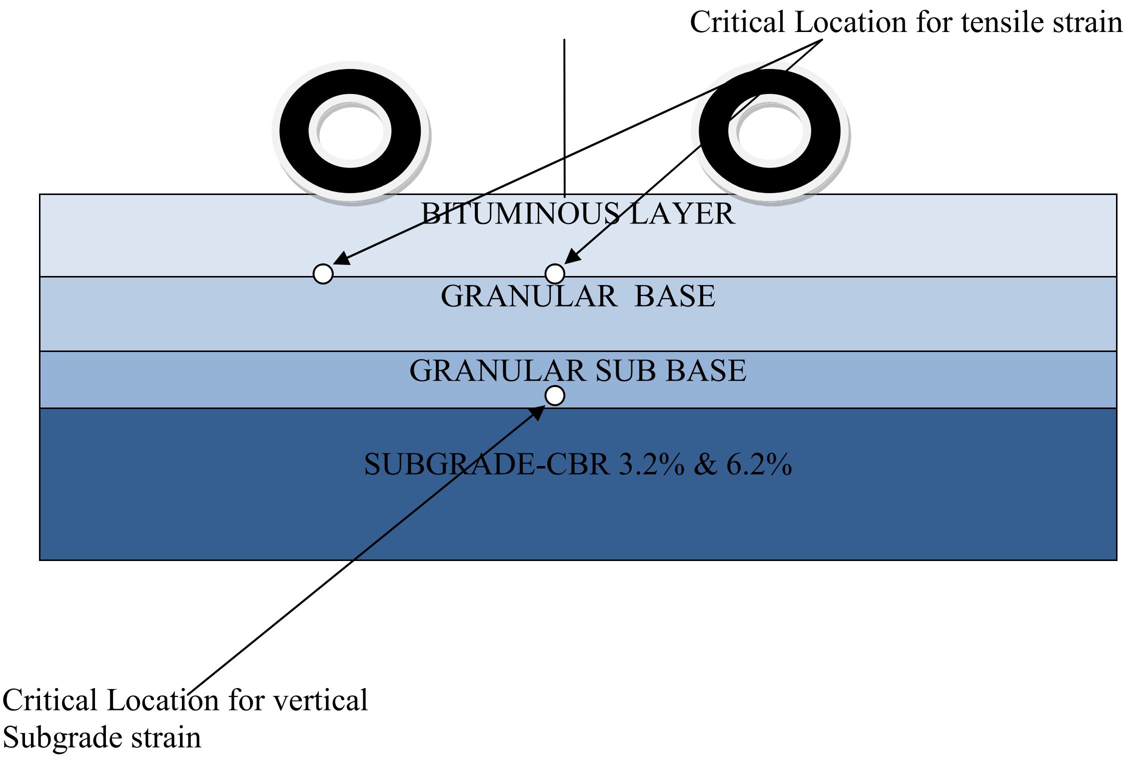


Figure. 5.2: Cross section of a bituminous pavement with granular base and subbase.

Thickness of each layer of flexible pavement resting on undisturbed subgrade soil at different traffic intensities with granular base and subbase.							
S.NO	*CBR Value*	*Traffic Intensity In (MSA)*	*Sub-Base (mm)*	*Base (mm)*	*DBM (mm)*	*BC(mm)*	*Total(mm)*
1	3.2	50	380	250	135	40	805
2	3.2	100	380	250	155	50	835
3	3.2	150	380	250	170	50	850

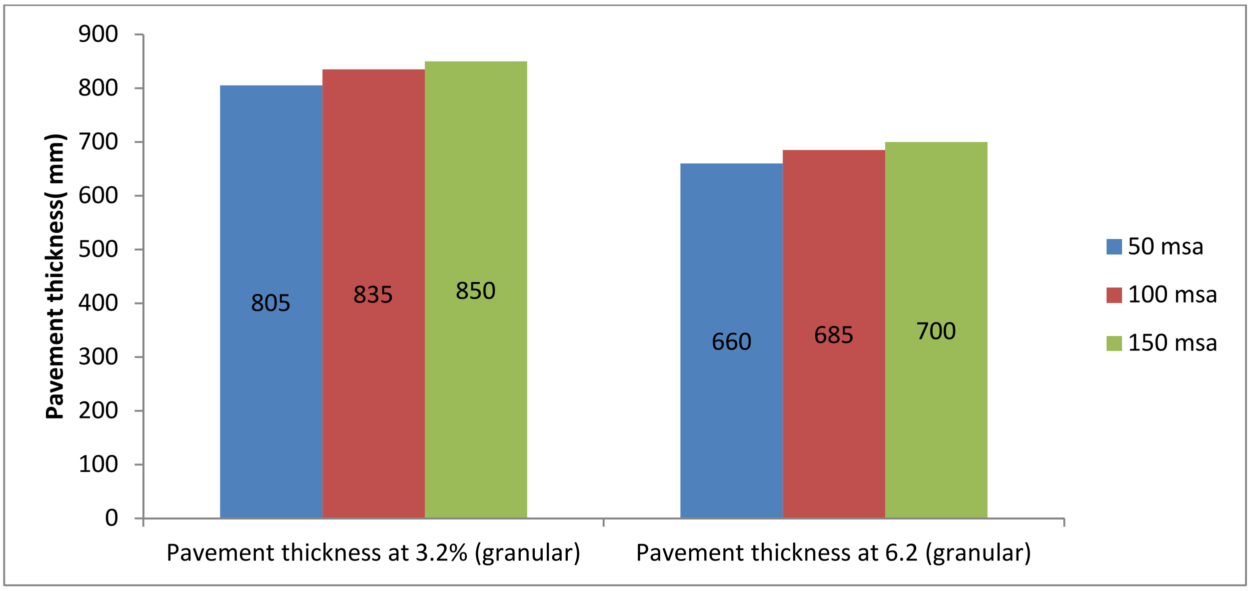
Table 5.4: Thickness for CBR 3.2% at 0% RBI 81 dosage of untreated soil

5.3.2 Pavement design analysis for granular base and granular sub-base for subgrade CBR value of 6.2%

As our CBR outcome at RBI 81 dosage 2% is 6.2%, we will use this % of CBR in our subgrade as it does not fulfill the requirements of getting in sub-base or base. % saving in the Table 5.5 is mentioned in comparison to CBR 3.2% with granular sub-base and base.

Thickness of each layer of flexible pavement resting on undisturbed subgrade soil at different traffic intensities with granular base and subbase at CBR 6.2%								
S.No	*CBR value*	*Traffic Intensity in (msa)*	*Sub-Base (mm)*	*Base (mm)*	*DBM (mm)*	*BC (mm)*	*Total (mm)*	*% Saving*
1	6.2	50	260	250	110	40	660	18.01
2	6.2	100	260	250	125	50	685	17.9
3	6.2	150	260	250	140	50	700	17.6

Table 5.5: Thickness for CBR 6.2% at 2% RBI 81 dosage of untreated soil



Graph 5.1: comparison is shown between CBR 3.2% at 0% RBI 81 dosage and CBR 6.2% at 2% RBI 81 dosage w.r.t pavement thickness

Analysis from graph 5.1:

From the graph it can be concluded that there is % saving of 18.01 %,17.9% & 17.6% in thickness of pavement if we shift our basic subgrade value from 3.2% to 6.2% ,we can achieve this at 2% RBI 81 dosage .According to AUSTROADS -code of practice RC 500.22 i.e. selection and design of pavements and surfacing, thickness of sub-base is specified to 150 mm so here the values for pavement design recommended by IRC 37:2012 are taken upto

150 mm only and actual strain values are checked with respect to calculated allowable values at different assumed traffic msa.

5.3.3 IITPAVE input & output data for cases at 0% & 2% RBI 81 dosages for subgrade

In tables mentioned below are input data and output data from IITPAVE, in input data 3 layers are taken for design which include (bituminous layer+DBM),granular base+granular sub-base and subgrade .Output data has been checked at critical strain points at 155mm and 0 mm from centre of wheel load. Resilient modulus for subgrade and subbase is taken from CL 5.2 (IRC 37:2012) and CL 7.1(IRC 37:2012) and resilient modulus for bituminous layer which is taken 3000MPa is for VG 30 at temp. 30°C from CL 7.4 (IRC 37:2012).Possion ratio for various layers is taken from CL 5.3 and CL 5.4 (IRC 37:2012).

1. IIT PAVE Data for CBR 3.2% -50 msa: In Table 5.6 the values of BC is 40mm, DBM is 135 mm, Granular Base is 250 mm and Granular sub-base is 380mm and output values are shown in table 5.7 at different critical points.

Table 5.6: IIT PAVE input data

<table>
<tr><td>Description</td><td colspan="6">Values</td></tr>
<tr><td>No. of layers</td><td colspan="6">3</td></tr>
<tr><td>E values (MPa)</td><td colspan="2">3000.00</td><td colspan="2">116.38</td><td colspan="2">32.00</td></tr>
<tr><td>Possion ratio values</td><td colspan="2">0.350</td><td colspan="2">.350</td><td colspan="2">.40</td></tr>
<tr><td>Thicknesses (mm)</td><td colspan="3">175.00</td><td colspan="3">630.00</td></tr>
<tr><td>Single wheel load (N)</td><td colspan="6">20000.00</td></tr>
<tr><td>Tyre pressure (MPa)</td><td colspan="6">0.56</td></tr>
<tr><td>Single Wheel/Dual Wheel</td><td colspan="6">Dual Wheel</td></tr>
</table>

Table 5.7: IIT PAVE output data

<table>
<tr><td>Z</td><td>R</td><td>epZ</td><td>epT</td><td>epR</td></tr>
<tr><td colspan="5">Horizontal Tensile Strain in Bituminous Layer</td></tr>
<tr><td>175</td><td>155.00</td><td>N.A.</td><td>0.1959E-03</td><td>N.A.</td></tr>
<tr><td colspan="5">Vertical Compressive Strain on Subgrade</td></tr>
<tr><td>805</td><td>155.00</td><td>0.3080E-03</td><td>N.A</td><td>N.A.</td></tr>
</table>

2. IIT PAVE output data for CBR 3.2% -100 msa: In Table 5.8 the values of BC is 50mm, DBM is 155 mm, Granular Base is 250 mm and Granular sub-base is 380mm and output values are shown in table 5.9 at different critical points.

Table 5.8: IIT PAVE input data

Description	*Values*		
No. of layers	3		
E values (MPa)	3000.00	116.38	32.00
Possion ratio values	0.350	.350	.40
Thicknesses (mm)	205.00	630.00	
Single wheel load (N)	20000.00		
Tyre pressure (MPa)	0.56		
Single Wheel/Dual Wheel	Dual Wheel		

Table 5.9: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
205	155.00	N.A.	**0.1617E-03**	N.A.
Vertical Compressive Strain on Subgrade				
835	155.00	**0.2668E-03**	N.A	N.A.

3. *IIT PAVE output data for CBR 3.2% -150 msa:* In Table 5.10 the values of BC is 50mm, DBM is 170 mm, Granular Base is 250 mm and Granular sub-base is 380mm and output values are shown in table 5.11 at different critical points.

Table 5.10: IIT PAVE input data

Description	*Values*		
No. of layers	3		
E values (MPa)	3000.00	116.38	32.00
Possion ratio values	0.350	.350	.40
Thicknesses (mm)	220.00	630.00	
Single wheel load (N)	20000.00		
Tyre pressure (MPa)	0.56		
Single Wheel/Dual Wheel	Dual Wheel		

Table 5.11: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
220	0.00	N.A.	**0.1513E-03**	N.A.
Vertical Compressive Strain on Subgrade				
850	155.00	**0.2591E-03**	N.A	N.A.

4. ***IIT PAVE output data for CBR 6.2 %-50 msa***: In Table 5.12 the values of BC is 40mm, DBM is 110 mm, Granular Base is 250 mm and Granular sub-base is 380mm and output values are shown in table 5.13 at different critical points.

Table 5.12: IIT PAVE input data

Description	*Values*		
No. of layers	3		
E values (MPa)	3000.00	186.85	56.50
Possion ratio values	0.350	.350	.40
Thicknesses (mm)	150.00	510.00	
Single wheel load (N)	20000.00		
Tyre pressure (MPa)	0.56		
Single Wheel/Dual Wheel	Dual Wheel		

Table 5.13: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
150	155.00	N.A.	**0.1906E-03**	N.A.
Vertical Compressive Strain on Subgrade				
660	155.00	**0.2876E-03**	N.A	N.A.

5. ***IIT PAVE output data for CBR 6.2% -100msa:*** In Table 5.14 the values of BC is 50mm, DBM is 125 mm, Granular Base is 250 mm and Granular sub-base is 380mm and output values are shown in table 5.15 at different critical points

Table 5.14: IIT PAVE input data

Description	*Values*		
No. of layers	3		
E values (MPa)	3000.00	186.85	56.50
Possion ratio values	0.350	.350	.40
Thicknesses (mm)	175.00	510.00	
Single wheel load (N)	20000.00		
Tyre pressure (MPa)	0.56		
Single Wheel/Dual Wheel	Dual Wheel		

Table 5.15: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
175	155.00	N.A.	**0.1636E-03**	N.A.
Vertical Compressive Strain on Subgrade				
685	155.00	**0.2538E-03**	N.A	N.A.

6. IIT PAVE output data for CBR 6.2% -150msa: In Table 5.16 the values of BC is 40mm, DBM is 135 mm, Granular Base is 250 mm and Granular sub-base is 380mm and output values are shown in table 5.17 at different critical points

Table 5.16: IIT PAVE input data

Description	*Values*		
No. of layers	3		
E values (MPa)	3000.00	186.85	56.50
Possion ratio values	0.350	.350	.40
Thicknesses (mm)	190.00	510.00	
Single wheel load (N)	20000.00		
Tyre pressure (MPa)	0.56		
Single Wheel/Dual Wheel	Dual Wheel		

Table 5.17: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
190	0.00	N.A.	**0.1555E-03**	N.A.
Vertical Compressive Strain on Subgrade				
700	155.00	**0.2360E-03**	N.A	N.A.

Table 5.18: Checking actual strain and allowable strain values for CBR 3.2%

Traffic	*Horizontal Tensile Strain in Bituminous Layer*		*Vertical Compressive Strain on Subgrade*	
	Allowable	*Actual*	*Allowable*	*Actual*
50 msa	2.07 E-04	1.95 E-04	3.71 E-04	3.08 E-04
100 msa	1.73 E-04	1.61 E-04	3.18 E-04	2.66 E-04
150 msa	1.56 E-04	1.51 E-04	2.91 E-04	2.59 E-04
	SAFE		SAFE	

Table 5.19: Checking actual strain and allowable strain values for CBR 6.2%

Traffic	*Horizontal Tensile Strain in Bituminous Layer*		*Vertical Compressive Strain on Subgrade*	
	Allowable	*Actual*	*Allowable*	*Actual*
50 msa	2.07 E-05	1.90 E-04	3.71 E-04	2.87 E-04
100 msa	1.73 E-05	1.63 E-04	3.18 E-04	2.53 E-04
150 msa	1.56 E-05	1.55 E-04	2.91 E-04	2.36 E-04
	SAFE		SAFE	

5.3.4 Pavement design analysis for bituminous pavement with cemented base and RBI 81 treated sub-base with aggregate interlayer for subgrade CBR value of 3.2%

It shows a five layer elastic structure consisting of bituminous surfacing, aggregate interlayer layer, cemented base, RBI 81 treated subbase and the subgrade. Material properties such as modulus and Poisson's ratio are the input parameters apart from loads and geometry of the pavement for the IITPAVE software.

- **Input data:** Laboratory CBR value of the subgrade soil sample collected.
- **Design traffic**: Design is made out for fix MSA i.e. 50,100,150.
- **Output data:** Strain checking and its results(Allowable and Actual)**,**Layer thickness for BC, DBM, WMM and GSB

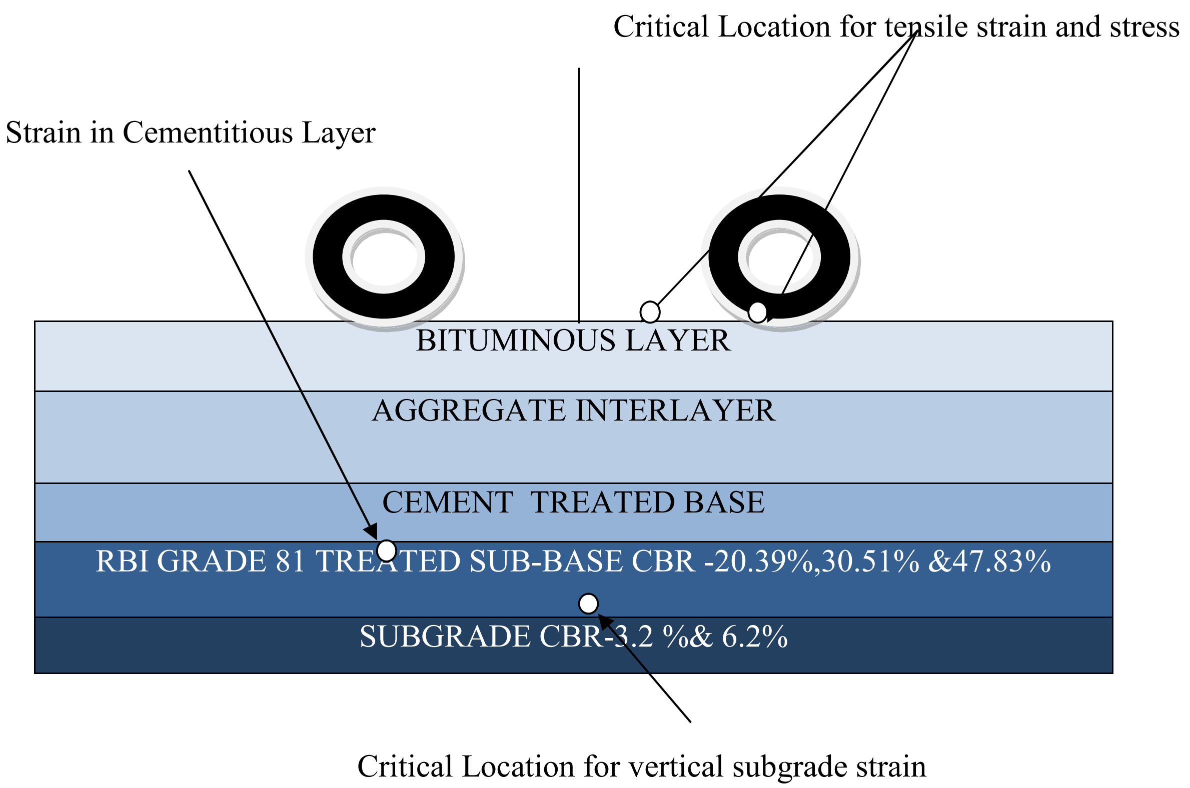


Figure. 5.3 Bituminous Surfacing, Cement Treated Base and RBI Grade 81Treated Sub-Base with Aggregate Interlayer

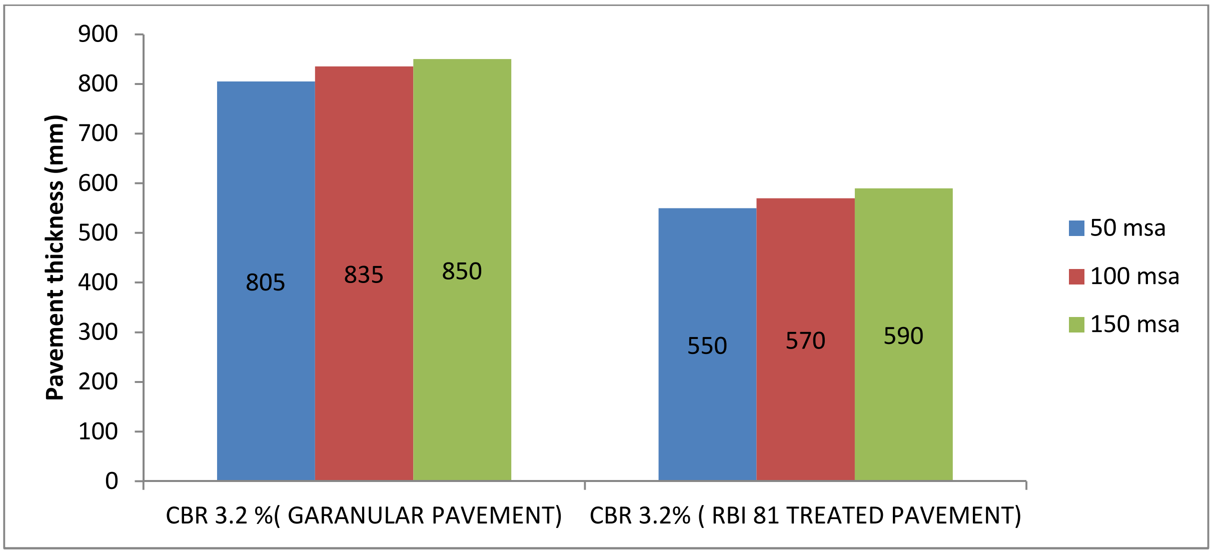
Comparison between of our basic CBR value according to combination first: bituminous surfacing with granular base and granular sub-base and combination second: bituminous surfacing, cemented base and RBI 81 treated sub-base with aggregate interlayer for basic CBR of 3.2%

Table5.20: Thickness for CBR 3.2% at 0% RBI Grade 81 dosage of untreated soil

Thickness of each layer of flexible pavement resting on undisturbed subgrade soil at different traffic intensities with granular base and subbase.							
S.NO	*CBR VALUE*	*TRAFFIC INTENSITY IN (msa)*	*SUB-BASE (mm)*	*BASE (mm)*	*DBM (mm)*	*BC (mm)*	*TOTAL (mm)*
1	3.2	50	380	250	135	50	805
2	3.2	100	380	250	155	50	835
3	3.2	140	380	250	170	50	850

Table5.21: Thickness for CBR 3.2% at 0% RBI Grade 81 dosage of treated soil

Thickness of each layer of flexible pavement resting on undisturbed subgrade soil at different traffic intensities consisting of bituminous surfacing, aggregate interlayer layer, base, RBI 81 treated subbase and the subgrade.									
S.NO	*CBR VALUE*	*TRAFFIC INTENSITY IN (msa)*	*SUB-BASE (mm)*	*BASE (mm)*	*AGGEREGATE INTERLAYER*	*DBM (mm)*	*BC (mm)*	*TOTAL (mm)*	*% SAVING*
1	3.2	50	250	100	100	50	50	550	31.6
2	3.2	100	250	120	100	50	50	570	31.7
3	3.2	150	250	140	100	50	50	590	30.5



Graph 5.2: Comparison between granular CBR 3.2% at 0% RBI Grade 81 dosage and cemented CBR 3.2% at 0% RBI Grade 81 dosage w.r.t pavement thickness

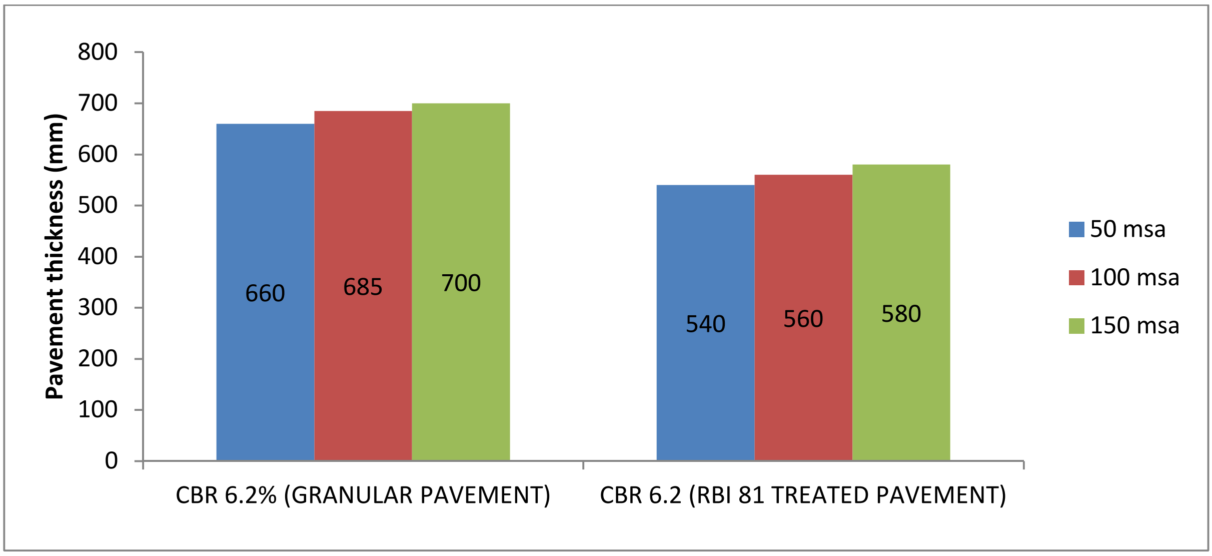
Comparison between our basic CBR value 6.2% at combination first: bituminous surfacing with granular base and granular sub-base and combination second: bituminous surfacing, cemented base and RBI 81 treated sub-base with aggregate interlayer is shown.

Table5.22: Thickness for CBR 6.2% at 2% RBI 81 dosage of untreated soil

Thickness of each layer of flexible pavement resting on undisturbed subgrade soil at different traffic intensities with granular base and subbase.							
S.NO	*CBR VALUE*	*TRAFFIC INTENSITY IN (msa)*	*SUB-BASE (mm)*	*BASE (mm)*	*DBM (mm)*	*BC (mm)*	*TOTAL (mm)*
1	6.2	50	260	250	110	50	660
2	6.2	100	260	250	125	50	685
3	6.2	140	260	250	150	50	710

Table5.23: Thickness for CBR 6.2% at 2% RBI 81 dosage of treated soil

Thickness of each layer of flexible pavement resting on undisturbed subgrade soil at different traffic intensities consisting of bituminous surfacing, aggregate interlayer layer, base, RBI 81 treated subbase and the subgrade. .									
S.NO	CBR	TRAFFIC INTENSITY IN (msa)	SUB-BASE (mm)	BASE (mm)	AGGEREGATE INTERLAYER	DBM (mm)	BC (mm)	TOTAL (mm)	% SAVING
1	6.2	50	240	100	100	50	50	540	18.18
2	6.2	100	240	120	100	50	50	560	18.20
3	6.2	150	240	140	100	50	50	580	17.15



Graph 5.3: Comparison between granular CBR 6.2% at 0% RBI Grade 81 dosage and cemented CBR 6.2% at 0% RBI Grade 81 dosage w.r.t pavement thickness

5.4 Analysis of pavement thickness for bound sub-base using Unconfined Compression Test

The material for bound sub-base may consist of soil, aggregate or soil aggregate Mixture modified with chemical stabilizers such as cement, lime-fly ash, commercially available stabilizers etc. here we are using RBI 81 instead of cement or fly ash. The relevant design parameter for bound sub-bases is the Elastic Modulus E, which can be determined from the unconfined compressive strength of the material.

- ***Strength Parameter***

  E_{cgsb}= 1000 UCS. (CL.7.2.2.2 IRC 37:2012)*

  Where UCS = 28 day strength of the Cementitious granular material

Table5.24: UCS values for different curing period

RBI 81 % dosage	*UCS VALUES IN Kg/cm² and MPa for 1,7,28 days*					
	CURING PERIOD					
	1 DAY (Kg/cm²)	1DAY (MPa)	7 DAYS (Kg/cm²)	7 DAYS (MPa)	28 DAYS (Kg/cm²)	28 DAYS (MPa)
0	1.93	0.189	2.13	0.208	5.91	0.581
2	2.072	0.203	3.630	0.355	5.850	0.572
4	1.99	0.195	5.155	0.505	6.837	0.670
6	2.059	0.200	6.395	0.627	10.003	0.980
8	2.2269	0.218	9.658	0.956	18.195	1.780

Table5.25: E, possion's ratio and thickness for various layers

LAYER	*E VALUE (MPa)*						*μ VALUE*	*THICKNESS(mm)*
BITUMENOUS LAYER	3000						0.35	100
AGGEREGATE INTERLAYER	450						0.35	100
CEMENT TREATED BASE AS PER IRC 37:2012	5000						0.25	Depend upon given msa
RBI 81 TREATED SUB-BASE	CBR	3.2	6.2	20.39	30.51	47.83	0.25	Depend upon given msa and IIT PAVE values
		600	600	670	980	1780		
SUBGRADE		32	56.50	121.20	156.8	209.1	0.4	500
RB1 Grade 81	630						0.35	

5.4.1 Pavement design using UCS method

Comparison between pavement thickness with CBR values at RBI 81 dosage 4%, 6% and 8% w.r.t CBR value of virgin soil in combination of cemented base and RBI 81 treated sub-Base with aggregate interlayer is shown .According to VICROADS - code of practice RC 500.22 i.e. selection and design of pavements and surfacing, thickness of cemented sub-base is specified to 130mm for CBR 20% for modulus 2000mpa Resilient modulus values for RBI 81 treated subbase are fixed 600 MPa for CBR 3.2% and 6.2% further E values from UCS test are used in calculating the strain values.

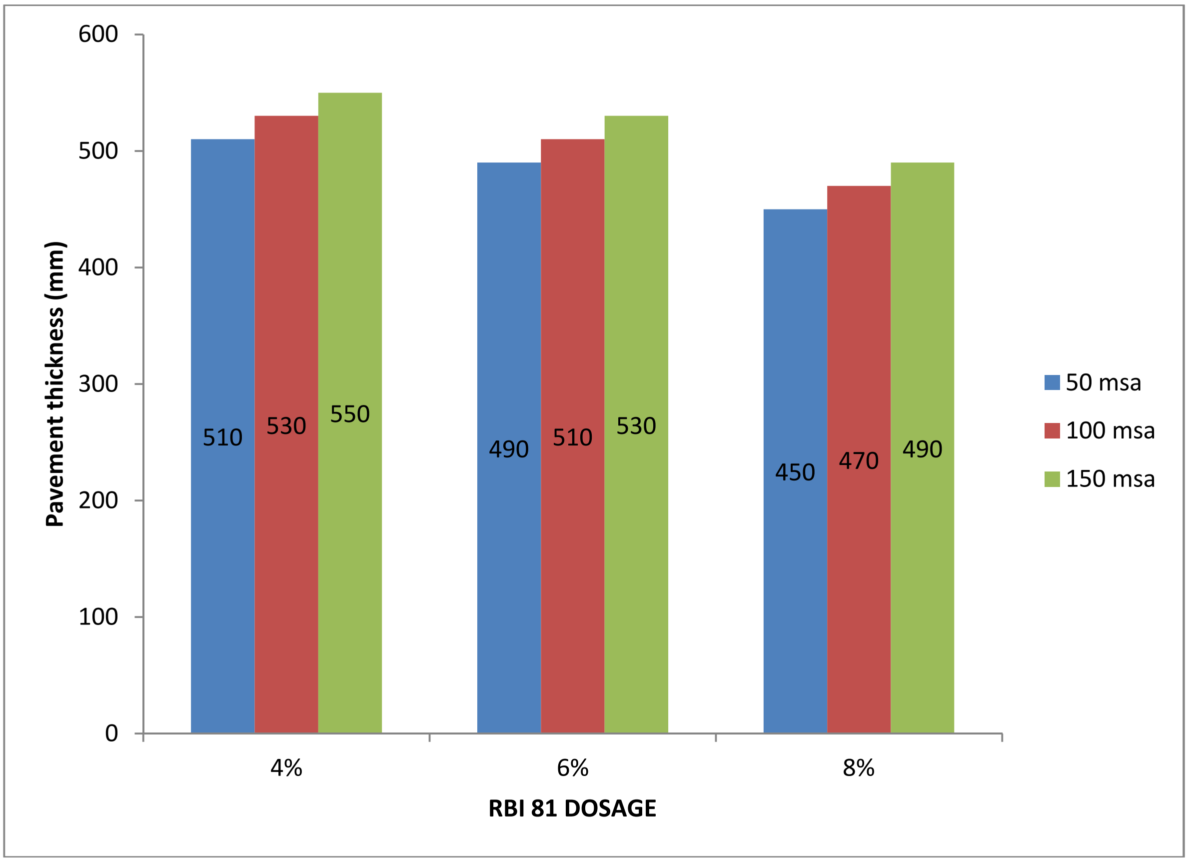
Thickness comparison between different dosages of RBI 81and there achieved CBR results are shown in Table 5.26 and Table 5.27 and difference in thickness can also be studied through Graph 5.4

Table5.26: Comparison Table for pavement thickness at RBI 81 dosage of 4%, 6% and 8% with RBI 81 dosage of 0% (Table 5.27)

Thickness of various layers and total thickness of pavement resting on stabilized subgrade and sub-base soil (IRC37:2012)									
S.NO	*RBI:SOIL*	*CBR VALUE*	*SUB-BASE (mm)*	*BASE (mm)*	*AGGEREGATE INTERLAYER*	*DBM (mm)*	*BC (mm)*	*TOTAL (mm)*	*THICKNESS REDUCTION (mm)*
For 50msa,100msa,150 msa									
50 msa									
1	96-4	20.39	210	100	100	50	50	510	40
2	94-6	30.51	190	100	100	50	50	490	60
3	92-8	47.83	150	100	100	50	50	450	100
100 msa									
1	96-4	20.39	210	120	100	50	50	530	40
2	94-6	30.51	190	120	100	50	50	510	60
3	92-8	47.83	150	120	100	50	50	470	100
150 msa									
1	96-4	20.39	210	140	100	50	50	550	40
2	94-6	30.51	190	140	100	50	50	530	60
3	92-8	47.83	150	140	100	50	50	490	100

Table 5.27: Pavement thickness for bound sub-base and stabilized subgrade CBR 3.2%

Thickness of each layer of flexible pavement resting on undisturbed subgrade soil at different traffic intensities consisting of bituminous surfacing, aggregate interlayer layer, base, RBI 81 treated subbase and the subgrade. .								
S.NO	CBR	TRAFFIC INTENSITY IN (msa)	SUB-BASE (mm)	BASE (mm)	AGGEREGATE INTERLAYER	DBM (mm)	BC (mm)	TOTAL (mm)
1	3.2	50	250	100	100	50	50	550
2	3.2	100	250	120	100	50	50	570
3	3.2	150	250	140	100	50	50	590



Graph 5.4: Comparison between dosages of RBI Grade 81 4%, 6% and 8% for bound base and sub-base and stabilized subgrade

5.4.2 IITPAVE input and output data for cases at 0%, 2% 4%, 6% and 8% RBI 81 dosage for design of RBI 81 treated sub-base.

IITPAVE input and output tables are shown below for given RBI grade 81 dosages and E value for sub-base is calculated through the results of UCS test. Pavement thickness is assumed according to the IRC 37:2012.Pavement is designed by considering dual wheel in input data.

1. IIT PAVE output data for CBR 3.2% -50 msa: In Table 5.28 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 100mm and RBI treated sub-base is 250mm, E value for sub-base is 600 MPa and output values are shown in table 5.29 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.

Table 5.28: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**600**	32
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	100	250	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table5.29: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1652E-03**	N.A.
Tensile Strain in RBI 81 Layer				
300	155.00	N.A	N.A	**0.3937E-04**
Vertical Compressive Strain on Subgrade				
550	155.00	**0.2853E-03**	N.A	N.A

2. IIT PAVE output data for CBR 3.2% -100 msa: In Table 5.30 the values of BC is50mm, DBM is 50mm, Aggregate Interlayer is100mm, cemented Base is 120mm and RBI treated sub-base is 250mm, E value for sub-base is 600 MPa and output values are shown in table 5.31 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base. Poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table 5.30: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**600**	32
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	120	250	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table5.31: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1592E-03**	N.A.
Tensile Strain in RBI 81 Layer				
320	155.00	N.A	N.A	**0.3957E-04**
Vertical Compressive Strain on Subgrade				
570	155.00	**0.2586E-03**	N.A	N.A

3. IIT PAVE output data for CBR 3.2% -150 msa: Table 5.32 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 140mm and RBI treated sub-base is 250mm, E value for sub-base is 600 MPa and output values are shown in table 5.33at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table5.32: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**600**	32
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	140	250	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table5.33: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1539E-03**	N.A.
Tensile Strain in RBI 81 Layer				
340	155.00	N.A	N.A	**0.3899E-04**
Vertical Compressive Strain on Subgrade				
590	155.00	**0.2356E-03**	N.A	N.A

***4. IIT PAVE output data for CBR 6.2% -50 msa*:** In Table 5.34 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer=100mm, cemented Base=100mm and RBI treated sub-base=240mm, E value for sub-base =600 MPa and output values are shown in table 5.35 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table5.34: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**600**	56.50
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	100	240	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table5.35: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1585E-03**	N.A.
Tensile Strain in RBI 81 Layer				
300	155.00	N.A	N.A	**0.3663E-04**
Vertical Compressive Strain on Subgrade				
540	155.00	**0.2518E-03**	N.A	N.A

***5. IIT PAVE output data for CBR 6.2% -100 msa*:** In Table 5.36 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 120mm and RBI treated sub-base is 240mm, E value for sub-base is 600 MPa and output values are shown in table 5.37 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table5.36: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**600**	56.50
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	120	240	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table 5.37: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1530E-03**	N.A.
Tensile Strain in RBI 81 Layer				
320	155.00	N.A	N.A	**0.3685E-04**
Vertical Compressive Strain on Subgrade				
560	155.00	**0.2198E-03**	N.A	N.A

***6. IIT PAVE output data for CBR 6.2% -150 msa*:** In Table 5.38 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 140mm and RBI treated sub-base is 240mm, E value for sub-base is 600 MPa and output values are shown in table 5.39 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases

Table5.38: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**600**	56.50
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	140	240	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

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Table5.39: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1582E-03**	N.A.
Tensile Strain in RBI 81 Layer				
340	155.00	N.A	N.A	**0.3633E-04**
Vertical Compressive Strain on Subgrade				
580	155.00	**0.2001E-03**	N.A	N.A

***7. IIT PAVE output data for CBR 20.39%-50 msa*:** In Table 5.40 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 100mm and RBI treated sub-base is 210mm, E value for sub-base is 670 MPa and output values are shown in table 5.41at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table5.40: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**670**	121.20
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	100	210	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table5.41: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1585E-03**	N.A.
Tensile Strain in RBI 81 Layer				
300	0.00	N.A	N.A	**0.2961E-04**
Vertical Compressive Strain on Subgrade				
510	155.00	**0.1877E-03**	N.A	N.A

8. IIT PAVE output data for CBR 20.39%-100 msa: In Table 5.42 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 120mm and RBI treated sub-base is 210mm, E value for sub-base is 670 MPa and output values are shown in table 5.43 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table5.42: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**670**	121.20
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	120	210	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table5.43: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1538E-03**	N.A.
Tensile Strain in RBI 81 Layer				
320	155.00	N.A	N.A	**0.3168E-04**
Vertical Compressive Strain on Subgrade				
530	155.00	**0.1707E-03**	N.A	N.A

9. IIT PAVE output data for CBR 20.39%-150 msa: In table 5.44 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 140mm and RBI treated sub-base is 210mm, E value for sub-base is 670 MPa and output values are shown in table 5.45 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table5.44: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**670**	121.20
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	140	210	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table5.45: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1397E-03**	N.A.
Tensile Strain in RBI 81 Layer				
340	155.00	N.A	N.A	**0.3135E-04**
Vertical Compressive Strain on Subgrade				
550	155.00	**0.1555E-03**	N.A	N.A

***10. IIT PAVE output data for CBR 30.51%-50msa*:** In table 5.46 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 100mm and RBI treated sub-base is 190mm, E value for sub-base is 980 MPa and output values are shown in table 5.47 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases

Table5.46: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**980**	156.80
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	100	190	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

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Table 5.47: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1513E-03**	N.A.
Tensile Strain in RBI 81 Layer				
300	155.00	N.A	N.A	**0.2519E-04**
Vertical Compressive Strain on Subgrade				
490	155.00	**0.1633E-03**	N.A	N.A

***11. IIT PAVE output data for CBR 30.51%-100msa**:* In table 5.48 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 120mm and RBI treated sub-base is 190mm, E value for sub-base is 980 MPa and output values are shown in table 5.49 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table 5.48: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**980**	156.80
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	120	190	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table 5.49: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1375E-03**	N.A.
Tensile Strain in RBI 81 Layer				
320	155.00	N.A	N.A	**0.2597E-04**
Vertical Compressive Strain on Subgrade				
510	155.00	**0.1590E-03**	N.A	N.A

12. IIT PAVE output data for CBR 30.51%-150msa: In table 5.50 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 140mm and RBI treated sub-base is 190mm, E value for sub-base is 980MPa and output values are shown in table 5.51 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table5.50: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**980**	156.80
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	140	190	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table 5.51: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1352E-03**	N.A.
Tensile Strain in RBI 81 Layer				
340	155.00	N.A	N.A	**0.2511E-04**
Vertical Compressive Strain on Subgrade				
530	155.00	**0.1362E-03**	N.A	N.A

13. IIT PAVE output data for CBR 47.83%-50msa: In table 5.52 the values of BC is 50mm, DBM is50mm, Aggregate Interlayer is 100mm, cemented Base is 100mm and RBI treated sub-base is 150mm, E value for sub-base is 1780MPa and output values are shown in table 5.53 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table5.52: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**1780**	209.10
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	100	150	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table 5.53: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1353E-03**	N.A.
Tensile Strain in RBI 81 Layer				
300	155.00	N.A	N.A	**0.1650E-04**
Vertical Compressive Strain on Subgrade				
450	155.00	**0.1505E-03**	N.A	N.A

14. IIT PAVE output data for CBR 47.83%-100msa: In table 5.54 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 120mm and RBI treated sub-base is 150mm, E value for sub-base is 1780MPa and output values are shown in table 5.55 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases

Table 5.54: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**1780**	209.10
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	120	150	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

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Table 5.55: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1313E-03**	N.A.
Tensile Strain in RBI 81 Layer				
320	155.00	N.A	N.A	**0.1751E-04**
Vertical Compressive Strain on Subgrade				
470	155.00	**0.1285E-03**	N.A	N.A

15. IIT PAVE output data for CBR 47.83%-150msa: In table 5.56 the values of BC is 50mm, DBM is 50mm, Aggregate Interlayer is 100mm, cemented Base is 140mm and RBI treated sub-base is150mm, E value for sub-base is 1780MPa and output values are shown in table 5.57 at different critical points, for tensile strain critical point is between RBI treated subbase and cemented base.poission ratio values taken are mentioned in IRC 37:2012 for various cases.

Table5.56: IIT PAVE input data

Description	*Values*				
No. of layers	5				
E values (MPa)	3000	450	5000	**1780**	209.10
Possion ratio values	0.35	0.35	0.25	0.25	0.40
Thicknesses (mm)	100	100	140	150	-
Single wheel load (N)	20000.00				
Tyre pressure (MPa)	0.56				

Table5.57: IIT PAVE output data

Z	*R*	*epZ*	*epT*	*epR*
Horizontal Tensile Strain in Bituminous Layer				
0	0.00	N.A.	**0.1287E-03**	N.A.
Tensile Strain in RBI 81 Layer				
340	155.00	N.A	N.A	**0.1805E-04**
Vertical Compressive Strain on Subgrade				
490	155.00	**0.1178E-03**	N.A	N.A

- Checking actual strain values and allowable strain value for the CBR values of 20.39%, 30.51% and 47.83% which we achieved at RBI grade 81 dosages of 4%, 6% an 8%.these CBR values are used in sub-base in pavement design

Table5.58: Checking actual strain and allowable strain values for CBR 20.39%

Traffic	*Horizontal Tensile Strain in Bituminous Layer*		*Vertical Compressive Strain on Subgrade*		*Tensile Strain in Cementitious Layer*	
	Allowable	*IITPAVE*	*Allowable*	*IITPAVE*	*Allowable*	*IITPAVE*
50 msa	2.07 E-04	1.58 E-04	3.71 E-04	1.87 E-04	1.579 E-04	0.29 E-04
100 msa	1.73 E-04	1.53 E-04	3.18 E-04	1.70 E-04	1.491 E-04	0.31 E-04
150 msa	1.56 E-04	1.39 E-04	2.91 E-04	1.55 E-04	1.441 E-04	0.31 E-04
REMARK	SAFE		SAFE		SAFE	

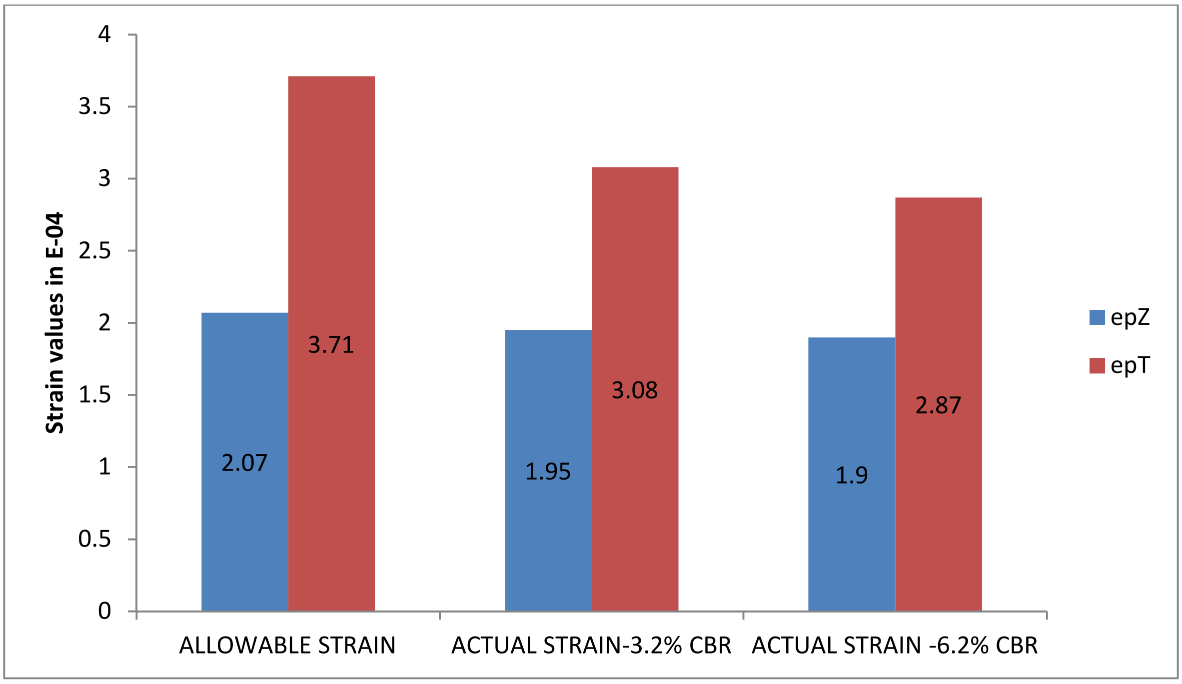
Table5.59: Checking actual strain and allowable strain values for CBR 30.51%

Traffic	Horizontal Tensile Strain in Bituminous Layer		Vertical Compressive Strain on Subgrade		Tensile Strain in RBI 81 Layer	
	Allowable	IITPAVE	Allowable	IITPAVE	Allowable	IITPAVE
50 msa	2.07 E-04	1.51 E-04	3.71 E-04	1.63 E-04	1.579 E-04	0.25 E-04
100 msa	1.73 E-04	1.37 E-04	3.18 E-04	1.59 E-04	1.491 E-04	0.25 E-04
150 msa	1.56 E-04	1.35 E-04	2.91 E-04	1.36 E-04	1.441 E-04	0.25 E-04
REMARK	SAFE		SAFE		SAFE	

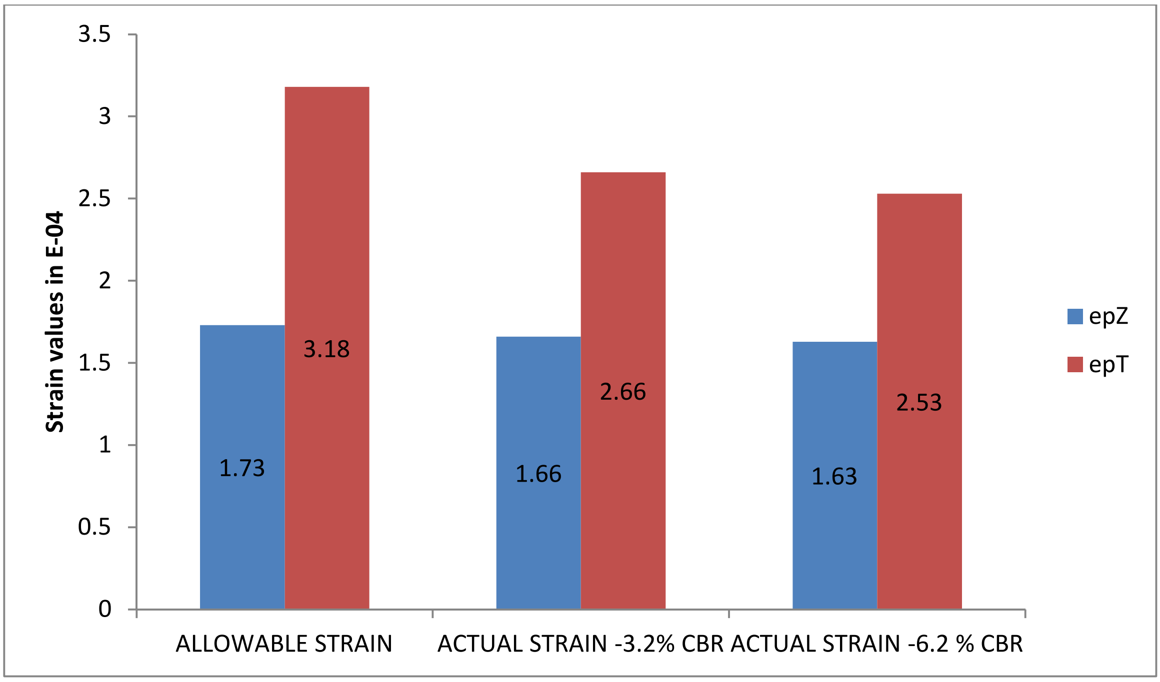
Table5.60: Checking actual strain and allowable strain values for CBR 47.83%

Traffic	Horizontal Tensile Strain in Bituminous Layer		Vertical Compressive Strain on Subgrade		Tensile Strain in RBI 81 Layer	
	Allowable	IITPAVE	Allowable	IITPAVE	Allowable	IITPAVE
50 msa	2.07 E-04	1.35 E-04	3.71 E-04	1.50 E-04	1.579 E-04	0.16E-04
100 msa	1.73 E-04	1.31 E-04	3.18 E-04	1.28 E-04	1.491 E-04	0.17 E-04
150 msa	1.56 E-04	1.28 E-04	2.91 E-04	1.17 E-04	1.441 E-04	0.18 E-04
REMARK	SAFE		SAFE		SAFE	

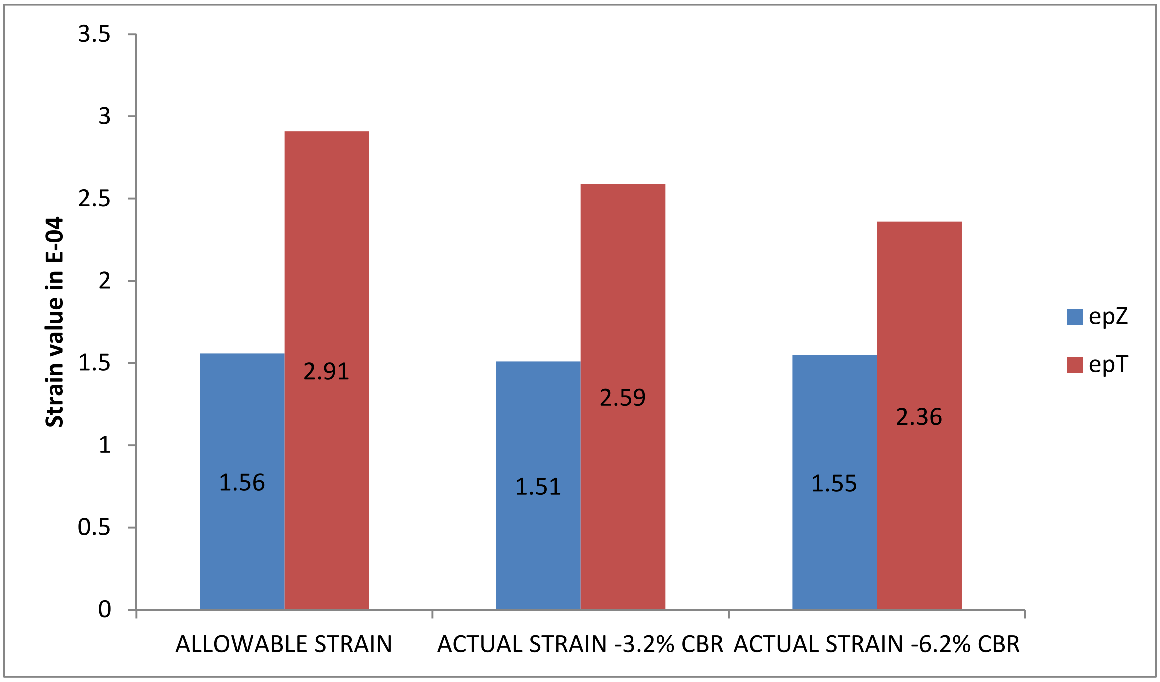
- Through Graphs the difference between allowable and actual strain values at different design traffics will be understood



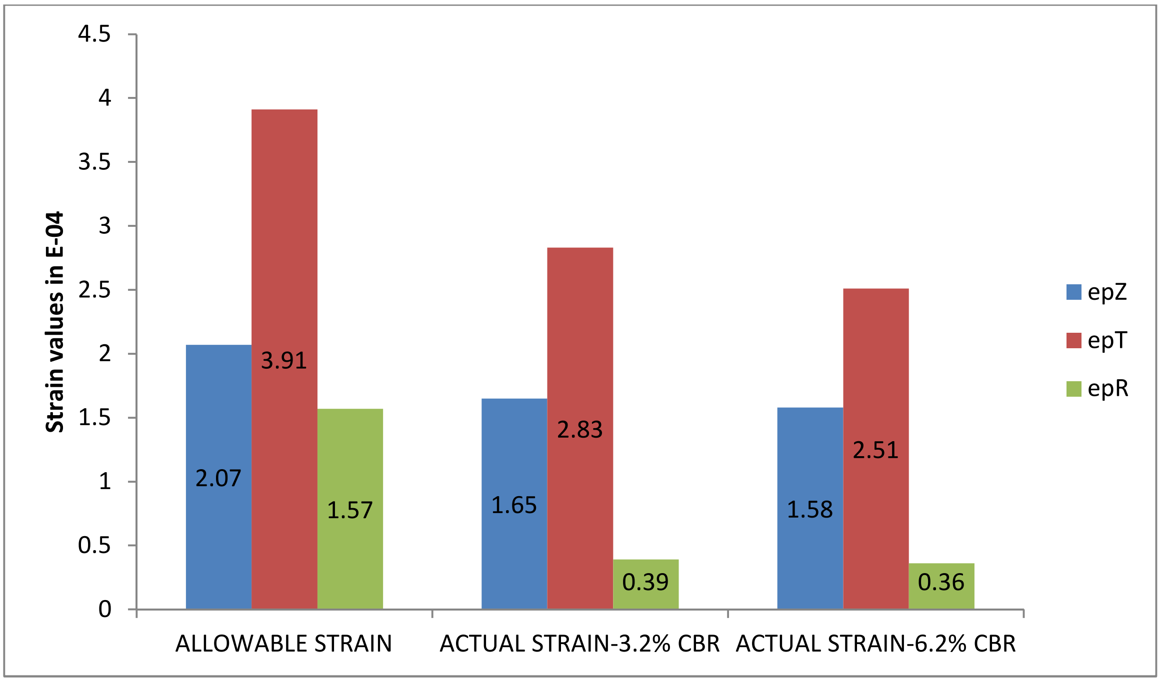
Graph 5.5: Checking of strain values for granular base and sub-base at 50 msa for CBR of 3.2% and 6.2%



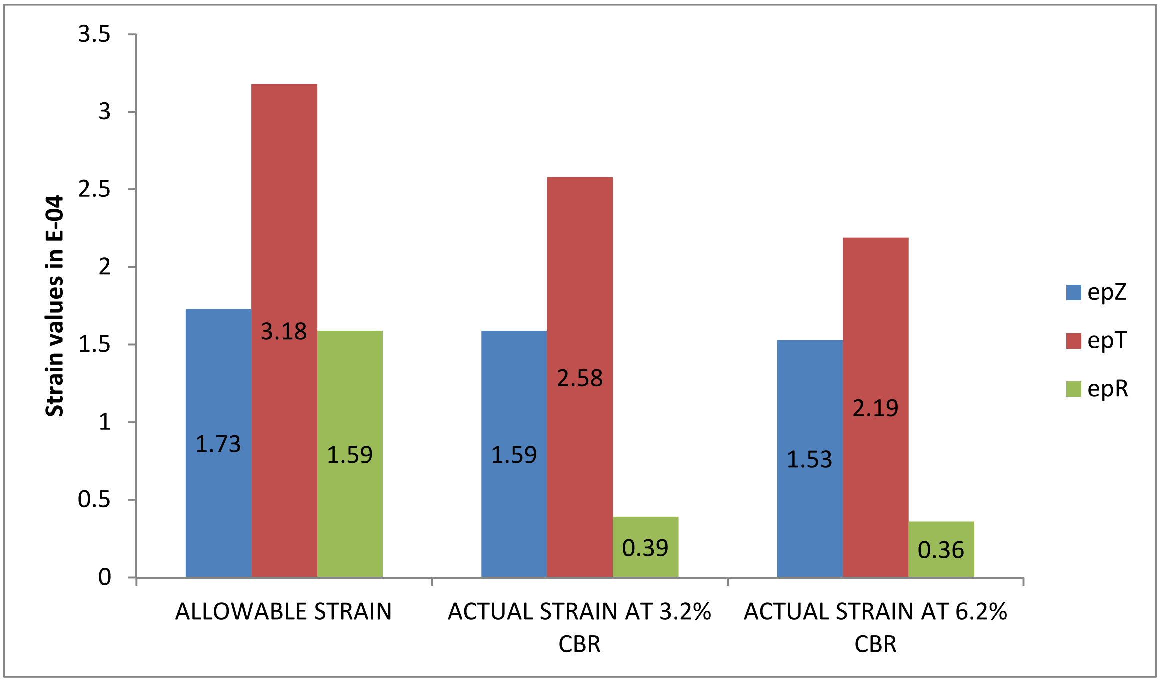
Graph 5.6: Checking of strain values for granular base and sub-base at 100 msa for CBR of 3.2 %and 6.2%



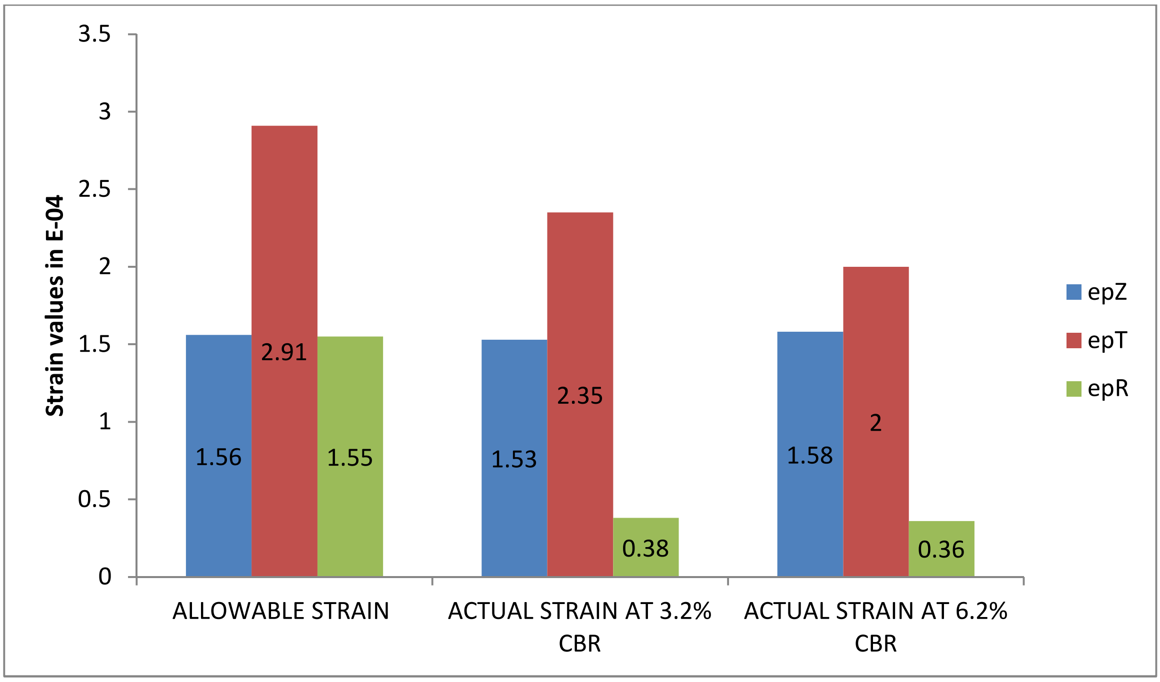
Graph 5.7: Checking of strain values for granular base and sub-base at 150 msa for CBR of 3.2 %and 6.2%



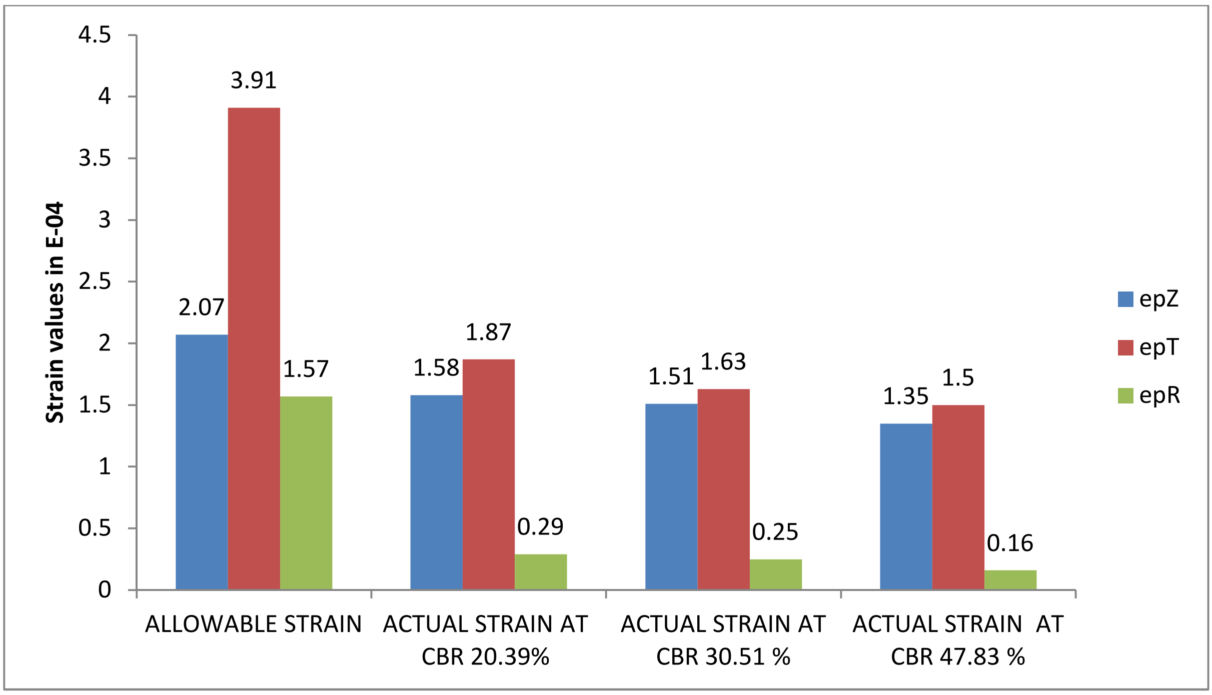
Graph5.8: Checking of strain values for cemented base and RBI Grade 81 treated sub-base at 50 msa for CBR of 3.2% and 6.2%



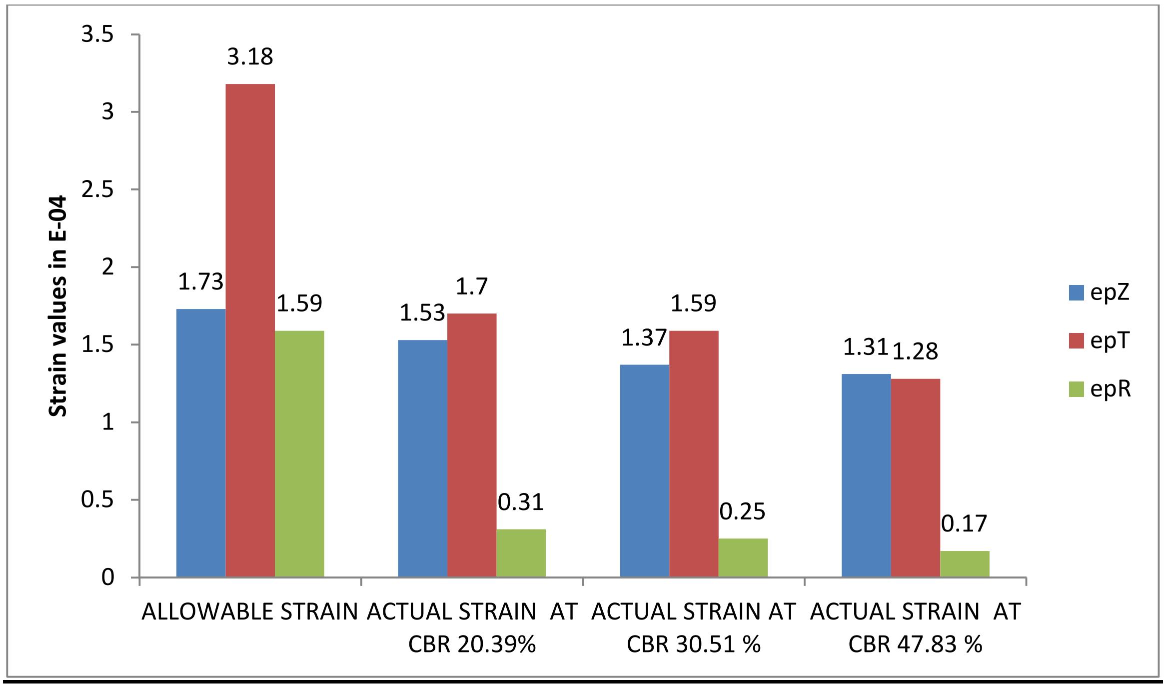
Graph 5.9: Checking of strain values for cemented base and RBI Grade 81 treated sub-base at 100 msa for CBR of 3.2% and 6.2%



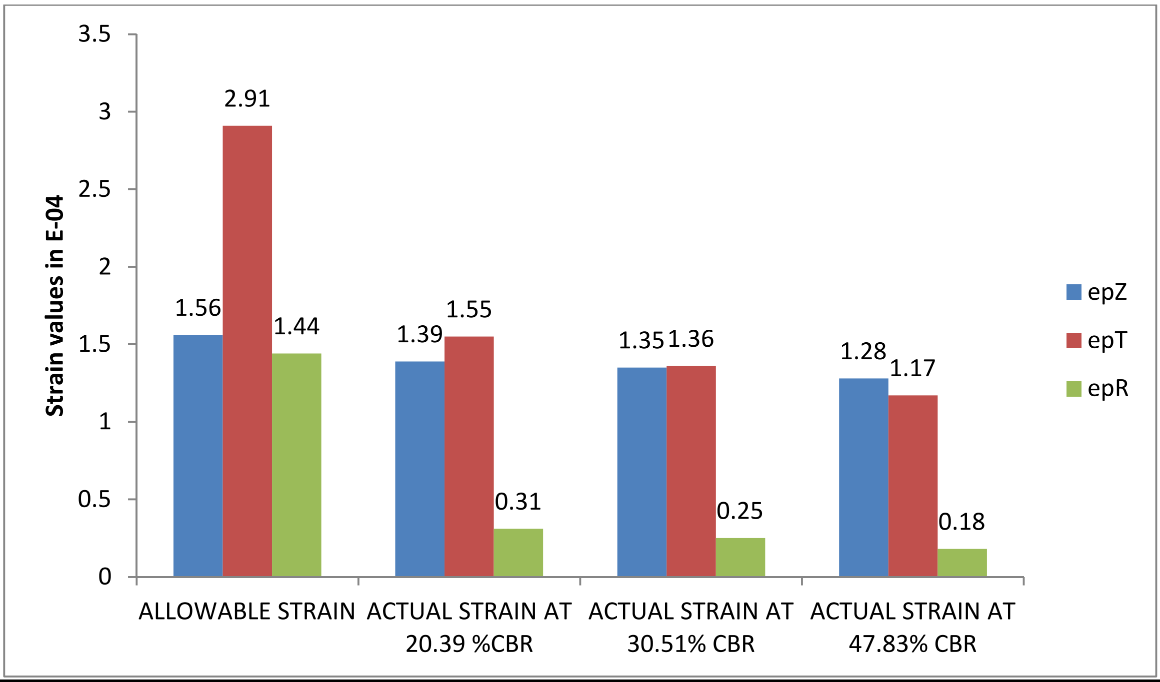
Graph 5.10: Checking of strain values for cemented base and RBI Grade 81 treated sub-base at 150 msa for CBR of 3.2% and 6.2%



Graph 5.11: Checking of strain values for cemented base and RBI Grade 81 treated sub-base at 50 msa for CBR 20.39%, 30.51% and 47.83%.



Graph 5.12: Checking of strain values for cemented base and RBI Grade 81 treated sub-base at 100 msa for CBR 20.39%, 30.51% and 47.83%.



Graph 5.13: Checking of strain values for cemented base and RBI Grade 81 treated sub-base at 100 msa for CBR 20.39%, 30.51% and 47.83%.

5.5 Cost analysis for pavement design

Cost analysis has been done for road having 1 km length, 3.75m width as shown in Tables. Schedule of rates of work is being taken by public work department- Delhi schedule of rates under Govt. of INDIA.

Table5.61: Cost Analysis for CBR 3.2 %Granular Sub-base and Base

S.No.	*Description*	*Layers*	*Layer Thickness (mm)*	*Cost of layer/m^3 (Rs.)*	*Total Cost of layer/Km (Rs.)*
1.	Soil Sample with CBR= 3.2% (Granular pavement) for design traffic = 50msa	GSB	380	1397	19,90,725
		WMM	250	2513	22,62,187
		DBM	135	11059	55,93,556
		BC	40	12065	18,09,750
		Total Cost of Road per Km (Rs.)			**1,16,56,218**
2.	Soil Sample with CBR= 3.2% (Granular pavement) for design traffic = 100msa	GSB	380	1397	19,90,725
		WMM	250	2513	22,62,187
		DBM	155	11059	65,22,231
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**1,29,37,330**
3.	Soil Sample with CBR= 3.2% (Granular pavement) for design traffic = 150msa	GSB	380	1397	19,90,725
		WMM	250	2513	22,62,187
		DBM	170	11059	70,53,737
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**1,35,58,836**

Table5.62: Cost Analysis for CBR 6.2%Granular Sub-Base and Base

S.No.	*Description*	*Layers*	*Layer Thickness (mm)*	*Cost of layer/m³ (Rs.)*	*Total Cost of layer/Km (Rs.)*
1.	Soil Sample with CBR= 6.2% (Granular pavement) for design traffic = 50msa	GSB	260	1397	13,62,075
		WMM	250	2513	22,62,187
		DBM	110	11059	55,57,712
		BC	40	12065	18,09,750
		Total Cost of Road per Km (Rs.)			**99,91,725**
2.	Soil Sample with CBR= 6.2% (Granular pavement) for design traffic = 100msa	GSB	260	1397	13,62,075
		WMM	250	2513	22,62,187
		DBM	125	11059	51,79,218
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**1,10,65,667**
3.	Soil Sample with CBR= 3=6.2% (Granular pavement) for design traffic = 150msa	GSB	260	1397	13,62,075
		WMM	250	2513	22,62,187
		DBM	150	11059	58,00,725
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**1,16,87,175**

Table5.63: Cost Analysis for CBR 3.2% RBI Grade 81Treated Sub-Base and Cemented Base

S.No.	*Description*	*Layers*	*Layer Thickness (mm)*	*Cost of layer/m^3 (Rs.)*	*Total Cost of layer/Km (Rs.)*
1.	Soil Sample with CBR= 3.2% (RBI Grade 81 treated pavement) for design traffic = 50msa	RBI 81 TREATED GSB	250	588	5,57,500
		CEMENTED BASE	100	686	2,57,250
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,188
		Total Cost of Road per Km (Rs.)			**56,11,126**
2.	Soil Sample with CBR= 3.2% (RBI Grade 81 treated pavement) for design traffic = 100msa	RBI 81 TREATED GSB	250	588	5,57,500
		CEMENTED BASE	120	686	3,08,700
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**56,62,575**
3.	Soil Sample with CBR= 3.2% (RBI Grade 81 treated pavement) for design traffic = 150msa	RBI 81 TREATED GSB	250	588	5,57,500
		CEMENTED BASE	140	686	3,60,150
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**57,15,025**

Table5.64: Cost Analysis for CBR 6.2% RBI Grade81 treated Sub-Base and cemented Base

S.No.	*Description*	*Layers*	*Layer Thickness (mm)*	*Cost of layer/m^3 (Rs.)*	*Total Cost of layer/Km (Rs.)*
1.	Soil Sample with CBR= 6.2% (RBI Grade 81 treated pavement) for design traffic = 50msa	RBI 81 TREATED GSB	240	588	5,39,200
		CEMENTED BASE	100	686	2,57,250
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**55,92,825**
2.	Soil Sample with CBR= 6.2% (RBI Grade 81 treated pavement) for design traffic = 100msa	RBI 81 TREATED GSB	240	588	5,39,200
		CEMENTED BASE	120	686	3,08,700
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**56,55,275**
3.	Soil Sample with CBR= 6.2% (RBI Grade 81 treated pavement) for design traffic = 150msa	RBI 81 TREATED GSB	240	588	5,39,200
		CEMENTED BASE	140	686	3,60,150
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**56,95,725**

Table5.65: Cost Analysis for CBR 20.39% RBI Grade81 Treated Sub-Base and Cemented Base

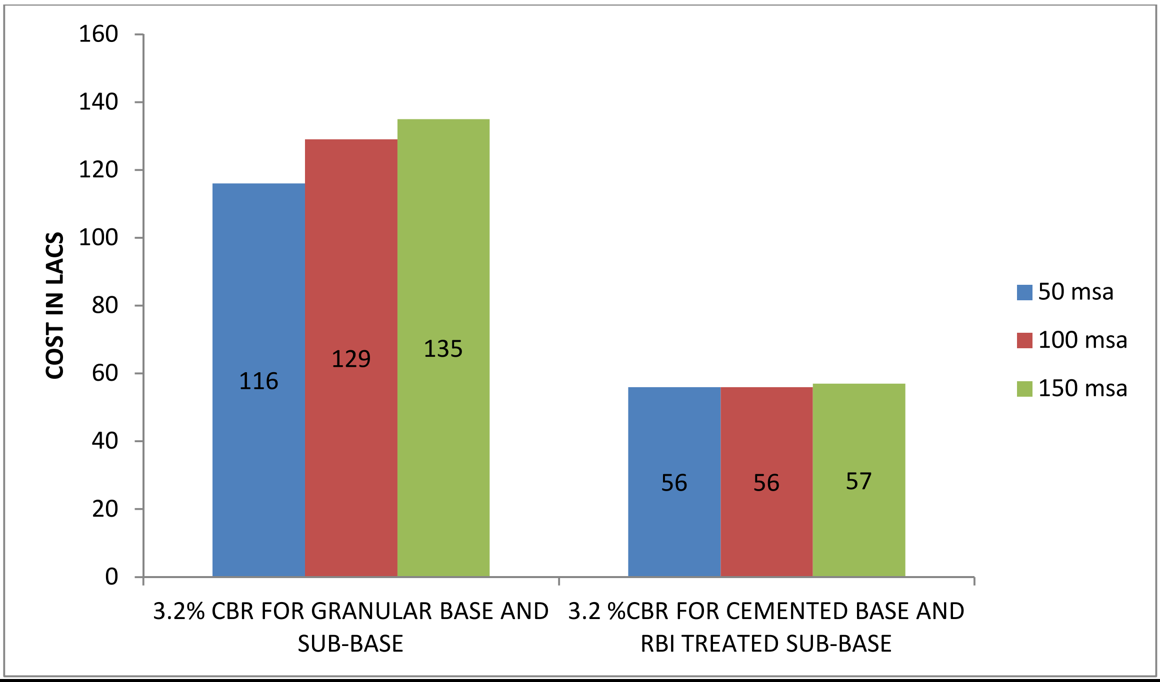
S.No.	*Description*	*Layers*	*Layer Thickness (mm)*	*Cost of layer/m³ (Rs.)*	*Total Cost of layer/Km (Rs.)*
1.	Soil Sample with CBR= 20.39% (RBI Grade 81 treated pavement) for design traffic = 50msa	RBI 81 TREATED GSB	210	588	3,85,300
		CEMENTED BASE	100	686	2,57,250
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**55,37,925**
2.	Soil Sample with CBR= 20.39% (RBI Grade 81 treated pavement) for design traffic = 100msa	RBI 81 TREATED GSB	210	588	3,85,300
		CEMENTED BASE	120	686	3,08,700
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**55,89,375**
3.	Soil Sample with CBR= 20.39% (RBI Grade 81 treated pavement) for Design Traffic = 150msa	RBI 81 TREATED GSB	210	588	3,85,300
		CEMENTED BASE	140	686	3,60,150
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**56,50,825**

Table 5.66: Cost Analysis for CBR 30.51%RBI Grade 81 Treated Sub-Base and Cemented Base

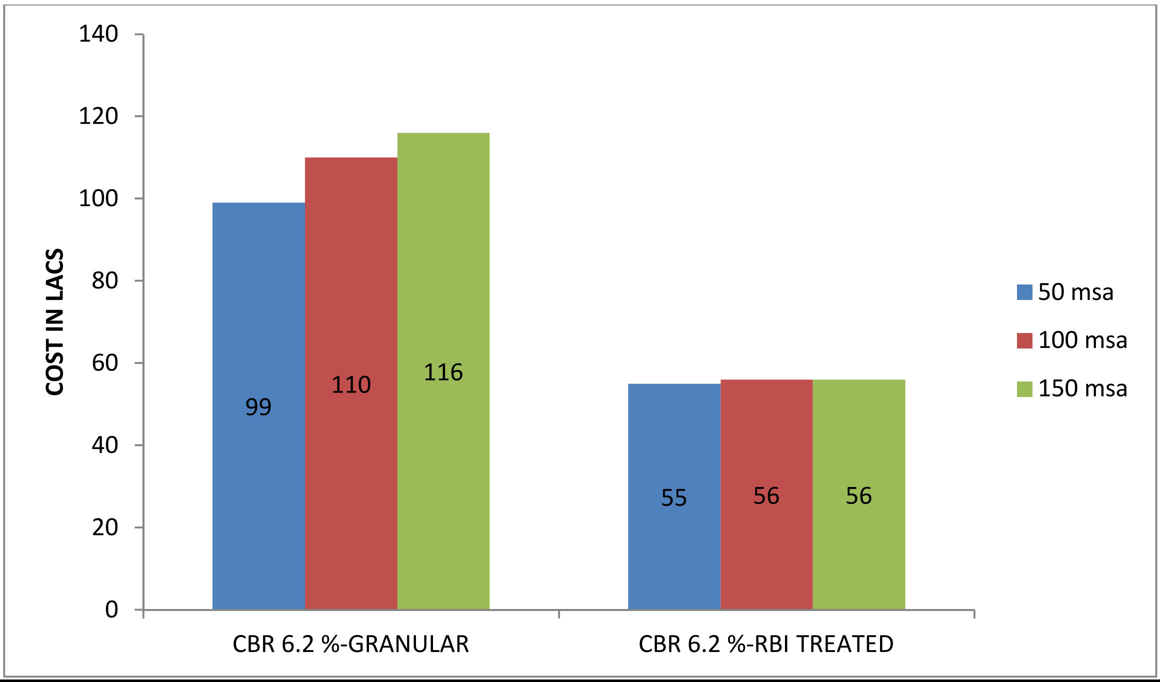
S.No.	*Description*	*Layers*	*Layer Thickness (mm)*	*Cost of layer/m^3 (Rs.)*	*Total Cost of layer/Km (Rs.)*
1.	Soil Sample with CBR= 30.51% (RBI Grade 81 treated pavement)for design traffic = 50msa	RBI 81 TREATED GSB	190	588	3,57,700
		CEMENTED BASE	100	686	2,57,250
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**55,01,325**
2.	Soil Sample with CBR= 30.51% (RBI Grade 81 treated pavement) for design traffic = 100msa	RBI 81 TREATED GSB	190	588	3,57,700
		CEMENTED BASE	120	686	3,08,700
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**55,52,775**
3.	Soil Sample with CBR= 30.51% (RBI Grade 81 treated pavement) for design traffic = 150msa	RBI 81 TREATED GSB	190	1905	3,57,700
		CEMENTED BASE	140	2513	3,60,150
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**56,05,225**

Table 5.67: Cost Analysis for CBR 47.83% RBI Grade 81 Treated Sub-Base and Cemented Base

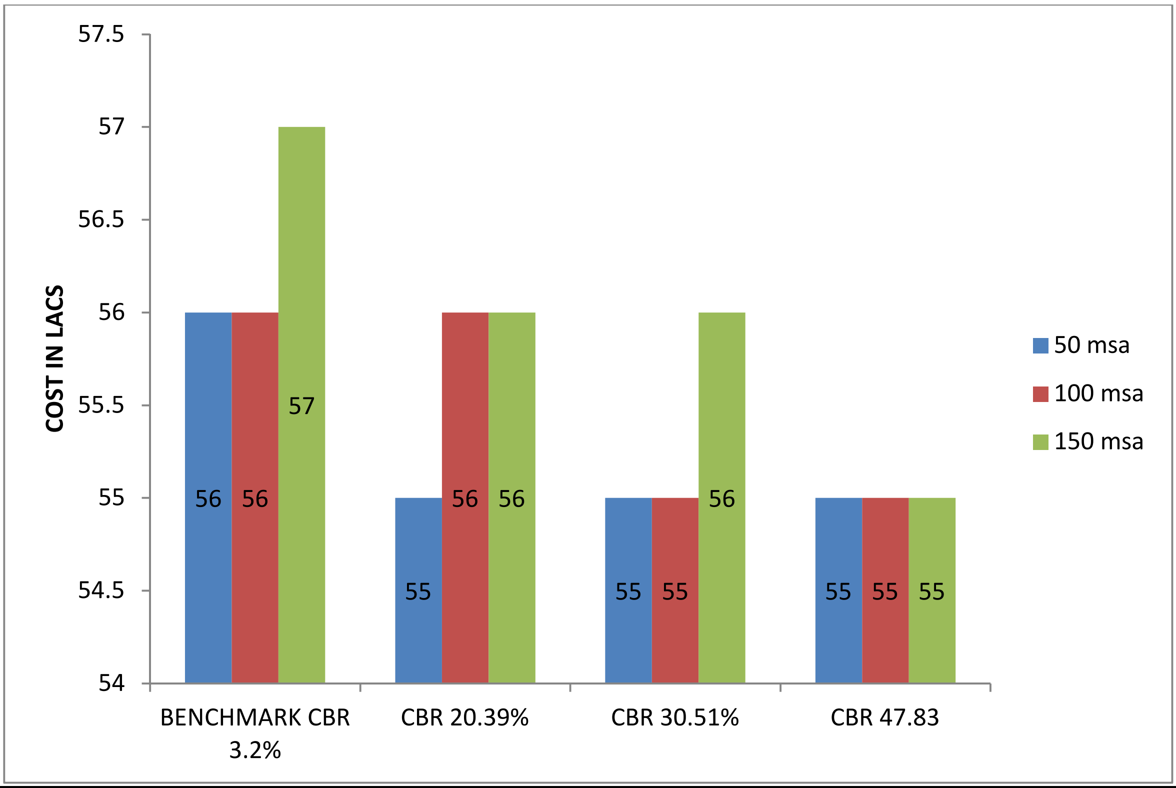
S.No.	*Description*	*Layers*	*Layer Thickness (mm)*	*Cost of layer/m^3 (Rs.)*	*Total Cost of layer/Km (Rs.)*
1.	Soil Sample with CBR= 47.83% (RBI Grade 81 treated pavement) for design traffic = 50msa	RBI 81 TREATED GSB	150	588	2,75,500
		CEMENTED BASE	100	686	2,57,250
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**55,28,125**
2.	Soil Sample with CBR= 47.83% (RBI Grade 81 treated pavement) for design traffic = 100msa	RBI 81 TREATED GSB	150	588	2,75,500
		CEMENTED BASE	120	686	3,08,700
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**55,79,575**
3.	Soil Sample with CBR= 47.83% (RBI Grade 81 treated pavement) for design traffic = 150msa	RBI 81 TREATED GSB	150	588	2,75,500
		CEMENTED BASE	140	686	3,60,150
		AGGREGATE INTERLAYER	100	1500	5,62,500
		DBM	50	11059	20,71,688
		BC	50	12065	22,62,187
		Total Cost of Road per Km (Rs.)			**55,31,025**



Graph 5.14: Cost analysis comparison at CBR 3.2 %for granular base and sub-base and cemented base and RBI Grade 81 treated sub-base



Graph 5.15: Cost analysis comparison at CBR 6.2 %for granular base and sub-base and cemented base and RBI Grade 81 treated sub-base



Graph 5.16: Cost analysis comparison at CBR 20.39%, 30.51 %and 47.83% for cemented base and RBI Grade 81 treated sub-base in comparison to CBR value 3.2 %for same case

5.5 SUMMARY OF COST ANALYSIS FOR PAVEMENT DESIGN

From the cost analysis for single lane of 1km length it can be concluded that if granular base and sub-base are being used without any stabilizer, expenditure of constructing a pavement will be upto116 lacs and if RBI grade 81 is being used in sub base and subgrade we are saving up to 56.8%. RBI grade 81 can also be used in base if mixed with soil at higher dosages, it is more cheaper than cement and lime and has longer durability There are common failures like fatigue cracking in cement treated subgrade and sub-base, these failures are not observed in RBI grade 81 treated soils due to its unique chemical composition and presence of fibers in it therefore we can save a lot in maintaince work also.

CHAPTER 6
CONCLUSIONS

Based on the experimental results of this study the following conclusions are drawn:-

1. In the atterbergs limit it was initiated that there was decrease in plasticity index at 2% dosage and constant increase at 4%, 6% and 8%, although both liquid limit and plastic limit are increasing constantly throughout.
2. Light compaction test showed that there was constant decrease in maximum dry density and increase in optimum moisture content except at 2% dosage where there was slight decrease. From the studies it is concluded that presence of fibers in RBI grade 81 results in decrease of MDD.
3. From the CBR test it was concluded that there is significant increase in soaked CBR value achieving 47.83 % at 8% RBI 81 dosage with respect to CBR value of 3.2% of virgin soil i.e. % increase of 1394%.
4. Remarkable increase in value of unconfined compression test was also observed specially at curing period of 7days and 28 days, increase in terms of E value is from 581 MPa at 0% RBI 81 on curing period of 28th day to 1780 MPa at 8% on curing period of 28th day.
5. While designing the pavement it was studied that using the RBI grade 81 in subgrade and sub-base can be very cost effective .It has been observed that more than 56.8 % can be saved if we are using RBI treated subbase instead of using granular sub-base and base.
6. From the results it can be said that RBI grade 81 can be used for high volume roads and subsequently improve the weaker strata.
7. Mechanism of stabilization was studied for untreated soil and treated soil and it can be concluded that RBI grade 81 is very superior and environment friendly soil stabilizer as lot of material and aggregate can be saved using RBI Grade 81.

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