EFFECT OF THE POSITION OF GEOTEXTILE ON THE STRENGTH CHARACTERISTICS OF SUBGRADE IN BITUMINOUS PAVEMENT

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DECLARATION

I, Tarun Gupta, hereby declare that this thesis entitled **"Effect of the Position of Geotextiles on the Strength Characteristics of Subgrade Soil in Bituminous Pavements"** is an authentic record of my study carried out as requirements for the award of degree of **Master of Engineering** in **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

In the past 20 years, many new road improvement techniques have revolved around the use of geosynthetics. In India, most of the flexible pavements are need to be constructed over weak sub-grade having low modulus values. The California bearing ratio (CBR) of these sub-grade soils has very low, resulting in more thickness of the road crust. Replacing of these existing weak subgrade soil may not be good option, thus it is required to stabilize these weak subgrade soil with suitable stabilizer.

Geosynthetics have been found to be a cost effective alternative to improve the weak subgrade soils in adverse locations. In this study, firstly the various properties of soil sample like grain size analysis, liquid limit, plastic limit, plasticity index & identification of soil has been evaluated and then CBR values of these soils have been improved using geotextiles. Non-Woven geotextiles are placed at different layers of various soil samples, and then a series of California Bearing Ratio (CBR) tests were conducted to evaluate the strength of the subgrade soil. It was observed that the CBR value increases, when the non-woven geotextile are placed at different layers of various soil sample. From this study, single layer of non-woven geotextiles is introduced at the depth of 0.85H from the bottom of the mould shows better performance than those samples with the geotextiles layer are placed at other depths.

In this study, the flexible pavement have been designed for both fatigue and rutting life of 100MSA at 90% and 80% reliability, when the non-woven geotextile are placed at three different depths of subgrade soil samples. The critical strain value for both fatigue and rutting life are analysed by programme IITPAVE software and are less than the allowable strain values as computed by IRC: 37-2012.

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CHAPTER – 01

INTRODUCTION

Flexible pavements are generally designed to have multiple layers, including the bitumen layer, surface course, aggregate base layer, aggregate subbase layer and sub grade soil. The quality and life of pavement is greatly affected by the type of sub-grade, sub-base and base course layers. Subgrade soil is the bottom most layer of the pavement whether it is rigid or flexible. The function of the subgrade is to give adequate support to the road crust and to support the traffic in the form of foundation. Generally, subgrade consists of various locally available soil materials that sometimes might be soft or that cannot have enough strength to support the traffic in the form of foundation structure.

The strength of the sub grade is mostly expressed in terms of California Bearing Ratio (CBR). Weaker the subgrade soil requires more thickness of road crust, whereas stronger subgrade requires less thickness of each pavement layers. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers that based upon the subgrade soil strength which is primarily dependent on California Bearing Ratio value of the soil sample soaked for four days. With the CBR value of the soil are known, the appropriate thickness of the road crust required above the subgrade soil for different traffic conditions is determined using the design charts, proposed by IRC-37-2012.

Sometimes the problematic subgrade is typically excavated and replaced, or it is improved by the addition of cement, lime, or excess aggregate. In any case, this type of solution is very costly and always time consuming. Geosynthetics have been found to be very cost effective alternative to improve the weak subgrade soils in adverse locations. Geo-synthetics are the synthetic products, where at least one of the components is made from a synthetic or natural polymer in nature, in the form of a sheet or a three dimensional structure.

Mostly, two types of geotextiles are used in engineering purposes i.e. non-woven, or a woven fabric. The non-woven fabric, are looks like a felt fabric, which is an arrangement of fibers either oriented or randomly patterned in a sheet form. Non-woven geotextile fabric is more stretcher than the woven geotextile.

Geotextiles may be used in those areas where the soil remains saturated part of the year, or over clay and moist silty weak subgrade soils. In this study, we have to use non-woven geotextiles. It has been used in flexible pavement for various purposes like reinforcement, layer separation, stabilization, filtration, drainage, and moisture barriers.

1.1 Geosynthetics:

Geosynthetics are the artificial fabrics which are used in integration with soil to stabilize the terrain. Geosynthetics are synthetic products, where at least one of the components is made from a synthetic or natural polymer, in the form of a sheet, a strip or a three dimensional structure, non-woven, knitted, or woven which is used in contact with soil/rock and/or other materials in geotechnical and civil engineering applications. The polymeric nature of the products that make suitable for use in the ground where high levels of durability are required.

1.2 Categories of Geosynthetics:

1. Geotextiles (Nonwoven, Woven)
2. Geogrid (Bonded, Extruded, Knitted, Woven)
3. Geomembrane (Bituminous, Elastomeric, Plastomeric)
4. Geonets
5. Geocomposites.
6. Geosynthesis clay liners.
7. Geofoams

Geotextiles:

Geotextiles are permeable or porous fabrics manufactured from synthetic materials like polypropylene, polyamide, polythene and glass fibres. Geotextiles are used with soil as an intergral part of man made products. Modern geotextiles do not decay under biological and chemical processes makes them useful in road construction and their maintenance. Their thickness may ranging from 0.125 to 7.5 mm. The permeabilities of the geotextile sheets are comparable in range from coarse gravel to fine sand.

Mostly, the Geotextiles can be produced as a non-woven, or a woven fabric.

Non-woven Geotextiles:

Non-woven geosynthetics can be manufactured either from short staple fibre (oriented or random pattern in a sheet) or continuous filament yarn. These fibres are bonded together either by thermal, mechanical or chemical techniques. Thermally bonded non-woven geotextile have a wide opening size with a typical thickness of about 0.5 to 1 mm.

Mechanically bonded non-woven with thickness of 2 to 5 mm. The load carry capacity of the Non-woven geotextiles is low because of their tensile strength is limited. Non-woven fabric is more stretchable than the wovens. Non-wovens have the ability to let water flow along the plane of the geotextile.

Woven Geotextiles:

The woven geotextile sheet is made up of two sets of parallel thread or yarns. These yarns are running along its length is called as warp and one perpendicular to it, is known as a waft. The manufactured technique of wovens is similar to the weave clothing textiles. Low to medium strength woven-geotextile are generally manufactured from polypropylene, is in the form of monofilament, multifilament, extruded tape etc. The permeability of multifilament or monofilament is higher than the extruded tape. In general, a woven geotextile is less likely to stretch, and does not let water flow as freely as non-woven geotextiles.

Geogrids:

Geo-grids are an open structures made from steel in the form of plain or mesh. Geogrids are produced with the molecular chains of polymer lattics, there by obtaining the material of high tensile strength. The polymer sheets are first perforated the size and distribution of holes being determined by the end products. Geo-grids are highly durable and is also used to the reinforce soil and similar materials.

Geogrids are commonly used to reinforce the retaining walls, subbases or subsoils below roads or structures. Their reinforcing function is achieved by positive interlocking of fill materials into the apertures. Geosynthetics (geogrid and geotextile) have been widely used for subgrade improvement and base reinforcement.

Geomembrane:

A geomembrane is very low permeable synthetic membrane manufactured from thermoplastic materials like HDPE, LDPE, and PVC or as multilayered bitumen geocomposites. Geomembrane are produced either extruded sheet polymer or a composite. The extruded geomembranes are manufactured by melting polymer resin (or chips) and forcing the molten polymer through a die using a screw extruder.

This sheet is formed either by a flat horizontal die or through a vertically oriented circular die to form a flat wide sheet advanced on a conveyor belt or a cylindrical tube of blown film, filled with air which is collapsed and pulled by nip rollers mounted high above the die. The thicknesses of the geomembrane vary from 10 to 15 mm. The width of the membrane reinforced with bitumen may be varying from 4 to 5 mm with thickness of 1.5 to 6 mm.

Geonets:

Geonets consists of two sets of round criss-crossing polymer strands that cross at a constant angle to give a very open material with large diamond or rectangle shaped apertures. Nearly all geonets are made of polyethylene. The size of the strands and apertures are 2 mm and 7 mm. Sometimes, the nets are lightly stretched during manufacture process to increase the elastic modulus. The strength of the geonets varying from 2 to 10 kN/m. A geonet is used for low strength soil reinforcement or for core material in fine drain geosynthetic composites.

Geocomposites:

A geocomposite consists of a combination of geotextiles, geogrids, geonets and/or geomembranes in a factory fabricated unit. The most common geocomposite configuration is called as drainage geocomposite. Drainage geocomposites are composed of a geotextile filter surrounding either a geonet (blanket drain), a thick preformed core (panel or edge drain), or a thin preformed core (wick drain).

The various applications of drainage geocomposites are blanket drains, panel drains, edge drains and wick drains. Other forms of composite products have been developed. For example: non-woven sheet and waffled core composites, non-woven sheet and net core composites etc.

Geosynthetic clay liners:

Geosynthetic clay liners or GCLs include a thin layer of finely-ground bentonite clay. GCLs are manufactured in thin layers of bentonite clay which is sandwiched between the two geotextiles or sometimes bonded to a geomembrane, bonding the layers with needling, stitching and/or chemical adhesives. The preferred sodium bentonite clay occurs naturally in Wyoming. GCLs are used as a composite component that beneath a geomembrane or by themselves in geoenvironmental. There applications are used in the transportation, geotechnical, hydraulic, and many private development applications.

Geofoam:

Geofoam is manufactured into large blocks which are stacked to form a lightweight, thermally insulating mass buried within a soil or pavement structure. The most common type of polymer used in manufacturing of geofoam materials is polystyrene. Typical applications of geofoams include: when the soil embankments built over the soft, weak soils; under roads, airfield pavements and railway track systems subject to excessive freeze-thaw conditions. Sometimes it is used under beneath on-grade storage tanks containing cold liquids.

1.3 Function of Non-woven geotextiles/geosynthetics in flexible pavements:

1.3.1. Filtration:

A non-woven geotextile acts a filter, when it allows the liquid to pass normal to its own plane while preventing most soil particles from being carried away by liquid current. The soil particles are being protected into the structure of the geosynthetics itself. It must also retain the smallest soil particle size without clogging or plugging. In filtration, it can perform two functions:

1. A geotextile is placed across a flow of liquid carrying fine particles, stops most of the particles (where they accumulate on the filter) while allowing water to pass through it.
2. A geotextile is placed in contact with a soil, allows water seeping from the soil to pass through, while preventing any movement of soil particles.

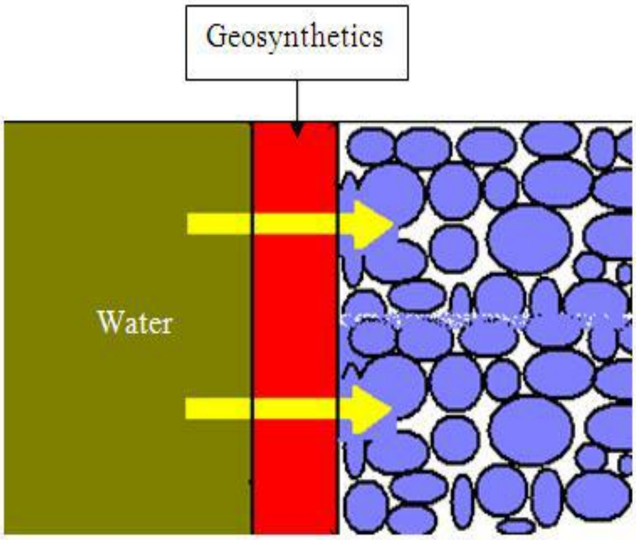

Figure 1.1: **Mechanism of Filtration of geosynthetics in Soil-aggregate layer**

1.3.2. Reinforcement:

The term "reinforcing" implies the mobilization of tension in the plane of the membrane or membrane reinforcing. It is the ability to distribute a concentrated load over a larger area of the subgrade, thus avoiding local overloading of the bearing capacity. The strain/deformation in any direction could be controlled by introducing the reinforcement (geotextile) by way of frictional forces acting against defomation.

Geotextile provides reinforcement through both the tensioned membrane and tensile member functions. This reinforcement ensures better load distribution for heavy weight and high modulus fabrics. Geotextile reinforced the soil mass and improved the stability of structure in terms of strength and defomations with respect to the unreinforced soil. It has also been suggested that interlocking (friction) between the aggregate-geosynthetic and soil geosynthetic surfaces may minimize lateral spreading of the aggregate and soil.

Some of their objectives were to analyze and explain geogrid reinforcement mechanisms in paved road applications through the use of stress, strain, and deflection measurements. They found that grid reinforcement reduced permanent deformation in flexible pavement systems and allowed up to 50% reduction in the thickness requirements of granular base based on equal load-deformation performance. The reinforcement mechanism has been reported to develop only in cases with subgrade CBR values below than 3.

1.3.3. Separation:

A geotextile acts as a separator when it is placed between a fine soil and a coarse material such as gravel or stone ballast. It prevents the fine soil and the coarse material from intermixing under the action of repeated applied loads. The field application of geotextiles as separator commonly adopted is: unpaved roads, paved roads railways etc. The separation function of geotextiles in unpaved road by providing the geotextile sheet between the granular subbase and weak subgrade, thus prevents contamination of the base coarse aggregate by the subgrade soil, thus preserving the original pavement design.

In paved road construction, geotextile sheet can be provided at three different locations i.e. at the interface between the aggregate subbase and the subgrade soil, within the pavement structure and a surface overlay. The various benefits are:

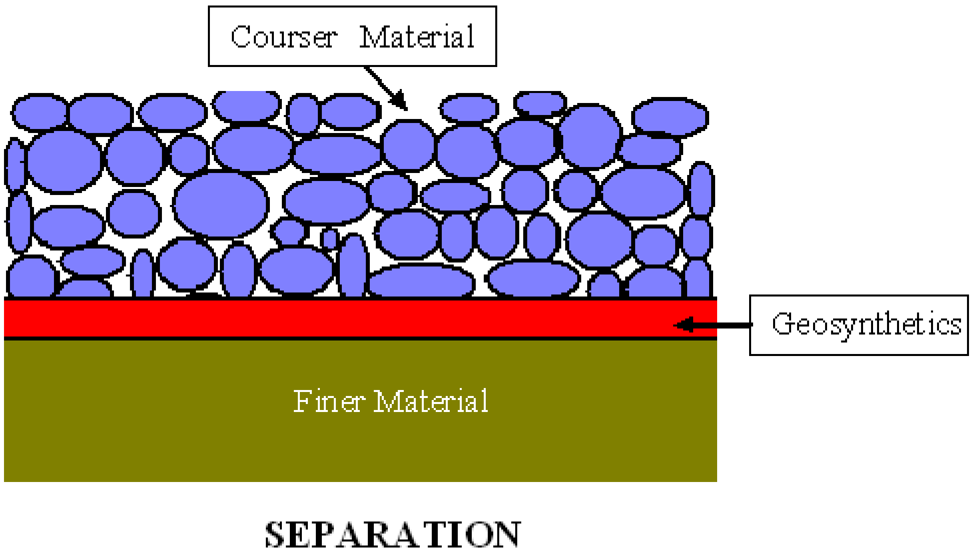

Figure 1.2: **Mechanism of Separation of geosynthetics in Soil-aggregate layer**

1. It prevent the pavement subbase aggregate from penetrating the soil subgarde
2. It reduces the rutting of the subbase aggregates while it is used as a haul road.
3. It prevent the fine soil particles from the subgrade soil entering the subbase aggregates

4. The presence of geotextile sheet improves the tensile strength and gives a better resistance to cracking and to provide longer fatigue life.
5. It also reduces the propogation of reflection cracks and thereby increasing the life of overlay.

1.4 Outline of Thesis

The thesis has been divided into six chapters:

- Ist chapter is about the general introduction of Geosynthetics and their classification.
- 2nd chapter is the literature review of the research work conducted with the use of geogrids and geotextiles for improving the strength of subgrade soil.
- 3rd chapter deals with the experimental programe wherein all test procedures are explained in detail.
- 4th chapter deals with the results and discussions where findings of experimental programme are discussed.
- 5th chapter includes the design of flexible pavement.
- 6th chapter consists of conclusion of the dissertation.

CHAPTER- 02
LITERATURE REVIEW

2.1 Literature Review on Geogrids and Geotextile:

S. A. Naeini & R. Ziaie Moayed (2009), conducted the California Bearing Ratio tests of three different type of soil samplse with different percentage of bentonite with or without geo-grid/ geotextiles reinforcement in one or multilayered. The result shows as the plasticity index of the soil increases, the California Bearing Ratio values decreases in both soaked and unsoaked conditions. The California Bearing Ratio is increased by using the geotextiles in two layers when it is compared with an unreinforced soil samples, but this CBR value is less than the value of CBR when the geotextile is placed in single layered reinforcement. Placement of the geotextiles at second layer, there was an increment in California Bearing Ratio values when it is compared with unreinforced soil sample under unsoaked and soaked conditions.

Placement of two layers of geotextiles at layer 2 and 4, the soaked values of California Bearing Ratio becomes increases about 35% at different plasticity index values, when it is compared with an unreinforced soil samples. However, this increase of the CBR value is less when it is compared with geotextiles is placed in single layer 3. However, the soaked CBR value is more than both unreinforced and one layered geotextile specimen. When a single layer of geotextile is placed at top layer 3 in soaked condition, there is an increase of California Bearing Ratio value by 40% as compared to unreinforced sample. Thus, placing of single layer of geotextile at layer 3 becomes more effective in soaked condition.

D.S.V. Prasad et.al (2010), concluded the load carrying capacity of a model flexible pavement system is increases when the geotextile reinforcement is introduced in gravel subbase laid on expansive subgrade soil. The depth of the subgrade soil is 500 mm and compacted in ten layers and gravel subbase is laid in two layers, each of 70 mm compacted thickness. The various reinforced materials like geogrid, bitumen coated chicken mesh, bitumen coated bamboo mesh and waste rubber tyres etc were mixed uniformly thoroughly. The base material WBM-II can laid in two compacted layers, each of 75 mm compacted thickness. It was observed that the total and elastic deformation values of the bituminous pavement system are decreased with the used of different types of reinforcing material. The load carrying capacity is maximum so as to obtain when the geogrid reinforcement is used. Geogrid cause less value of rebound deflection than any other reinforcement material is provided.

Sivapragasam, C. Vanitha, S. (2010), introduced the Synthetic non-woven geotextile were placed at different depth of the soil so that the improvements in soil bearing capacity are checked by CBR and UCS test. Single layer of geotextile is introduced at the centre (mid depth) shows that there is an increase of CBR (2.42%) and UCS (0.484N/mm^2), better performance than those samples with the geotextiles layer at other depth.

A.K. Choudhary et.al (2011), improved the CBR value of expansive soil subgrade using geosynthetics. This study is based upon the placement of multiple layers of reinforcement namely non-woven geotextiles and jute geo-textile within the sub-grade soil. It is observed that the placing of horizontal layer of geotextile within the specimen is effective for controlling the swelling. He found that the expansion ratio of the soil becomes decreases when the geotextile is placed in the single layer of unreinforced soil. This ratio is also decreasing when there is an increasing of the number of reinforcing layer but these decreases in values are significant when the jute geotextile is used and marginal decrease in the case of non-woven geo-textiles. It means that the placement of geotextile is also controls the swelling of soil. It is found that the CBR value of the soil also increases when the number of reinforcing layers is increased. Non-woven geo-textiles offer better reinforcing material than the jute geo-textile but it can be useful for low cost road projects.

Sarika Dhule & S.S. Valunjkar (2011), improved that the properties of weak subgrade soil and soft murrum with the addition of geogrid in different percentage i.e. 1%, 2%, 2.5% and 3%. It is found that the CBR value of soil also increases with addition of geogrid. She also found that the effect on CBR value of murrum 2% of cement with different percentage of geogrids.

The California Bearing Ratio value of the soil is increased by the addition of 2.5% geogrid. The author used compacted soil samples for performing the laboratory California Bearing Ratio tests. It concluded that the shear strength and permeability of soil are the affecting properties on compaction characteristics.

Pradeep Singh and K.S. Gill (2011), carried out the experimental test to determine the optimum position of geogrid/geotextiles reinforcement in the subgrade soil by conducting the California Bearing Ratio (CBR) test and unconfined compressive test (UCS). He is found that the CBR value of the weak soil becomes increases by 50% - 100%, when the geotextile is placed in a single layer. The improvement of the weak subgrade depends upon the postion of the geogrid and California Bearing Ratio value of unreinforced soil. He found that when geo-grid/ geotextiles reinforcement is placed at 0.2H from the top of the mould will increases the CBR value from 3.6% in unreinforced sample to 8.7%, when it is reinforced. Thus, the stress-strain behaviour of subgrade soil under the static load is also improved, when the geotextile is placed at optimum position.

P. Senthil Kumar R. Rajkumar (2012), studied the performance of woven and non-woven geotextiles are placed between the soft subgrade soil and unbound gravel in an unpaved bituminous pavement system, is carried out experimentally the California Bearing Ratio testing arrangement in laboratory. There is a comparison of reinforcement ratio which is determined by using the CBR strength test. It shows that the performance is improved with the use of woven and non-woven geotextile. The author concluded that the reinforcement ratio is obtained, which is based upon the CBR load penetration relation of both soft subgrade soil -gravel and soft subgrade soil-geotextile-gravel separately, for woven and nonwoven geotextile.

From the figure 2.1, shows that the reinforcement ratio is more throughout the test, that indicates with the use of geotextiles offer more resistance even to lower penetration. Thus the reinforcement ratio increases, with an increase of load in reinforced soil sample.

In order to quantify the amount of increase in the penetration resistance, the reinforcement ratio is taken into consideration.

$$Reinforcement\ ratio = \frac{Load\ with\ geotextile}{Load\ without\ geotextile}$$

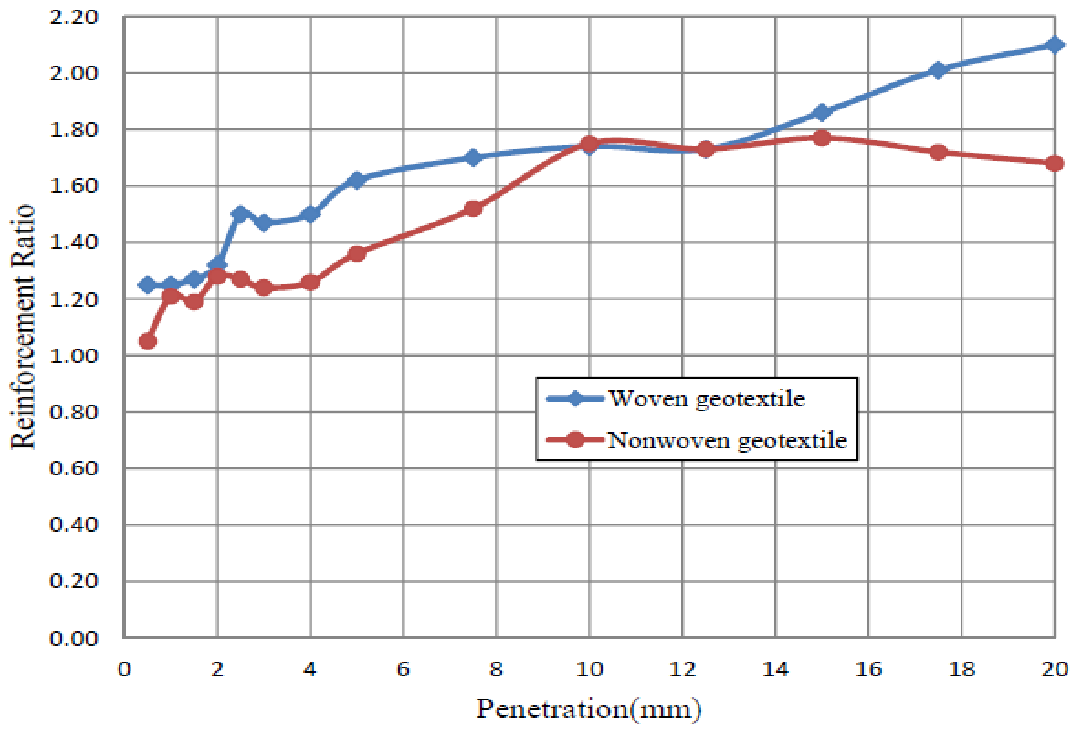

***Figure 2.1*: Variation of Reinforcememt Ratio for Woven geotextile & Non-woven geotextile**

Vignesh Jayaraman & Evangelin Ramani Sujatha (2012), provides geogrid that acts as a reinforcement to improve the strength of weak subgrade soil. The author conducted the California Bearing Ratio tests on such weak subgrade soil with geogrid are placed at different depths within the sample, in a single, double layer and triple layer. It is found that the best performance in the single layer occurs, when geogrid is placed at 0.66H distance from the base of mould. It is also found that the California Bearing Ratio value of 3 layers of geogrid is placed in soil sample is lesser than 2 layers, but the CBR of soil sample placed in single layer is higher than of these two cases and hence it is concluded that the geogrid reinforcement increases the strength of the weak subgrade soil in both soaked and un-soaked condition. Thus for better efficiency, the geogrids reinforcement are provided in a single or multilayer to the sub-grade increases the strength of the soil and thus reduces the thickness of the road crust.

Babagouda patil & Nitesh motekar (2012), the author was conducted the CBR tests on clayey soil with unreinforced and reinforced in a single layer of geogrid. When the sample is reinforced, reinforcing material like geogrid was placed in a single layer at different depths of the soil specimen 20%, 40%, 60% and 80% from the bottom of the mould. It is found that the CBR values will increases, when a single layer of geogrid is used in clayey soil sample. The maximum value of CBR 16.64% is obtained when the geogrid was placed at 0.8H from the bottom of the mould for unsoaked condition and 12.36% for soaked condition. From the results, it is clear that the optimum depth of the geogrid is 0.8H from the bottom of the mould to get the maximum density. The stress-strain behaviour of the sub-grade soils under static load condition is improved when geogrid was provided at optimum position.

Ambika Kuity & Tapas Kumar Roy (2013), carried out the strength of subgrade soil that affects the thickness of the road crust which is placed over it. This soil samples are mixed with some waste material i.e. pondash (P) and rice husk ash (R). Sometimes, lime (L) is added to the weak subgrade soil acts as an admixture so as to stabilize it. The mix composition ratios are taken as S: P (2:3), S: R (5:1 and 4:1), S: P: R (10:15:2) and S: P: L (50:75:1, 50:75:2, 50:75:3). California bearing ratio (CBR) tests are conducted in both soaked and unsoaked conditions and its values of these mixes to increased by 1.16 to 2.06 times and 1.22 to 3.72 times with respect to the unreinforced soil. Thus the optimum depth of the geogrids are at 1/2 and 1/3 height (both from top and bottom of the sample) of the mould. The unsoaked values of CBR test did not show any change with the use of geogrid but the soaked CBR value shows the considerably increases. The unsoaked and soaked values of CBR test of S: P (2:3) is increased by 1.44 and 1.08 times than the unreinforced condition, when the geogrid is placed at the 1/2 height from the bottom of mould.

***Table 2.1*: Description of mix with identification marks.**

S.no.	Mix Composition	Ratio
1	Soil-pondash (SP)	2:3
2	Soil-rice husk ash	
	Mix type 1 (SR1)	5:1
	Mix Type 2 (SR2)	4:1
3	Soil- pondash-rice husk ash (SPR)	10:15:2
4	Soil-pondash-lime	
	Mix Type 2 (SPL1)	50:75:1
	Mix Type 2 (SPL2)	50:75:2
	Mix Type 3 (SPL3)	50:75:3

Where, S = Soil, P = Pond ash, R = Rice husk ash, L = Lime

From the soaked values of CBR test, S: P: R (10:15:2) and S: P: L (50:75:1) are preferred mix, when the geogrid is placed at 1/3 height from the top of the mould. Unsoaked CBR and soaked CBR for parent soil and the mixture have been conducted without geogrid and with geogrid at the height of 1/2H and 1/3H of the CBR sample. The variations are presents in the Figures 2.2 and 2.3 for unsoaked and soaked CBR test.

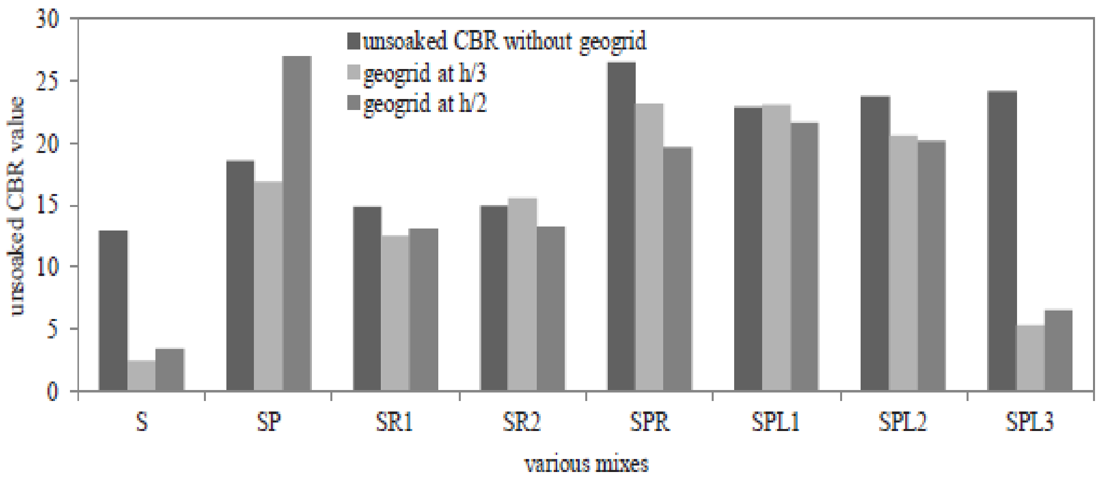

Figure 2.2: **Unsoaked CBR value without geogrid and with geogrid at h/3 and h/2 layer**

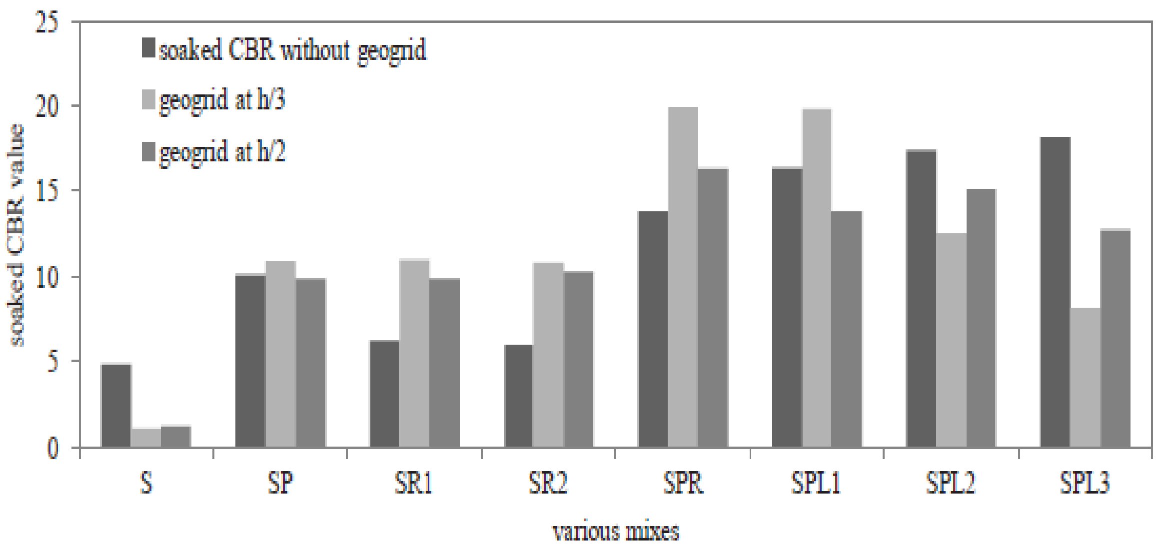

Figure 2.3**: Soaked CBR value without geogrid and with geogrid at h/3 and h/2 layer**

Mayura Yeole and J.R. Patil (2013), the author is studied that the use of geotextiles reinforcement in the soil subgrade can improved the bearing capacity of that soil. It acts as a tensioned material in granular soil. It is carried out a laboratory California Bearing Ratio test on the granular soil with or without geo-textile which was placed in single or double layer in the mould. The single layer of the geotextile was placed at the depth of (25, 50, 100mm) from the top of the mould, the maximum value of CBR is obtained at 25mm is 14.47%. The percentage increased in the CBR value at 25mm from the top of the mould in soil sample is 29.55% and when the geo-textile was placed in two layers at (25 &75 mm), (50 &75 mm), (50 &100 mm), California Bearing Ratio was increased and it was maximum at 25 & 75mm geo-textile layer by 38.21%. The percentage increased in the CBR value at 25 & 75 mm from the top of the mould in soil sample is 38.21%, when this California Bearing Ratio is compared with unreinforced soil sample.

Akolade, A.S & Alaniyan, O.S (2014), studied three types of sample A, B and C in random and determines their index properties and their strength characteristics. In order to their strength of these three samples, California Bearing Test was conducted. The strength of these soils is very low under soaked condition. The author had been used the application of geogrids at different depths of soil samples to increase the strength of the subgrade soil. The strength of the subgrade soil is measured by the California Bearing Ratio (CBR) test. It can be concluded that when the geogrids is placed at the depth of 3/5 H, where H is the height of the mould from the base and it gives better increase in the strength of unreinforced soil samples in soaked and unsoaked condition.

It can also be concluded from the experiments that geogrids is acts as a reinforcement material for adverse effects on soil strength posed by increased moisture content. The use of geogrids is an effective and modern form of improving road construction on the poor sub-grade materials and it is advised that the geogrid is placed at the depth of 3/5 H from the base of themould in the subgrade soil.

The results of soaked CBR values with and without reinforcement at different depths also affects the number of layers. There is an increase of CBR values under the soaked condition when the geogrid is placed at the depth of 2/5 (12.8%, 11%, 8.8%), 3/5(15.1%, 14%, 12.2%) and 4/5(11%, 10%, 8.3%) from the base the of the mould of samples A, B & C, when it is compared with the CBR value of unreinforced soil sample without geogrid and reinforced with geogrid.

Archana Muraleedharan (2016), studied the optimum position of geogrid reinforcement between the subbase and soil subgrade in order to improve their strength. The optimum depth for placement of geogrid by conducting the laboratory California Bearing Ratio test by reinforcing geogrid in single, double layer, triple layer and in four layers both in unsoaked and soaked condition and drainage characteristics of subgrade soil with and without reinforcement by conducting permeability test. The strength of the subgrade soil is increased when the geogrid reinforcement is used in the soil samples. It was found that when the geogrid is placed at the depth of 3/4 H from the base of the mould shows higher CBR than 1/3H, 1/2H, 2/3H as shown in table 2.2. CBR value of two layer geogrid reinforcement is higher than single layer. CBR value of three layer geogrid reinforcement is higher than single layer and double layer but CBR value of four layers is less than single, double, triple layers and there is considerable improvement in drainage characteristics of subgrade soil on inclusion of geogrid.

Table 2.2: **Results of CBR test when geogrid is reinforced in single layer.**

Depth	**Without Geogrids**	**1/3H**	**1/2H**	**2/3H**	**3/4H**
CBR (%)	2.675	3.13	10.7	13.4	25.3

CHAPTER-03

EXPERIMENTAL PROGRAMME

3.1 Materials Used:

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

Three soil sample A, B & C was collected from three different locations. Sample A was collected from Ambala region whereas; Sample B and C were collected from Patiala district. The required properties of soil samples A, B and C were determined as shown in below tables. Sample A is clayey in nature, sample B is silty sand and sample A is a granular soil using grain size analysis.

3.2 Properties of Soil Sample A:

Table 3.1: **Properties of tested soil specimen A**

S.No.	Tests	Properties	Description	Relevent IS Codes
1.	Grain Size Analysis	Fines, < 75µ (%)	53.7	IS 2720 Part IV
		Sand (%)	46.3	IS 2720 Part IV
2.	Compaction Test	MDD (kN/m^3)	18.5	IS 2720 Part VIII
		OMC (%)	14%	IS 2720 Part VIII
3.	Casagrande Tests	Liquid Limit (%)	32.5	IS 2720 Part V
		Plastic Limit (%)	20	IS 2720 Part V
		Plasticity Index (%)	12.5	IS 2720 Part V
		Flow Index	29	IS 2720 Part V
		Toughness Index	0.68	IS 2720 Part V
4.		Classification	CL (Clay and silt with low compressibility	IS 1498-2007

3.3. Grain Size Distribution of Sample B:

The soil sample was obtained locally & used for the study. The grain size distribution showed that the percentage passing the 2.36 mm sieve was 100% with 12.1% passing the 0.075mm sieve. As per Indian classification system the material is classified as a Silty Sand material, with a group symbol of SM.

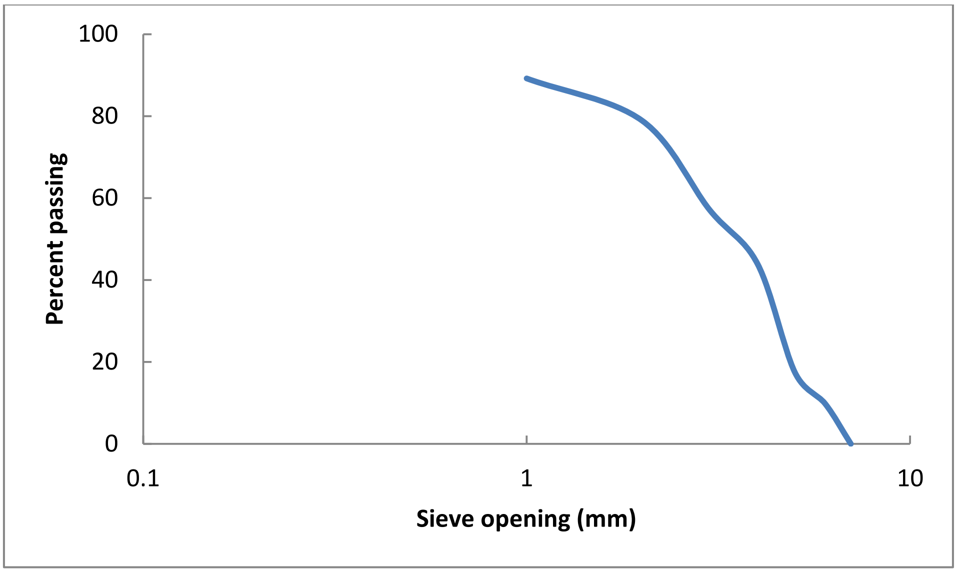

Figure 3.1: **Grain Size Distribution of Sample B**

3.3.1 Properties of Soil Sample B:

Table 3.2: **Properties of tested soil specimen B**

S.No.	Tests	Properties	Description	Relevent IS Codes
1.	Grain Size Analysis	Fines, < 75μ (%)	12.1	IS 2720 Part IV
		Sand (%)	87.90	IS 2720 Part IV
		Effective size (D_{10}) (mm)	0.055	IS 2720 Part IV
		D_{30} (mm)	0.208	IS 2720 Part IV
		D_{60} (mm)	0.432	IS 2720 Part IV
		Uniformity coefficient, C_u	7.85	IS 2720 Part IV
		Coefficient of curvature, C_c	1.82	IS 2720 Part IV
2.	Compaction Test	MDD(kN/m^3)	18.82	IS 2720 Part VIII
		OMC (%)	13.1	IS 2720 Part VIII
3.		Classification	Silty Sand	IS 1498-2007

3.4 Grain Size Distribution of Sample C:

It is done to determine the percentage of various grain sizes. The grain size distribution helps in determining the textural classification of soils whether it is gravel, sand, silt, clay, etc. which is then useful in evaluating the engineering characteristics. IS: 2720- Part iv (2006) is used. The sieves for soil tests used are 4.75 mm to 75 microns and grain size distribution is shown in Figure. 3.2

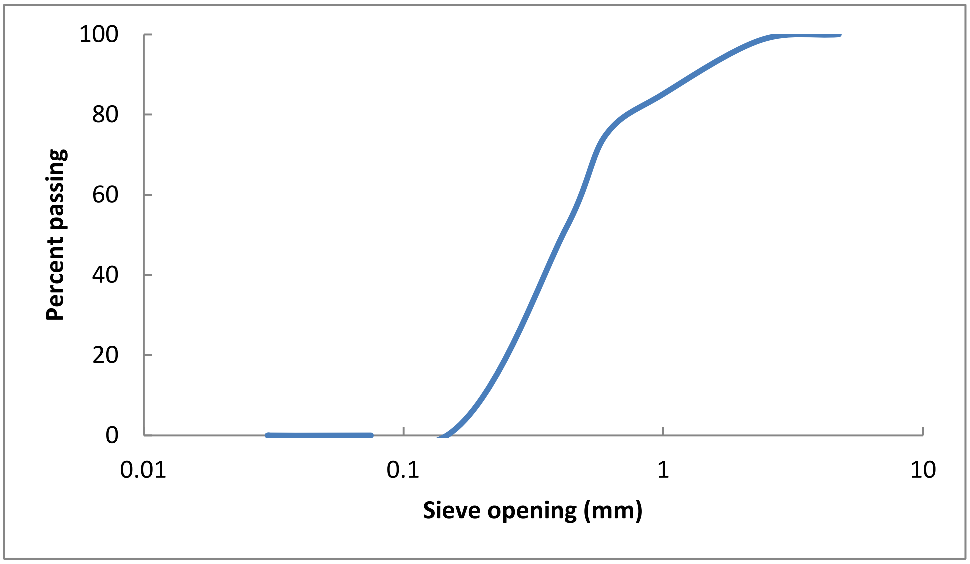

Figure 3.2: **Grain Size Distribution of Sample C**

3.4. 1 Properties of Soil Sample C:

Table 3.3: **Properties of tested soil sample C**

S.No.	Tests	Properties	Description	Relevent IS Codes
1.	Grain Size Analysis	Fines, < 75μ (%)	0	IS 2720 Part IV
		Sand (%)	100	IS 2720 Part IV
		Effective size (D_{10}) (mm)	0.053	IS 2720 Part IV
		D_{30} (mm)	0.10	IS 2720 Part IV
		D_{60} (mm)	0.490	IS 2720 Part IV
		Uniformity coefficient, C_u	9.24	IS 2720 Part IV
		Coefficient of curvature, C_c	0.385	IS 2720 Part IV
2.	Compaction Test	MDD (kN/m^3)	19.81	IS 2720 Part VIII
		OMC (%)	11	IS 2720 Part VIII
3.		Classification	Sand	IS 1498-2007

3.5 Properties of Geotextiles:

The properties of the geotextile used in this study are as under:-

Table 3.4: **Properties of geotextile (Maccaferri India)**

S. No.	Description	Properties
1	Type of Geotextiles	Non-Woven
2	Type of fiber	Polypropylene
3	Pore size	less than 75 microns
4	Grab Tensile strength	570 N
5	Puncturing strength	180 N
6	Grab Elongation	50%
7	Permittivity	1 sec^{-1}
8	Water Permeability	20.4 lit/ m^2/ sec

Figure 3.3: **Pictorial Representation of non-woven geotextile**

3.6 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.

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 3.5:* Standard Loads adopted for different Penetrations**

Penetration of Plunger (mm)	Standard Load (kg)
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 which 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.

3.6.1 Equipments and tool required:

1. Cylindrical mould with inside dia 150 mm and height 175 mm, provided with a detachable extension collar 50 mm height and a detachable perforated base plate 10 mm thick.

2. Spacer disc 148 mm in dia and 47.7 mm in height along with handle.
3. Metal rammers. Weight 2.6 kg with a drop of 310 mm (or) weight 4.89 kg a drop 450 mm.
4. Weights. One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in dia, with a central hole 53 mm in diameter.
5. Loading machine. With a capacity of at least 5000 kg and equipped with a movable head or base that travels at an uniform rate of 1.25 mm/min. Complete with load indicating device.
6. Metal penetration piston 50 mm dia and minimum of 100 mm in length.

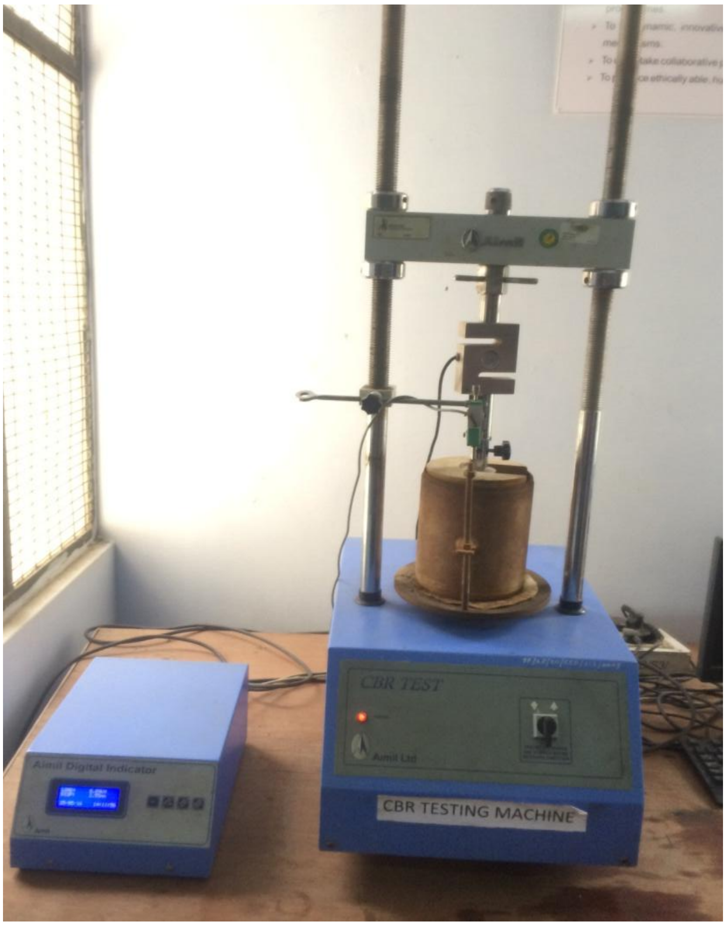

Figure 3.4: **California bearing ratio testing Machine**

3.6.2 Preparation of test specimen:

1. Take about 4.5 to 5.5 kg of soil and mix thoroughly with the required water.
2. Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base .Place the filter paper on the top of the spacer disc.

3. Compact the mix soil in the mould using either light compaction or heavy compaction. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows by the 2.6 kg rammer. For heavy compaction compact the soil in 5 layers, 56 blows to each layer by the 4.89 kg rammer.
4. Remove the collar and trim off soil.
5. Turn the mould upside down and remove the base plate and the displacer disc.
6. Weigh the mould with compacted soil and determine the bulk density and dry density.
7. Put filter paper on the top of the compacted soil (collar side) and clamp the perforated base plate on to it.

3.6.3 Procedure:

1. Place the mould assembly with the surcharge weights equal to the weight of base material 2.5 kg shall be placed on the compact soil specimen.
2. Immerse the mould assembly and weights in a tank of water and soak it for 96 hours. Remove the mould from tank.
3. Place the mould assembly with the surcharge weights on the penetration test machine.
4. Seat the penetration piston at the centre of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.
5. Set the stress and strain dial gauge to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.
6. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12 mm. Note the maximum load and corresponding penetration if it occurs for a penetration less than 12.5 mm.
7. Detach the mould from the loading equipment. Take about 20 to 50 g of soil from the top 3 cm layer and determine the moisture content.

RESULTS AND DISCUSSIONS

4.1 California Bearing Ratio

CBR test were conducted on Sample A, B and C with unreinforced and reinforced with a single layer of non-woven geotextile at different depth under soaked condition. Geotextiles were placed in single layer at three different depths such that 1/3H (0.33H), 2/3H (0.66H) and 0.85H from the bottom of the mould for all the samples as shown in figure 4.1

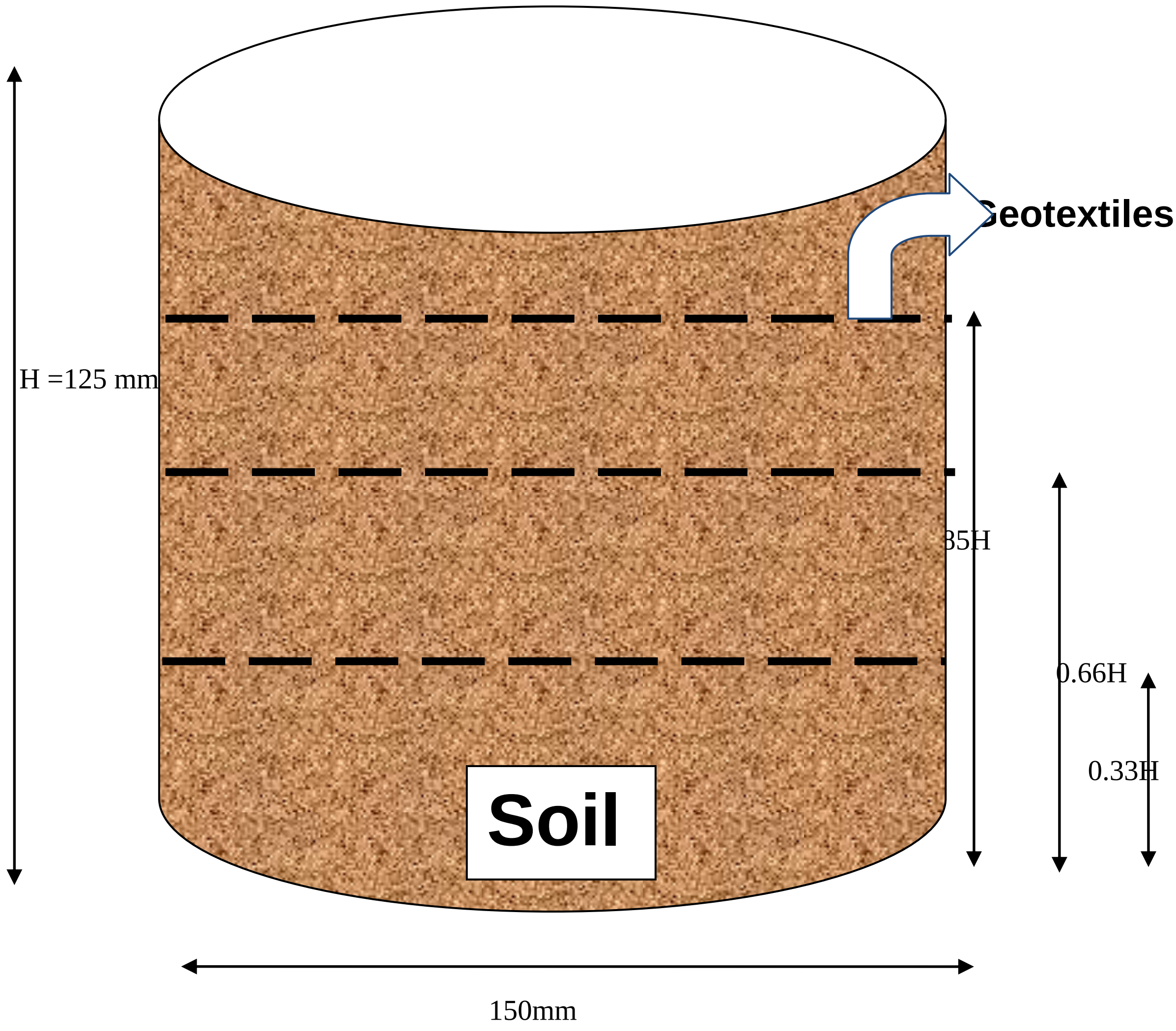

Figure 4.1: **Placing of single layer of geotextiles at different depths in CBR mould**

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4.1.1 Load Penetration curves for unreinforced Sample A:

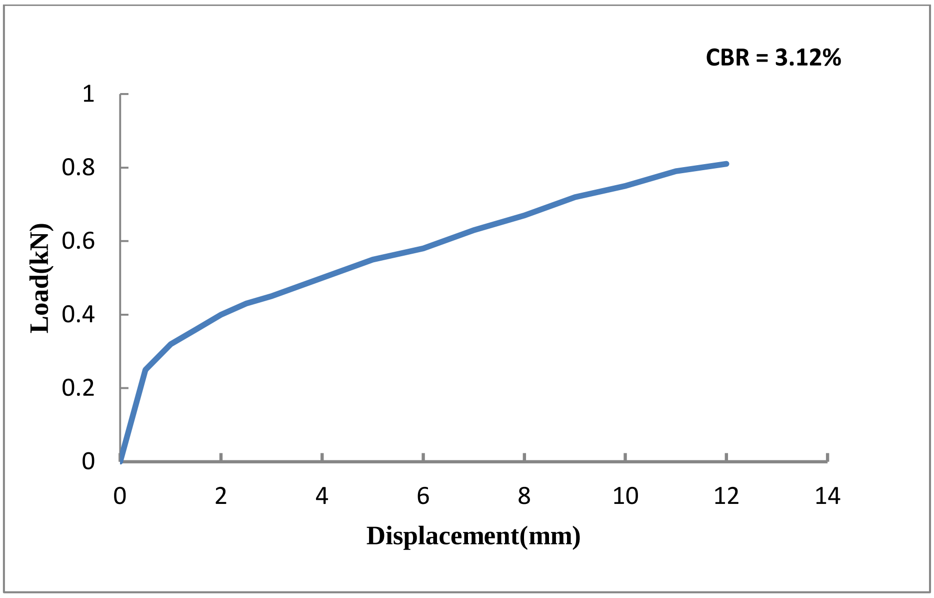

Figure 4.2: **Load Penetration curves for unreinforced Sample A**

4.1.2 Load Penetration curves for Geotextile layer placed at 1/3 from the bottom of the mould in sample A:

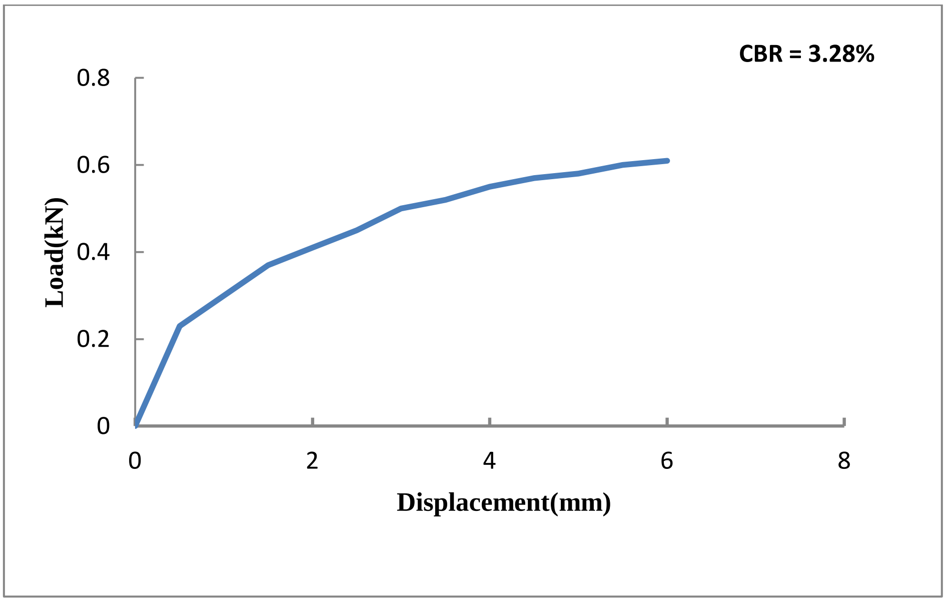

Figure 4.3: **Load Penetration curves for Geotextile layer placed 1/3 from the bottom of the mould in sample A**

4.1.3 Load Penetration curves for Geotextile layer placed at 2/3 from the bottom of the mould in sample A:

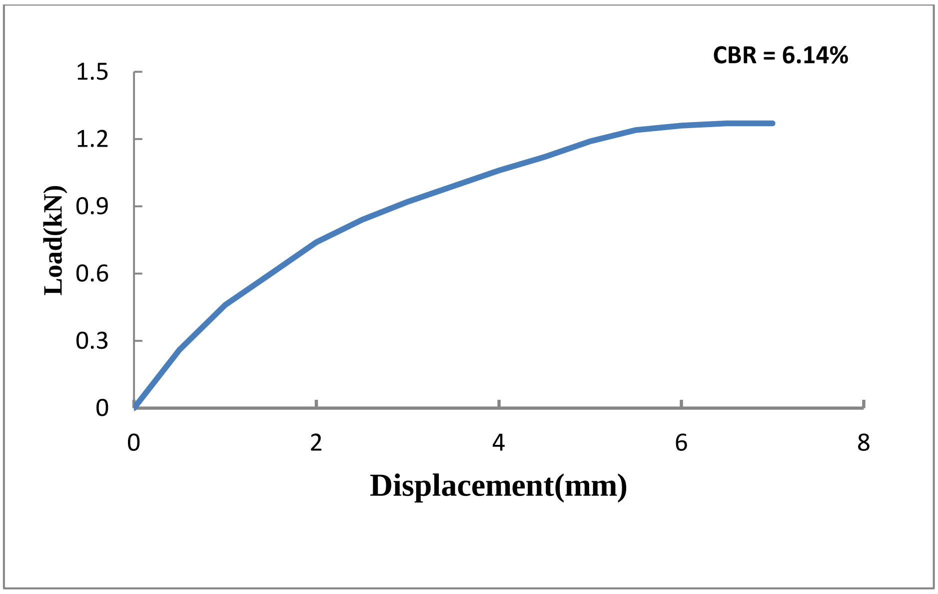

Figure 4.4: **Load Penetration curves for Geotextile layer placed at 2/3 from the bottom of the mould in sample A**

4.1.4 Load Penetration curves for Geotextile layer placed at 0.85H from the bottom of the mould in sample A:

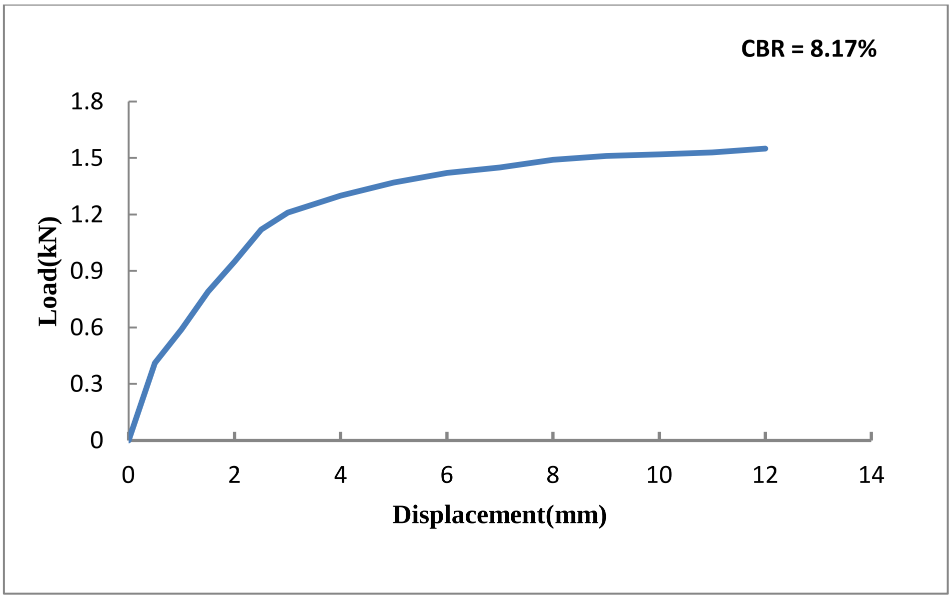

Figure 4.5: **Load Penetration curves for Geotextile layer placed at 0.85H from the bottom of the mould in sample A.**

The California Bearing Ratio test was conducted on unreinforced sample A. The CBR value obtained at 2.5 mm is 3.2%. This sample A is reinforced with geotextile, in which the geotextile were placed at different depths i.e. 1/3H, 2/3H and 0.85H from the bottom of the mould. The CBR values become increases 3.28%, 6.14% and 8.17% at depths 1/3H, 2/3H and 0.85H.

4.1.5 Load Penetration curves for unreinforced Sample B:

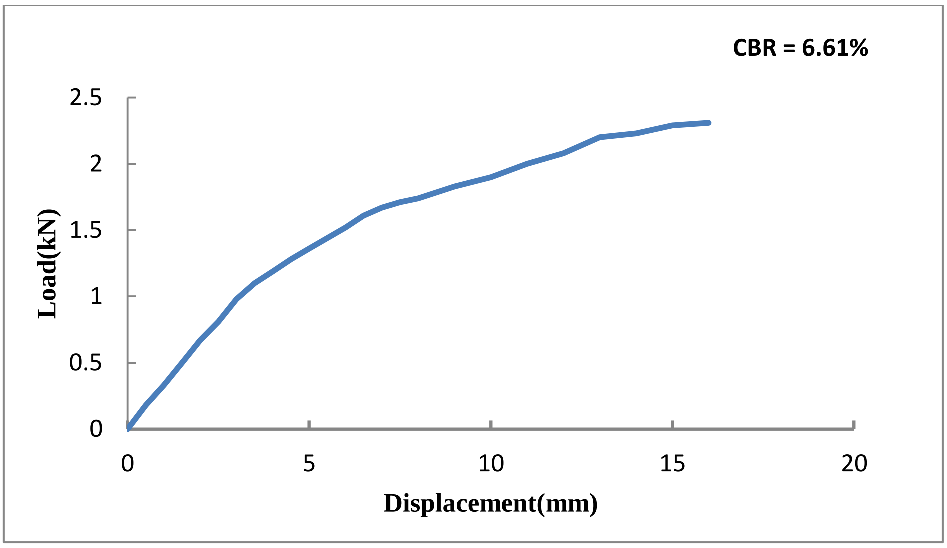

***Figure 4.6*: Load Penetration curves for unreinforced Sample B**

4.1.6 Load Penetration curves for Geotextile layer placed at 1/3 from the bottom of the mould in sample B:

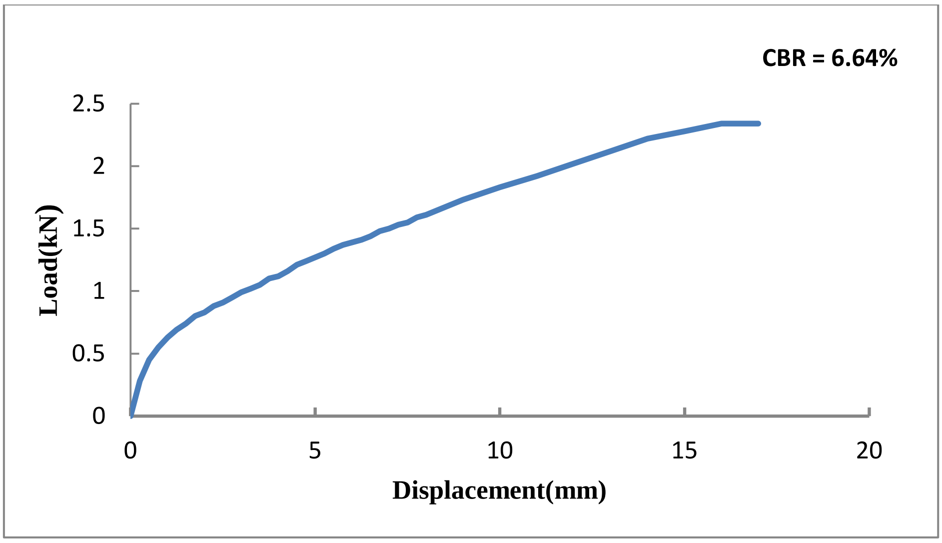

***Figure 4.7:* Load Penetration curves for Geotextile layer placed at 1/3 from the bottom of the mould in sample B**

4.1.7 Load Penetration curves for Geotextile layer placed at 2/3 from the bottom of the mould in sample B:

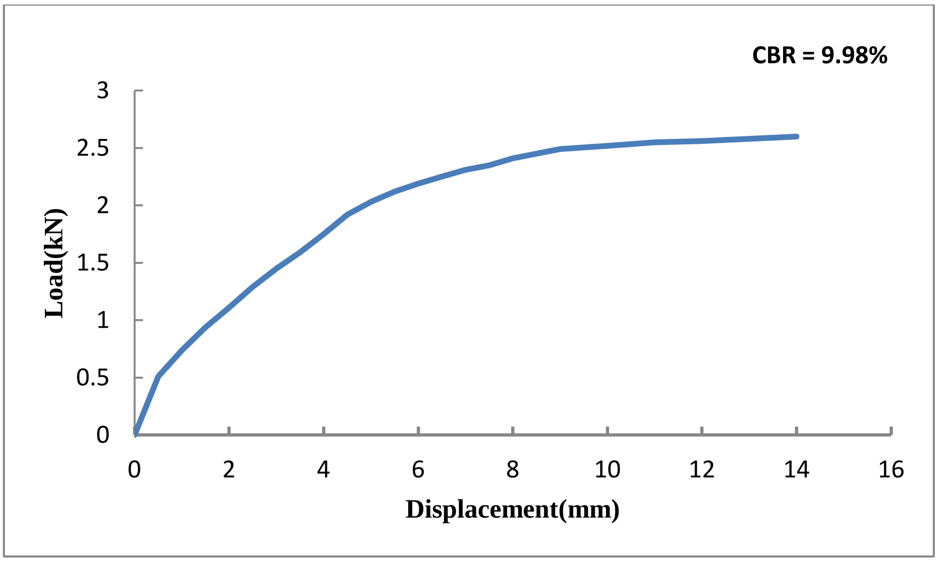

Figure 4.8: **Load Penetration curves for Geotextile layer placed at 2/3H from the bottom of the mould in sample B.**

4.1.8 Load Penetration curves for Geotextile layer placed at 0.85H from the bottom of the mould in sample B:

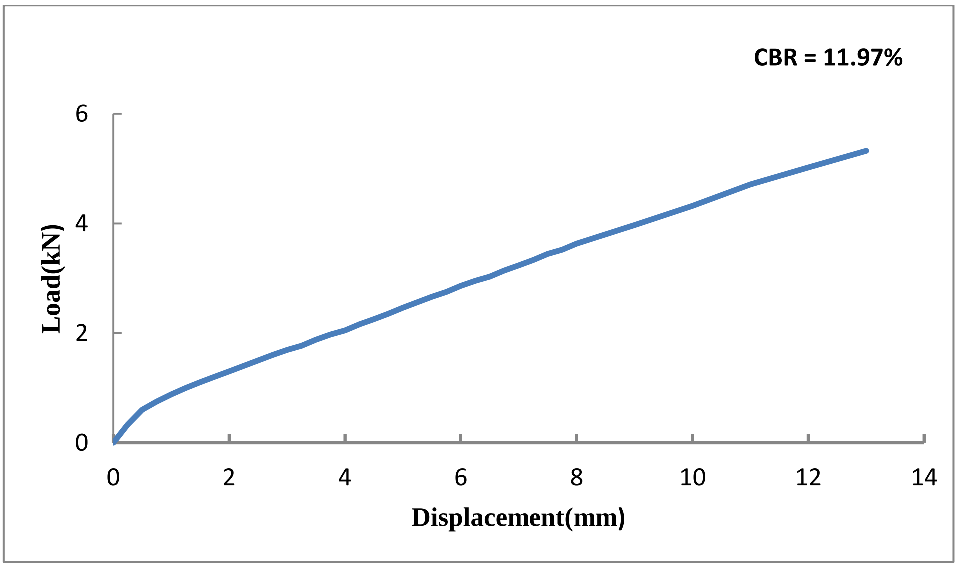

Figure 4.9: **Load Penetration curves for Geotextile layer placed at 0.85H from the bottom of the mould in sample B**

The California Bearing Ratio test was conducted on unreinforced sample B. The CBR value obtained at 2.5 mm is 6.61%. This sample B is reinforced with geotextile, in which the geotextile are placed at different depths i.e. 1/3H, 2/3H and 0.85H from the bottom of the mould. The CBR values become increases 6.64%, 9.98% and 11.97% at depths 1/3H, 2/3H and 0.85H.

4.1.9 Load Penetration curves for unreinforced Sample C:

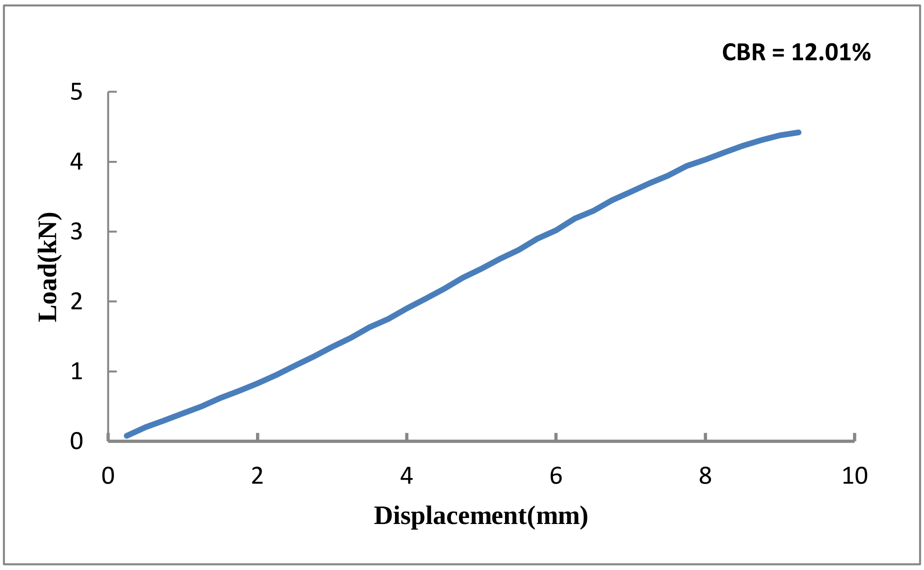

Figure 4.10: **Load Penetration curves for unreinforced Sample C**

4.1.10 Load Penetration curves for Geotextile layer placed at 1/3 from the bottom of the mould in sample C:

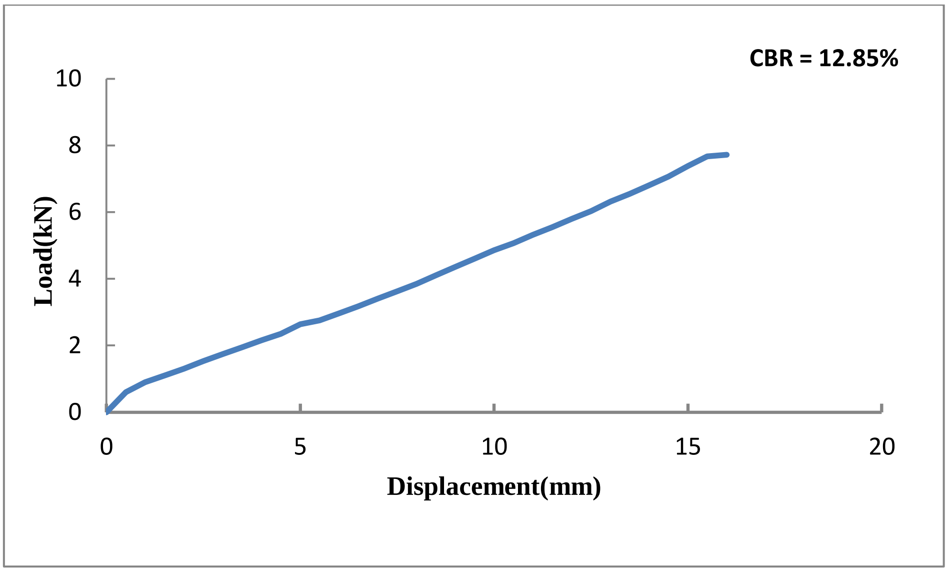

Figure 4.11: **Load Penetration curves for Geotextile layer placed at 1/3 from the bottom of the mould in sample C**

4.1.11 Load Penetration curves for Geotextile layer placed at 2/3 from the bottom of the mould in sample C:

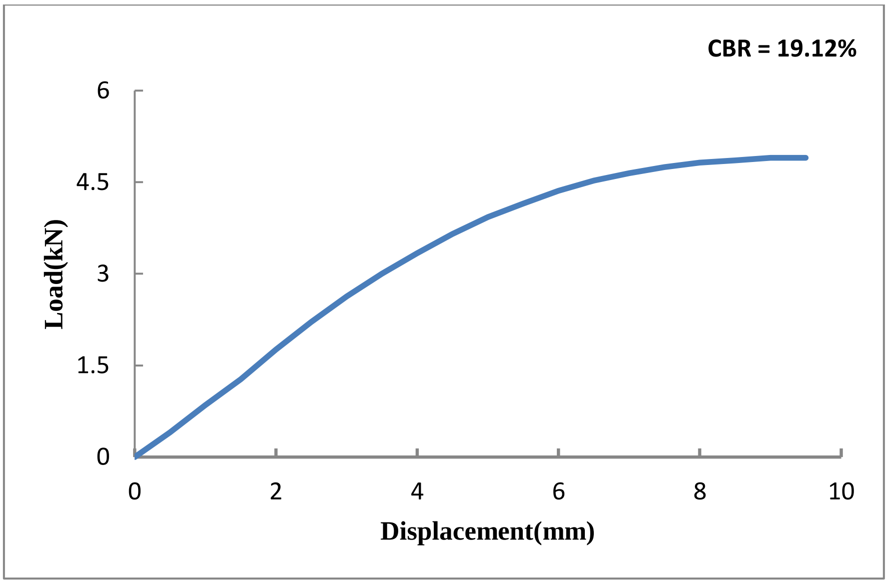

Figure 4.12: **Load Penetration curves for Geotextile layer placed at 2/3 from the bottom of the mould in sample C**

4.1.12 Load Penetration curves for Geotextile layer placed at 0.85H from the bottom of the mould in sample C:

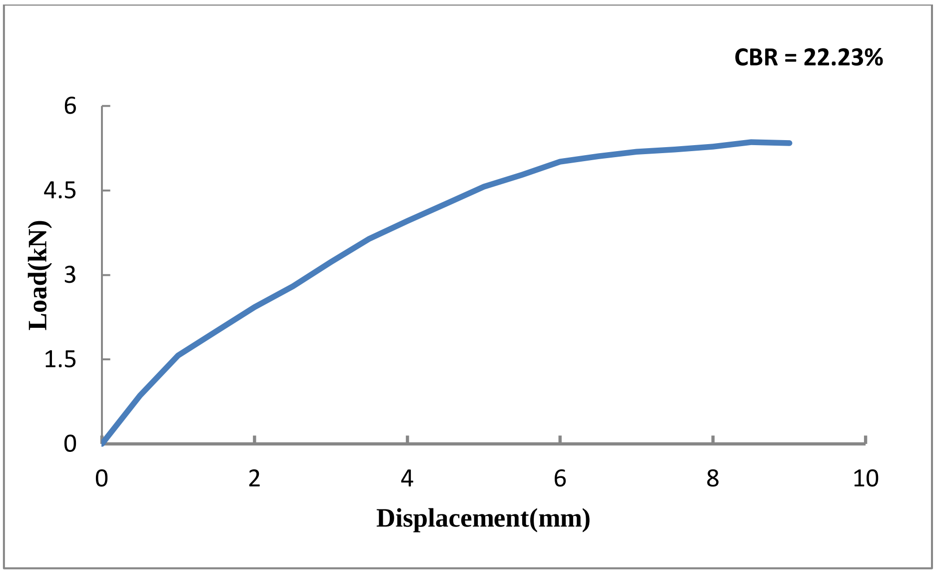

Figure 4.13: **Load Penetration curves for Geotextile layer placed at 0.85H from the bottom of the mould in sample C**

The California Bearing Ratio test was conducted on unreinforced sample C. The CBR value obtained at 2.5 mm is 12.01%. This sample C is reinforced with geotextile, in which the geotextile are placed at different depths i.e. 1/3H, 2/3H and 0.85H from the bottom of the mould. The CBR values become increases 12.85%, 19.12% and 22.23% at depths 1/3H, 2/3H and 0.85H.

From the above test results, there was the considerable increase in the CBR values of all the three different samples under soaked condition, when the non- geotextiles are placed at three different positions from the bottom of the mould. The representation of CBR results of samples A, B and C in table 4.1.

Table 4.1: **CBR values of Sample A, B & C with and without geotextiles**

S. No.	Samples	Soil without Geotextiles (%)	Soil with Geotextiles at different depths (%) from the base of the mould		
			0.33H	0.66H	0.85H
1	A	3.12	3.28	6.14	8.17
2	B	6.61	6.64	9.98	11.97
3	C	12.01	12.85	19.12	22.23

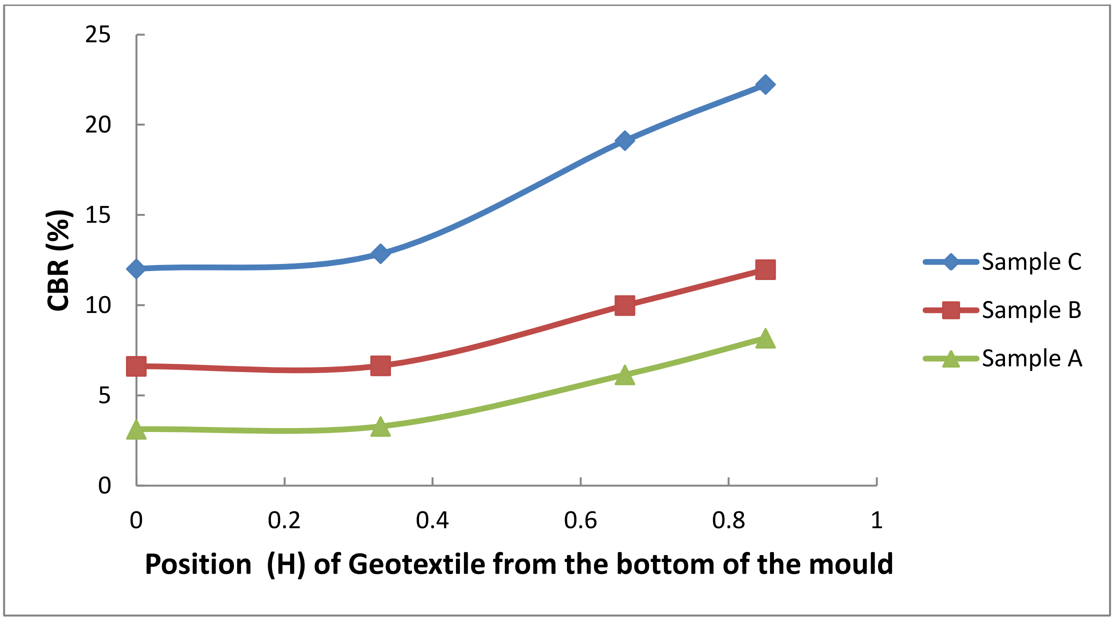

Figure 4.14: **Representation of results when single layer of geotextile are placed at different position in sample A, B and C**

The values of the soaked CBR are (3.28%, 6.14% and 8.17%), (6.64%, 9.98% and 11.97%) and (12.85%, 19.12% and 22.23%) respectively, when the geotextiles are placed at 0.33H, 0.66H and 0.85H from the bottom of the mould in sample A, B and C. The percentage increase of soaked CBR values are (5.12%, 96.8% and 161%), (0.45%, 50.9% and 81%) and (7%, 59% and 85%) respectively, when the geotextiles are placed at 0.33H, 0.66H and 0.85H from the bottom of the mould in sample A, B and C.

CHAPTER- 05

DESIGN OF FLEXIBLE PAVEMENT

5.1 PRINCIPLES OF PAVEMENT DESIGN:-

The pavement structure is a linear elastic multilayered 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 (ε_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. The three layered pavement structure and their critical strain as shown in figure 5.1.

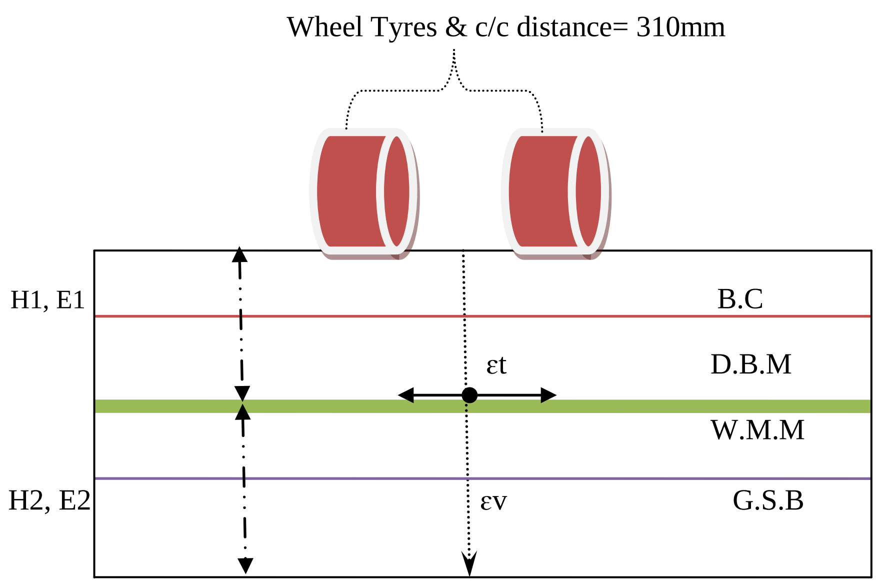

Figure 5.1: **Three layered pavement structure and location of their critical strains**

5.2 Fatigue Model:-

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

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

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

N_f = fatigue life, ε_t = Maximum 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.

5.3 Rutting model:-

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

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

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

Where, N = Number of cumulative 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 upto 30 msa and 10% of the length for the design traffic beyond.

In fatigue life analysis, the thickness of the granular subbase layer and wet mix macadam layer is constant (200+250 = 550 mm), so that the thickness of the dense bituminous macadam layer is decreased followed by the geotextile is placed at different locations. The critical horizontal strain is calculated from IITPAVE software. For fatigue life 100MSA, this critical strain value should be less than the allowable horizontal strain value calculated (as equation 5.1 and 5.2).The percentage saving of DBM layer thickness is also computed. Table 5.1 to 5.28 represents the Pavement Composition for Soil Samples A, B and C with geotextiles at different location and their output results from IITPAVE, in Fatigue Life 100MSA at 90% and 80% reliability.

In rutting life analysis, the thickness of the dense bituminous macadam layer and bituminous concrete layer is constant (150+50 = 200 mm), so that the thickness of the granular layer is decreased followed by the geotextile is placed at different locations. The critical vertical strain is calculated from IITPAVE software. For rutting life 100MSA, this critical strain value should be less than the allowable vertical strain value calculated (as equation 5.3 and 5.4).The percentage saving of granular layer thickness is also computed. Table 5.29 to 5.56 represents the Pavement Composition for Soil Samples A, B and C with geotextiles at different location and their output results from IITPAVE, in Rutting Life 100MSA at 90% and 80% reliability.

The thickness of the road crust is calculated according to IRC: 37- 2012 and IRC: 37-2001 at 90% and 80% reliability. Table 5.57 to 5.84 shows the Pavement Composition for Soil Sample A, B and C with geotextiles at different location and their output results from IITPAVE, in Fatigue Life & Rutting Life = 100MSA.

***Table 5.1:* Pavement Composition for Soil Sample A with geotextiles at different location for Fatigue Life 100MSA at 90% reliability**

S.No	Design CBR (%)	Placement of Geotextiles from bottom of the mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	Fatigue Life (MSA)	% Saving in DBM Layer Thickness
1.	3.12	0	200	250	165	50	665	165	170	100	0
2.	3.28	0.33H	200	250	160	50	660	167	170	100	3.03
3.	6.14	0.66H	200	250	130	50	630	164	170	100	21.2
4.	8.17	0.85H	200	250	118	50	618	162	170	100	28.4

* Horizontal Strain in micron (10^{-6}) ** Allowable Horizontal Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3
E values (MPa) 3000.00 97.52 31.20
Mu values 0.350.350.35
thicknesses (mm) 215.00 450.00
single wheel load (N) 20000.00
tyre pressure (MPa) 0.56
Dual Wheel

***Table 5.2:* The output result from IITPAVE in sample A of CBR = 3.12%**

Z	R	epZ	epT	epR
215.00	0.00	0.1529E-03	0.1581E-03	0.1107E-03
215.00L	0.00	0.3953E-03	0.1581E-03	0.1107E-03
215.00	155.00	0.1468E-03	**0.1652E-03**	0.9222E-04
215.00L	155.00	0.3903E-03	0.1652E-03	0.9222E-04

Horizontal Strain in micron = **165.2 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3
E values (MPa) 3000.00 102.52 32.80
Mu values 0.350.350.35
thicknesses (mm) 210.00 450.00
single wheel load (N) 20000.00
tyre pressure (MPa) 0.56
Dual Wheel

***Table 5.3:* The output result from IITPAVE in sample A of CBR = 3.28%**

Z	R	epZ	epT	epR
210.00	0.00	0.1553E-03	0.1605E-03	0.1117E-03
210.00L	0.00	0.4020E-03	0.1605E-03	0.1117E-03
210.00	155.00	0.1478E-03	**0.1675E-03**	0.9081E-04
210.00L	155.00	0.3946E-03	0.1675E-03	0.9081E-04

Horizontal Strain in micron = $\mathbf{167.5 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 175.73 56.22

Mu values 0.350.350.35

thicknesses (mm) 180.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.4:* The output result from IITPAVE in sample A of CBR = 6.14%**

Z	R	epZ	epT	epR
180.00	0.00	0.1577E-03	0.1592E-03	0.1056E-03
180.00L	0.00	0.3994E-03	0.1592E-03	0.1056E-03
180.00	155.00	0.1374E-03	**0.1641E-03**	0.6430E-04
180.00L	155.00	0.3689E-03	0.1641E-03	0.6430E-04

Horizontal Strain in micron = $\mathbf{164.1 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 210.90 67.50

Mu values 0.350.350.35

thicknesses (mm) 168.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.5:* The output result from IITPAVE in sample A of CBR = 8.17%**

Z	R	epZ	epT	epR
168.00	0.00	0.1603E-03	0.1593E-03	0.1045E-03
168.00L	0.00	0.4021E-03	0.1593E-03	0.1045E-03

168.00	155.00	0.1326E-03	**0.1627E-03**	0.5193E-04
168.00L	155.00	0.3580E-03	0.1627E-03	0.5193E-04

Horizontal Strain in micron = **162.7×10^{-6}**

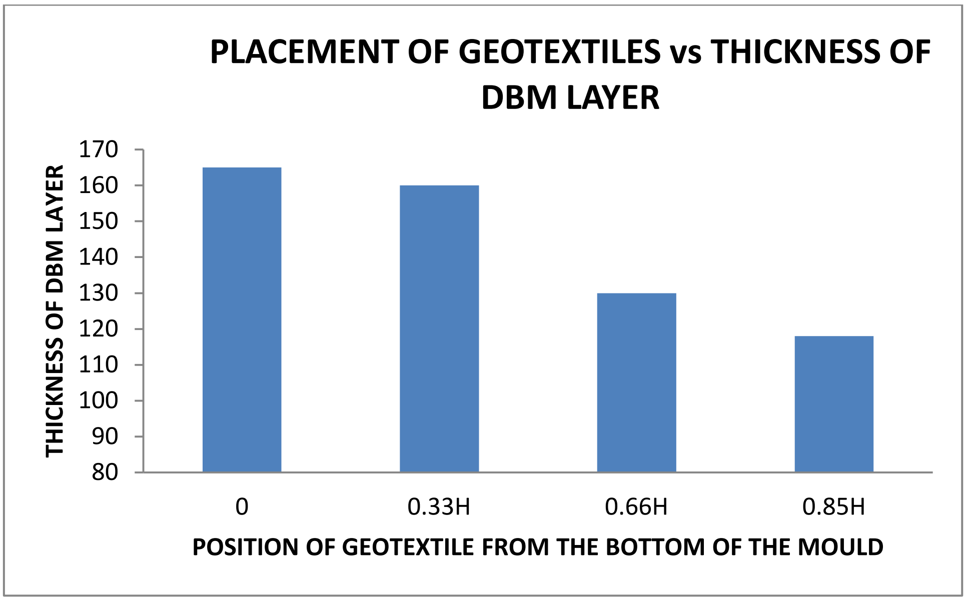

Figure 5.2: **Placement of Geotextiles in sample A with layer of DBM thickness at 90% reliability.**

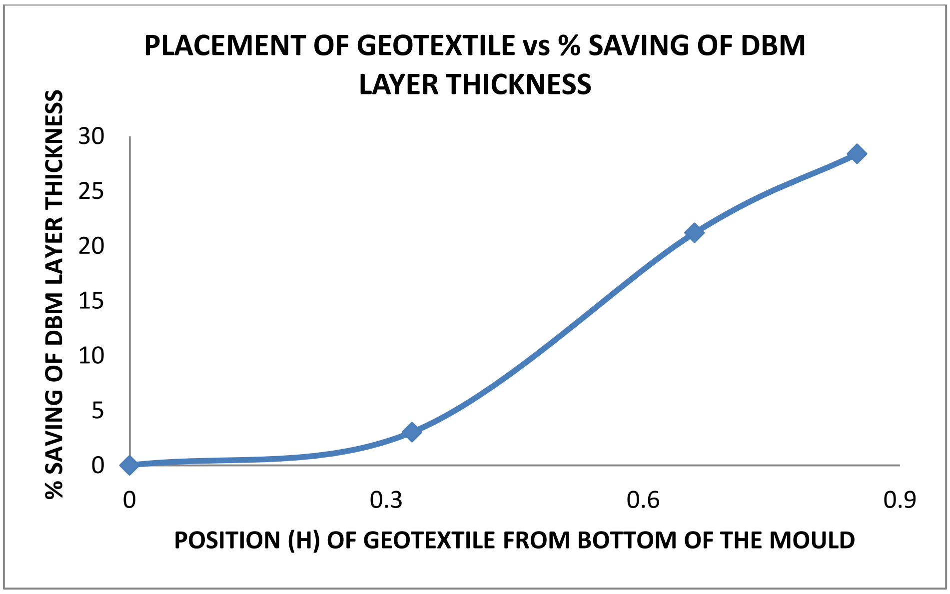

Figure 5.3: **Placement of Geotextiles in sample A with % saving of DBM thickness at 90% reliability**

For fatigue life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample A, there is a saving of thickness of Dense Bituminous macadam (DBM) layer are 3.03%, 21.2% and 28.4% at 90percent reliability as shown in figure 5.3. Figure 5.2 gives the variation of DBM layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.3 gives the variation of placement of geotextile vs saving (%) of DBM layer thickness.

Table 5.6: **Pavement Composition for Soil Sample B with geotextiles at different location for Fatigue Life 100MSA at 90% reliability**

S.No.	Design CBR (%)	Placement of Geotextiles from bottom of the mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	Fatigue Life (MSA)	% Saving in DBM Layer Thickness
1.	6.61	0	200	250	128	50	628	162	170	100	0
2.	6.64	0.33H	200	250	128	50	628	162	170	100	0
3.	9.98	0.66H	200	250	105	50	605	165	170	100	17.9
4.	11.97	0.85H	200	250	95	50	595	165	170	100	25.7

* Horizontal Strain in micron (10^{-6})   ** Allowable Horizontal Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 184.40 59.00

Mu values 0.350.350.35

thicknesses (mm) 178.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.7: **The output result from IITPAVE in sample B of CBR = 6.61%**

Z	R	epZ	epT	epR
178.00	0.00	0.1571E-03	0.1581E-03	0.1046E-03
178.00L	0.00	0.3967E-03	0.1581E-03	0.1046E-03
178.00	155.00	0.1357E-03	**0.1627E-03**	0.6148E-04
178.00L	155.00	0.3640E-03	0.1627E-03	0.6148E-04

Horizontal Strain in micron = **162.7 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 184.70 59.11

Mu values 0.350.350.35

thicknesses (mm) 178.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.8: **The output result from IITPAVE in sample B of CBR = 6.64%**

Z	R	epZ	epT	epR
178.00	0.00	0.1570E-03	0.1579E-03	0.1045E-03
178.00L	0.00	0.3963E-03	0.1579E-03	0.1045E-03
178.00	155.00	0.1356E-03	**0.1626E-03**	0.6139E-04
178.00L	155.00	0.3636E-03	0.1626E-03	0.6139E-04

Horizontal Strain in micron = **162.6×10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 239.80 76.72

Mu values 0.350.350.35

thicknesses (mm) 155.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.9: **The output result from IITPAVE in sample B of CBR = 9.98%**

Z	R	epZ	epT	epR
155.00	0.00	0.1670E-03	0.1638E-03	0.1060E-03
155.00L	0.00	0.4176E-03	0.1638E-03	0.1060E-03
155.00	155.00	0.1300E-03	**0.1652E-03**	0.3973E-04
155.00L	155.00	0.3566E-03	0.1652E-03	0.3973E-04

Horizontal Strain in micron = **165.2×10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 269.40 86.20

Mu values 0.350.350.35

thicknesses (mm) 145.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.10: **The output result from IITPAVE in sample B of CBR = 11.97%**

Z	R	epZ	epT	epR
145.00	0.00	0.1718E-03	0.1655E-03	0.1069E-03
145.00L	0.00	0.4270E-03	**0.1655E-03**	0.1069E-03

145.00	155.00	0.1254E-03	0.1649E-03	0.2709E-04
145.00L	155.00	0.3483E-03	0.1649E-03	0.2709E-04

Horizontal Strain in micron = **165.5 x 10^{-6}**

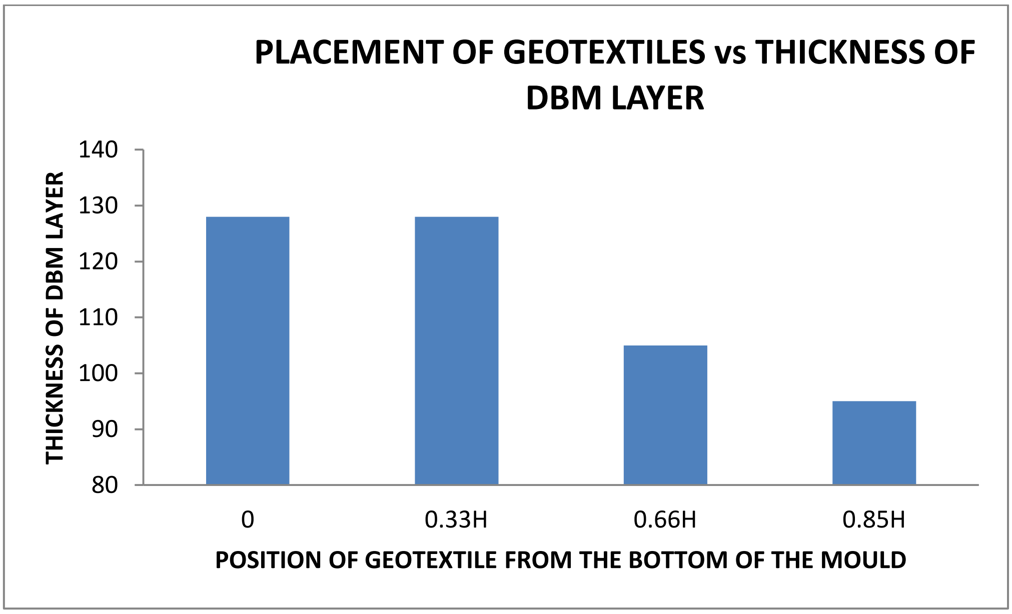

Figure 5.4: **Placement of Geotextiles in sample B with layer of DBM thickness at 90% reliability**

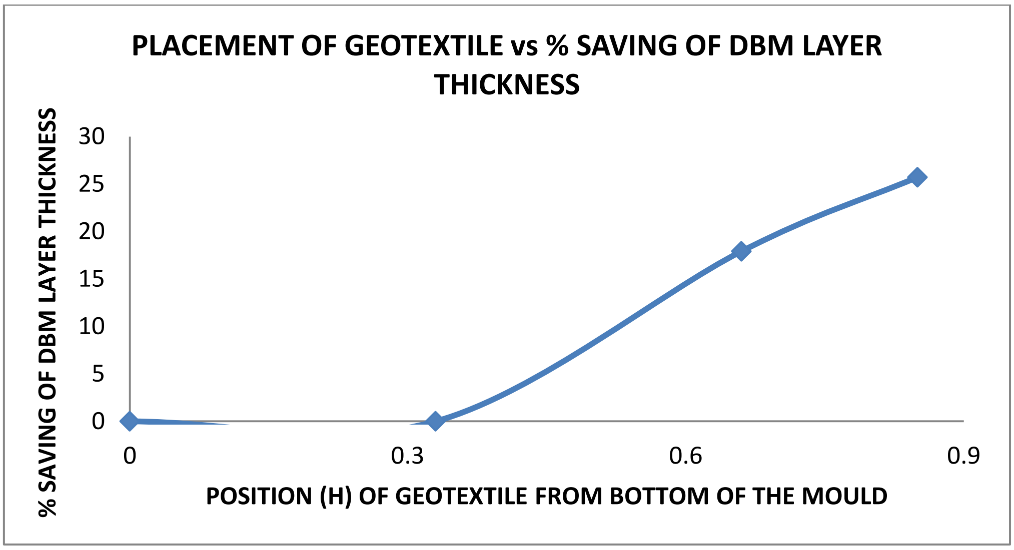

Figure 5.5: **Placement of Geotextiles in sample B with % saving of DBM thickness at 90% reliability**

For fatigue life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample B, there is a saving of thickness of Dense Bituminous macadam (DBM) layer are 0%, 17.9% and 25.7% at 90percent reliability as shown in figure 5.5. Figure 5.4 gives the variation of DBM layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.5 gives the variation of placement of geotextile vs saving (%) of DBM layer thickness.

Table 5.11: **Pavement Composition for Soil Sample C with geotextiles at different location for Fatigue Life 100MSA at 90% reliability**

S.No	Design CBR (%)	Placement of Geotextiles from bottom of the mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	Fatigue Life (MSA)	% Saving in DBM Layer Thickness
1.	12.01	0	200	250	95	50	595	165	170	100	0
2.	12.85	0.33H	200	250	92	50	592	165	170	100	3.15
3.	19.12	0.66H	200	250	72	50	572	163	170	100	24.2

* Horizontal Strain in micron (10^{-6}) ** Allowable Horizontal Strain Values in micron (10^{-6})

The input to IITPAVE:-

No. of layers 3

E values (MPa) 3000.00 270.00 86.38

Mu values 0.350.350.35

thicknesses (mm) 145.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.12: **The output result from IITPAVE in sample C of CBR = 12.01%**

Z	R	epZ	epT	epR
145.00	0.00	0.1717E-03	0.1653E-03	0.1068E-03
145.00L	0.00	0.4262E-03	**0.1653E-03**	0.1068E-03
145.00	155.00	0.1252E-03	0.1647E-03	0.2698E-04
145.00L	155.00	0.3477E-03	0.1647E-03	0.2698E-04

Horizontal Strain in micron = **165.3×10^{-6}**

The input to IITPAVE:-

No. of layers 3

E values (MPa) 3000.00 281.90 90.20

Mu values 0.350.350.35

thicknesses (mm) 142.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.13: **The output result from IITPAVE in sample C of CBR = 12.85%**

Z	R	epZ	epT	epR
142.00	0.00	0.1726E-03	**0.1650E-03**	0.1066E-03
142.00L	0.00	0.4271E-03	0.1650E-03	0.1066E-03
142.00	155.00	0.1230E-03	0.1636E-03	0.2252E-04
142.00L	155.00	0.3428E-03	0.1636E-03	0.2252E-04

Horizontal Strain in micron = **165.0 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 363.60 116.32

Mu values 0.350.350.35

thicknesses (mm) 122.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.14: **The output result from IITPAVE in sample C of CBR = 19.12%**

Z	R	epZ	epT	epR
122.00	0.00	0.1812E-03	**0.1633E-03**	0.1072E-03
122.00L	0.00	0.4386E-03	0.1633E-03	0.1072E-03
122.00	155.00	0.1068E-03	0.1565E-03	0.9765E-05
122.00L	155.00	0.3081E-03	0.1565E-03	0.9765E-05

Horizontal Strain in micron = **163.3 x 10^{-6}**

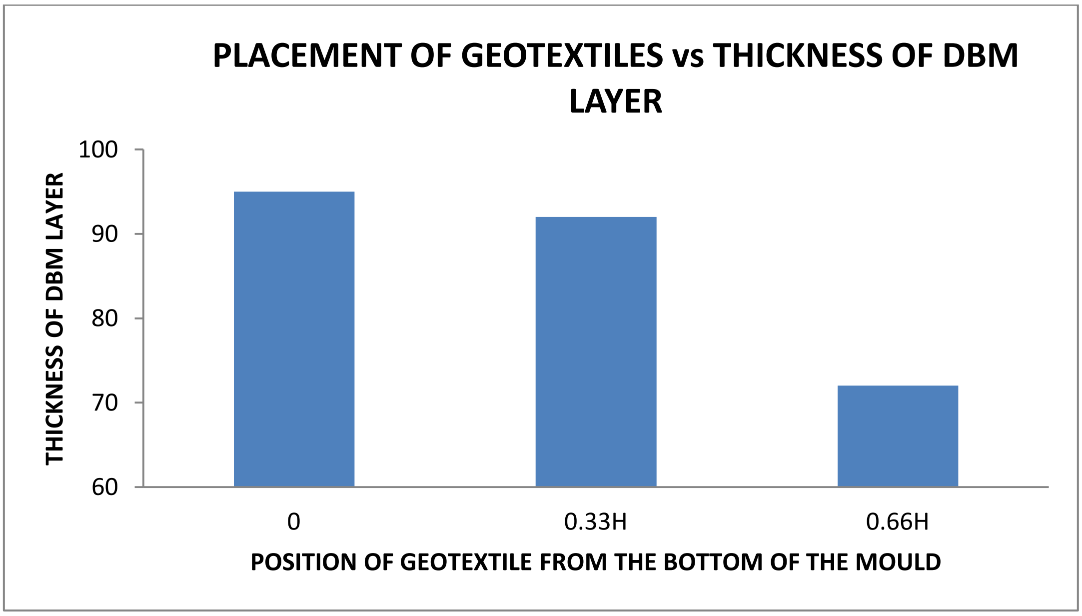

Figure 5.6: **Placement of Geotextiles in sample C with layer of DBM thickness at 90% reliability**

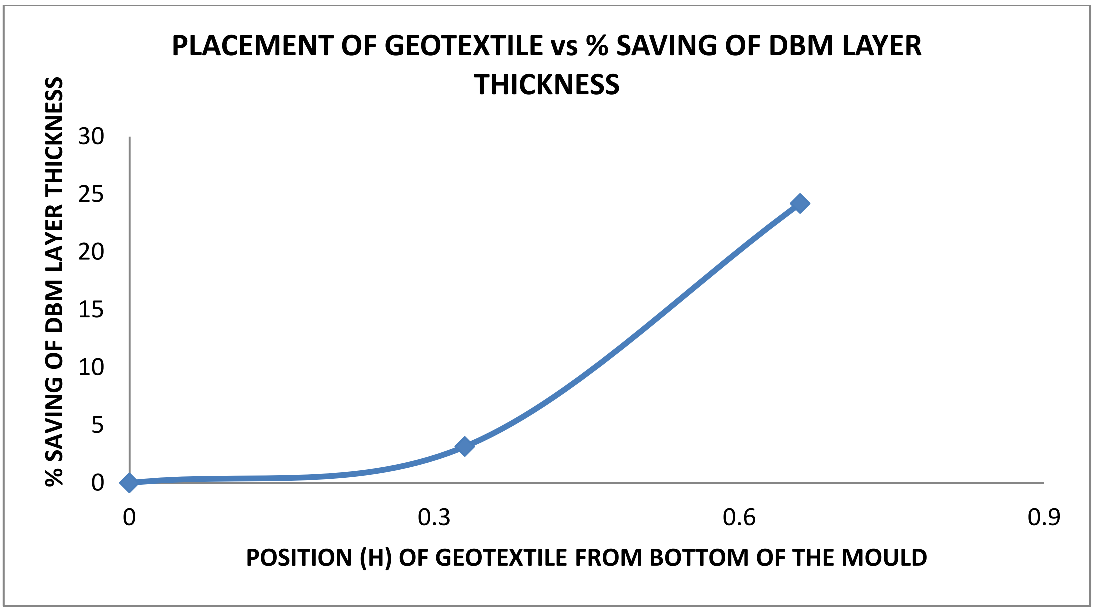

Figure 5.7: **Placement of Geotextiles in sample C with % saving of DBM thickness at 90% reliability**

For fatigue life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H and 0.66H from the base of the mould in sample C, there is a saving of thickness of Dense Bituminous macadam (DBM) layer are 3.15% and 24.2% at 90percent reliability as shown in figure 5.7. Figure 5.6 gives the variation of DBM layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.7 gives the variation of placement of geotextile vs saving (%) of DBM layer thickness.

***Table 5.15:* Pavement Composition for Soil Sample A with geotextiles at different location for Fatigue Life 100MSA at 80% reliability**

S.No	Design CBR (%)	Placement of Geotextiles from bottom of the mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	Fatigue Life (MSA)	% Saving in DBM Layer Thickness
1.	3.12	0	200	250	205	50	705	192	198	100	0
2.	3.28	0.33H	200	250	200	50	700	193	198	100	2.5
3.	6.14	0.66H	200	250	160	50	660	189	198	100	21.9
4.	8.17	0.85H	200	250	142	50	642	190	198	100	30.73

* Horizontal Strain in micron (10^{-6}) ** Allowable Horizontal Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 97.52 31.20

Mu values 0.350.350.35

thicknesses (mm) 255.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.16:* The output result from IITPAVE in sample A of CBR = 3.12%**

Z	R	epZ	epT	epR
255.00	0.00	0.1797E-03	0.1814E-03	0.1244E-03
255.00L	0.00	0.4264E-03	0.1814E-03	0.1244E-03
255.00	155.00	0.1794E-03	**0.1920E-03**	0.1126E-03
255.00L	155.00	0.4320E-03	0.1920E-03	0.1126E-03

Horizontal Strain in micron = **192.0 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 102.52 32.80

Mu values 0.350.350.35

thicknesses (mm) 250.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.17:* The output result from IITPAVE in sample A of CBR = 3.28%**

Z	R	epZ	epT	epR
250.00	0.00	0.1815E-03	0.1830E-03	0.1245E-03
250.00L	0.00	0.1815E-03	0.1830E-03	0.1245E-03
250.00	155.00	0.1800E-03	**0.1934E-03**	0.1106E-03
250.00L	155.00	0.4340E-03	0.1934E-03	0.1106E-03

Horizontal Strain in micron = **193.4 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 175.70 56.22

Mu values 0.350.350.35

thicknesses (mm) 210.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.18:* The output result from IITPAVE in sample A of CBR = 6.14%**

Z	R	epZ	epT	epR
210.00	0.00	0.1893E-03	0.1820E-03	0.1117E-03
210.00L	0.00	0.4326E-03	0.1820E-03	0.1117E-03
210.00	155.00	0.1711E-03	**0.1899E-03**	0.7726E-04
210.00L	155.00	0.4069E-03	0.1899E-03	0.7726E-04

Horizontal Strain in micron = **189.9 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 210.90 67.50

Mu values 0.350.350.35

thicknesses (mm) 192.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.19:* The output result from IITPAVE in sample A of CBR = 8.17%**

Z	R	epZ	epT	epR
192.00	0.00	0.1977E-03	0.1844E-03	0.1179E-03
192.00L	0.00	0.4442E-03	0.1844E-03	0.1179E-03

192.00	155.00	0.1673E-03	**0.1904E-03**	0.5991E-04
192.00L	155.00	0.3974E-03	0.1904E-03	0.5991E-04

Horizontal Strain in micron = **190.4 x 10^{-6}**

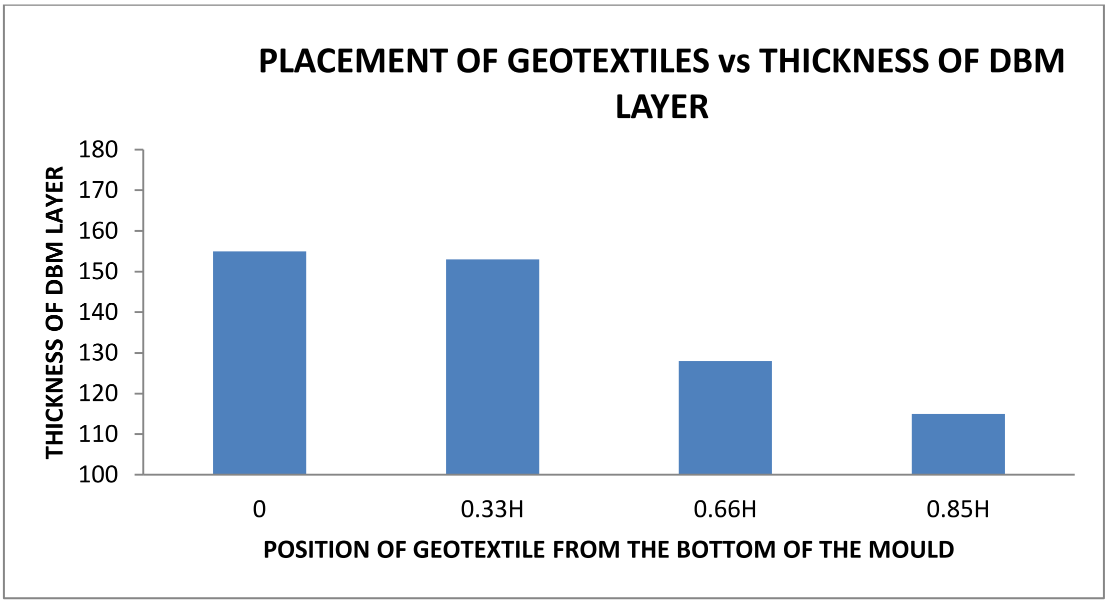

Figure 5.8: **Placement of Geotextiles in sample A with layer of DBM thickness at 80% reliability**

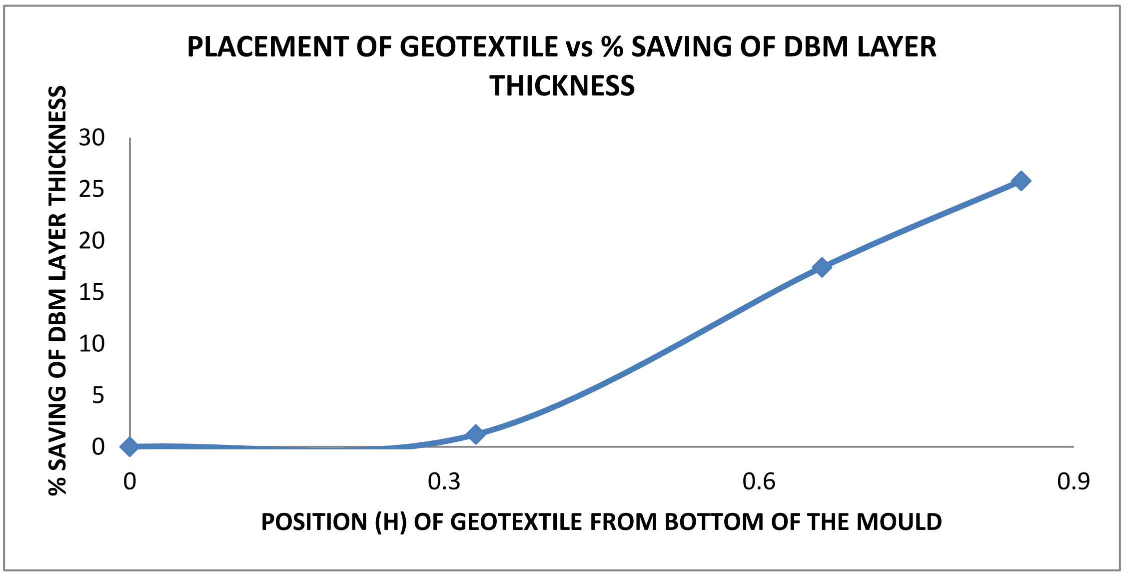

Figure 5.9: **Placement of Geotextiles in sample A with % saving of DBM thickness at 80% reliability**

For fatigue life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample A, there is a saving of thickness of Dense Bituminous macadam (DBM) layer are 2.5%, 21.9% and 30.73% at 80percent reliability as shown in figure 5.9. Figure 5.8 gives the variation of DBM layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.9 gives the variation of placement of geotextile vs saving (%) of DBM layer thickness**.**

Table 5.20: **Pavement Composition for Soil Sample B with geotextiles at different location for Fatigue Life 100MSA at 80% reliability**

S.No	Design CBR (%)	Placement of Geotextiles from bottom of the mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	Fatigue Life (MSA)	% Saving in DBM Layer Thickness
1.	6.61	0	200	250	155	50	655	190	198	100	0
2.	6.64	0.33H	200	250	153	50	653	192	198	100	1.2
3.	9.98	0.66H	200	250	128	50	628	190	198	100	17.41
4.	11.97	0.85H	200	250	115	50	615	190	198	100	25.8

* Horizontal Strain in micron (10^{-6}) ** Allowable Horizontal Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 184.40 59.00

Mu values 0.350.350.35

thicknesses (mm) 205.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.21: **The output result from IITPAVE in sample B of CBR = 6.61%**

Z	R	epZ	epT	epR
205.00	0.00	0.1917E-03	0.1831E-03	0.1177E-03
205.00L	0.00	0.4364E-03	0.1831E-03	0.1177E-03
205.00	155.00	0.1705E-03	**0.1905E-03**	0.7306E-04
205.00L	155.00	0.4056E-03	0.1905E-03	0.7306E-04

Horizontal Strain in micron = **190.5 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 184.70 59.11

Mu values 0.350.350.35

thicknesses (mm) 203.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.22: **The output result from IITPAVE in sample B of CBR = 6.64%**

Z	R	epZ	epT	epR
203.00	0.00	0.1939E-03	0.1851E-03	0.1189E-03
203.00L	0.00	0.4420E-03	0.1851E-03	0.1189E-03
203.00	155.00	0.1715E-03	**0.1923E-03**	0.7244E-04
203.00L	155.00	0.4091E-03	0.1923E-03	0.7244E-04

Horizontal Strain in micron = $\mathbf{192.3 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 239.80 76.72

Mu values 0.350.350.35

thicknesses (mm) 178.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.23: **The output result from IITPAVE in sample B of CBR = 9.98%**

Z	R	epZ	epT	epR
178.00	0.00	0.2062E-03	0.1873E-03	0.1192E-03
178.00L	0.00	0.4568E-03	0.1873E-03	0.1192E-03
178.00	155.00	0.1638E-03	**0.1907E-03**	0.4462E-04
178.00L	155.00	0.3895E-03	0.1907E-03	0.4462E-04

Horizontal Strain in micron = $\mathbf{190.7 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 269.40 86.20

Mu values 0.350.350.35

thicknesses (mm) 165.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.24: **The output result from IITPAVE in sample B of CBR = 11.97%**

Z	R	epZ	epT	epR
165.00	0.00	0.2155E-03	0.1897E-03	0.1212E-03
165.00L	0.00	0.4704E-03	0.1897E-03	0.1212E-03

165.00	155.00	0.1588E-03	**0.1900E-03**	0.2799E-04
165.00L	155.00	0.3787E-03	0.1900E-03	0.2799E-04

Horizontal Strain in micron = **190.0 x 10^{-6}**

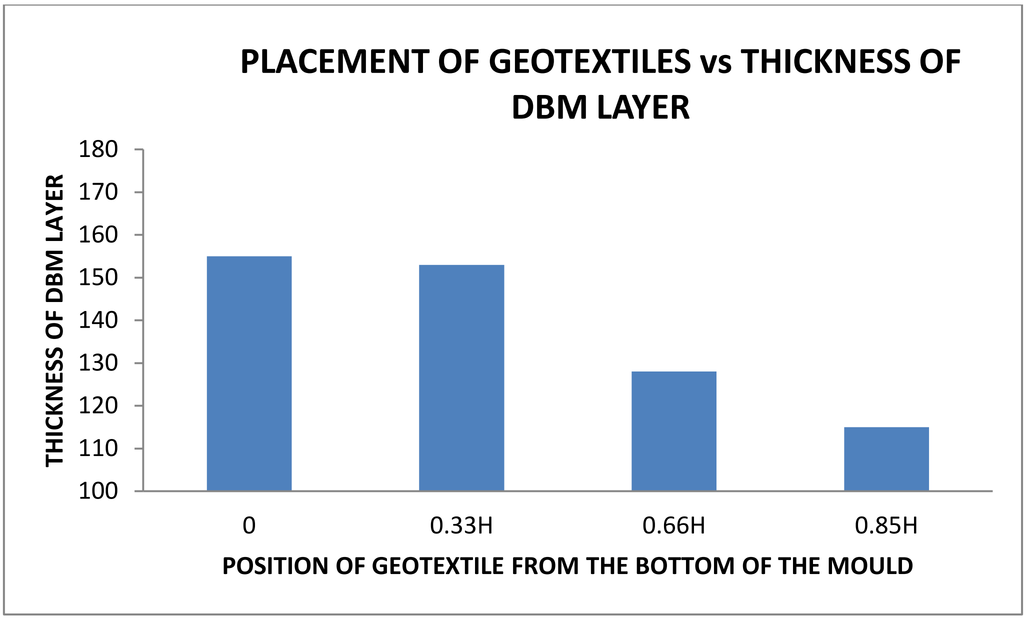

Figure 5.10: **Placement of Geotextiles in sample B with layer of DBM thickness at 80% reliability**

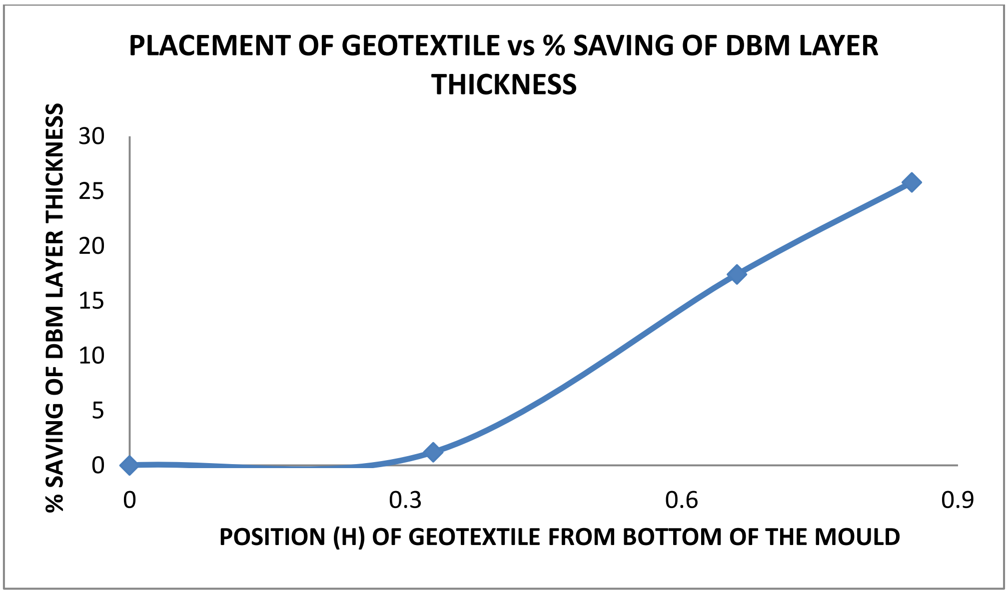

Figure 5.11: **Placement of Geotextiles in sample B with % saving of DBM thickness at 80% reliability**

For fatigue life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample B, there is a saving of thickness of Dense Bituminous macadam (DBM) layer are 1.2%, 17.4% and 25.80% at 80percent reliability as shown in figure 5.11. Figure 5.10 gives the variation of DBM layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.11 gives the variation of placement of geotextile vs saving (%) of DBM layer thickness.

Table 5.25: **Pavement Composition for Soil Sample C with geotextiles at different location for Fatigue Life 100MSA at 80% reliability**

S.No	Design CBR (%)	Placement of Geotextiles from bottom of the mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	Fatigue Life (MSA)	% Saving in DBM Layer Thickness
1.	12.01	0	200	250	113	50	613	191	198	100	0
2.	12.85	0.33H	200	250	110	50	610	190	198	100	2.6
3.	19.12	0.66H	200	250	83	50	583	190	198	100	26.54

* Horizontal Strain in micron (10^{-6}) ** Allowable Horizontal Strain Values in micron (10^{-6})

The input to IITPAVE:-

No. of layers 3

E values (MPa) 1700.00 270.00 86.38

Mu values 0.350.350.35

thicknesses (mm) 163.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.26: **The output result from IITPAVE in sample C of CBR = 12.01%**

Z	R	epZ	epT	epR
163.00	0.00	0.2181E-03	0.1918E-03	0.1226E-03
163.00L	0.00	0.4767E-03	**0.1918E-03**	0.1226E-03
163.00	155.00	0.1592E-03	0.1916E-03	0.2615E-04
163.00L	155.00	0.3811E-03	0.1916E-03	0.2615E-04

Horizontal Strain in micron = **191.8×10^{-6}**

The input to IITPAVE:-

No. of layers 3

E values (MPa) 1700.00 281.90 90.20

Mu values 0.350.350.35

thicknesses (mm) 160.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.27: **The output result from IITPAVE in sample C of CBR = 12.85%**

Z	R	epZ	epT	epR
160.00	0.00	0.2186E-03	0.1904E-03	0.1192E-03
160.00L	0.00	0.4743E-03	**0.1904E-03**	0.1192E-03
160.00	155.00	0.1563E-03	0.1893E-03	0.4462E-04
160.00L	155.00	0.3732E-03	0.1893E-03	0.4462E-04

Horizontal Strain in micron = **190.4 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 363.60 116.32

Mu values 0.350.350.35

thicknesses (mm) 133.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.28: **The output result from IITPAVE in sample C of CBR = 19.12%**

Z	R	epZ	epT	epR
133.00	0.00	0.2401E-03	0.1900E-03	0.1249E-03
133.00L	0.00	0.4992E-03	**0.1900E-03**	0.1249E-03
133.00	155.00	0.1349E-03	0.1794E-03	0.2563E-04
133.00L	155.00	0.3264E-03	0.1794E-03	0.2563E-04

Horizontal Strain in micron = **190.0 x 10^{-6}**

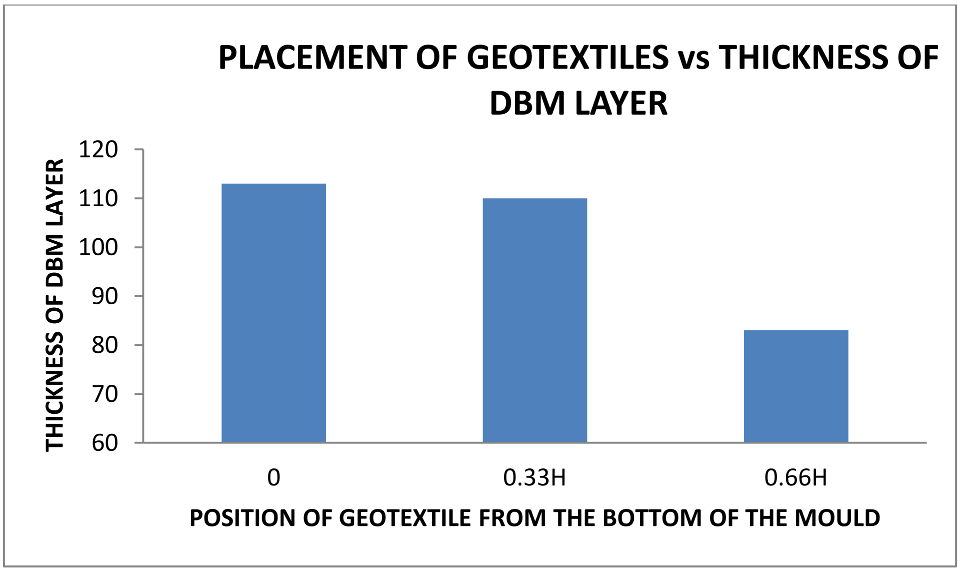

Figure 5.12: **Placement of Geotextiles in sample C with layer of DBM thickness at 80% reliability**

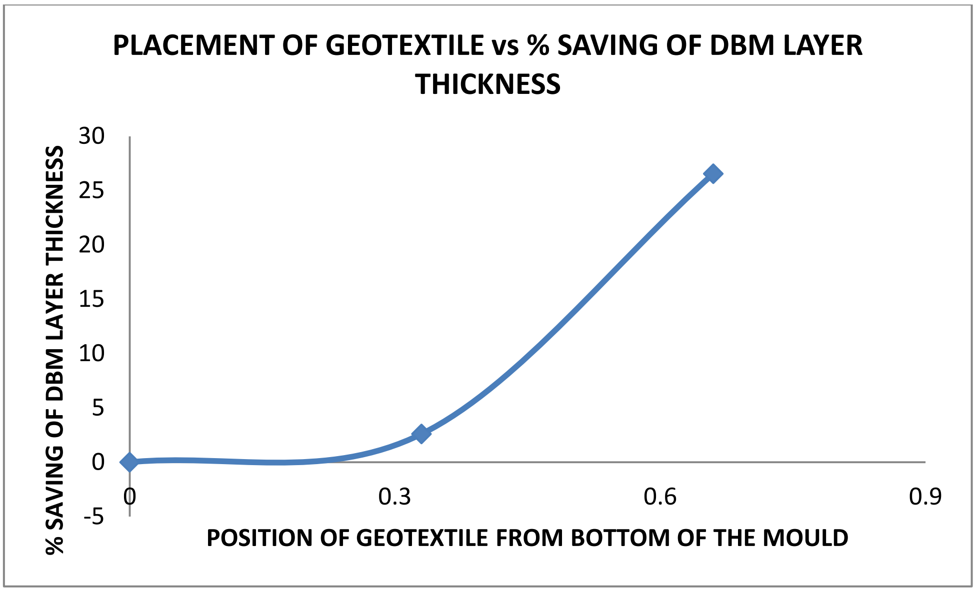

Figure 5.13: **Placement of Geotextiles in sample C with % saving of DBM thickness at 80% reliability**

For fatigue life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H and 0.66H from the base of the mould in sample C, there is a saving of thickness of Dense Bituminous macadam (DBM) layer are 2.6%, and 26.54% at 80percent reliability as shown in figure 5.13. Figure 5.12 gives the variation of DBM layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.13 gives the variation of placement of geotextile vs saving (%) of DBM layer thickness

Table 5.29: **Pavement Composition for Soil Sample A with geotextiles at different location for Rutting Life 100MSA at 90% reliability**

S.No	Design CBR (%)	Placement of Geotextiles from bottom of the mould	Granular Layer Thickness (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	ε_v*	ε_v**	Rutting Life (MSA)	% Saving in Granular Layer Thickness
1.	3.12	0	590	150	50	790	310	319	100	0
2.	3.28	0.33H	575	150	50	775	312	319	100	2.6
3.	6.14	0.66H	370	150	50	570	312	319	100	36.7
4.	8.17	0.85H	315	150	50	515	311	319	100	46.08

* Vertical Strain in micron (10^{-6}) ** Allowable Vertical Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 110.10 31.20

Mu values 0.350.350.35

thicknesses (mm) 200.00 590.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.30: **The output result from IITPAVE in sample A of CBR = 3.12%**

Z	R	epZ	epT	epR
790.00	0.00	0.1713E-03	0.1165E-03	0.1079E-03
790.00L	0.00	0.2991E-03	0.1184E-03	0.1060E-03
790.00	155.00	0.1784E-03	0.1203E-03	0.1139E-03
790.00L	155.00	**0.3105E-03**	0.1203E-03	0.1139E-03

Vertical Strain in micron = **310.5 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 113.60 32.80

Mu values 0.350.350.35

thicknesses (mm) 200.00 565.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.31: **The output result from IITPAVE in sample A of CBR = 3.28%**

Z	R	epZ	epT	epR
765.00	0.00	0.1730E-03	0.1190E-03	0.1060E-03
765.00L	0.00	0.3008E-03	0.1176E-03	0.1075E-03
765.00	155.00	0.1805E-03	0.1211E-03	0.1144E-03
765.00L	155.00	**0.3128E-03**	0.1211E-03	0.1144E-03

Vertical Strain in micron = $\mathbf{312.8 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 161.00 56.22

Mu values 0.350.350.35

thicknesses (mm) 200.00 370.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.32: **The output result from IITPAVE in sample A of CBR = 6.14%**

Z	R	epZ	epT	epR
570.00	0.00	0.1786E-03	0.1168E-03	0.9915E-04
570.00L	0.00	0.2946E-03	0.1168E-03	0.9870E-04
570.00	155.00	0.1900E-03	0.1212E-03	0.1097E-03
570.00L	155.00	**0.3125E-03**	0.1212E-03	0.1097E-03

Vertical Strain in micron = $\mathbf{312.5 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 179.70 67.50

Mu values 0.350.350.35

thicknesses (mm) 200.00 315.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.33: **The output result from IITPAVE in sample A of CBR = 8.17%**

Z	R	epZ	epT	epR
515.00	0.00	0.2941E-03	0.1159E-03	0.9576E-04
515.00L	0.00	0.2941E-03	0.1159E-03	0.9569E-04

515.00	155.00	0.3008E-03	0.1211E-03	0.1071E-03
515.00L	155.00	**0.3008E-03**	0.1211E-03	0.1071E-03

Vertical Strain in micron = **300.8 x 10^{-6}**

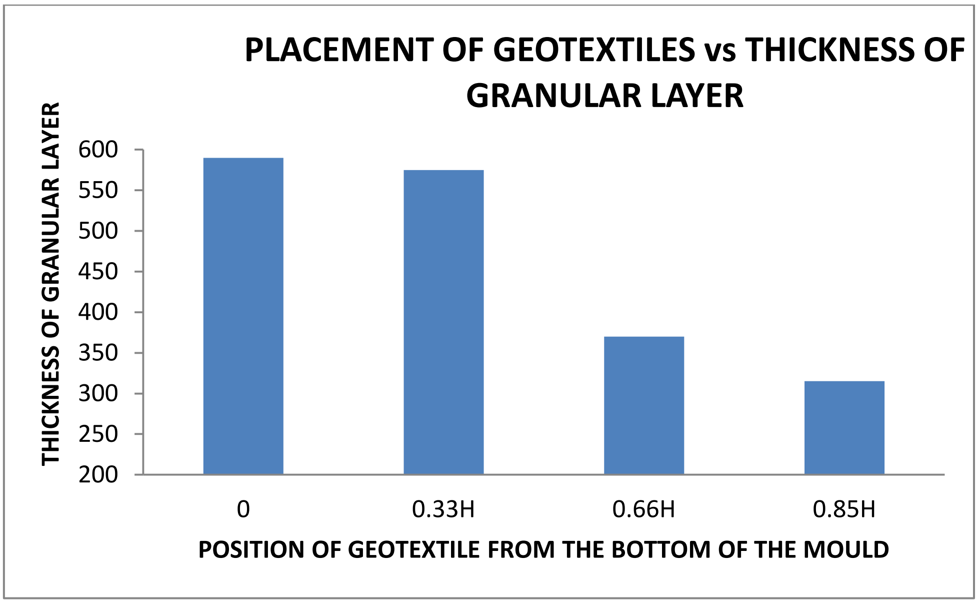

Figure 5.14: **Placement of Geotextiles in sample A with layer of Granular Layer thickness at 90% reliability**

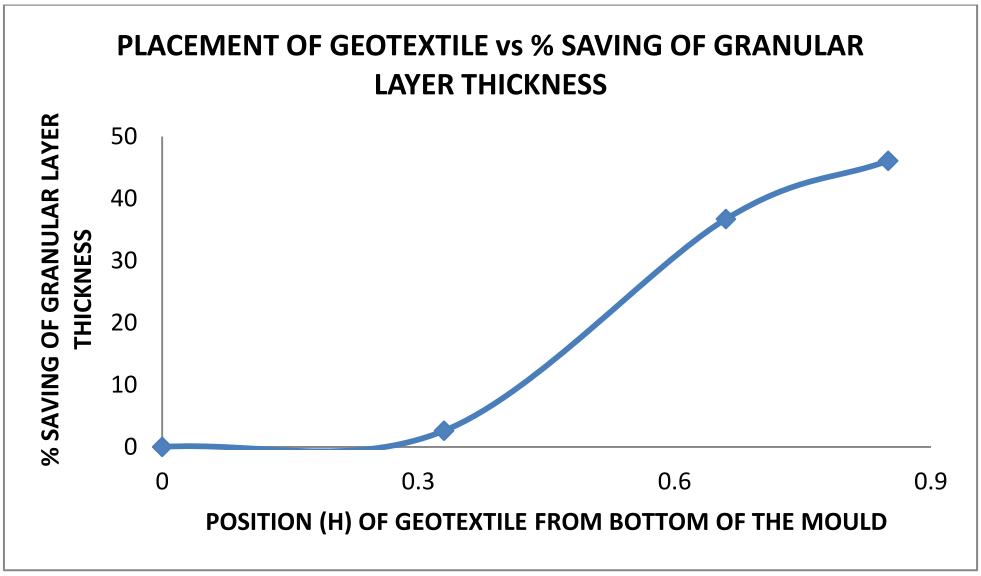

Figure 5.15: **Placement of Geotextiles in sample A with % saving of Granular layer thickness at 90% reliability**

For rutting life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample A, there is a saving of Granular layer thickness are 2.6%, 36.7% and 46.08% at 90 percent reliability as shown in figure 5.15. Figure 5.14 gives the variation of Granular layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.11 gives the variation of placement of geotextile vs saving (%) of Granular layer thickness.

***Table 5.34:* Pavement Composition for Soil Sample B with geotextiles at different location for Rutting Life 100MSA at 90% reliability**

S.No	Design CBR (%)	Placement of Geotextiles from bottom of the mould	Granular Layer Thickness (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	ε_v*	ε_v**	Rutting Life (MSA)	% Saving in Granular Layer Thickness
1.	6.61	0	355	150	50	555	312	319	100	0
2.	6.64	0.33H	355	150	50	555	312	319	100	0
3.	9.98	0.66H	280	150	50	480	309	319	100	22.85
4.	11.97	0.85H	245	150	50	445	310	319	100	32.85

* Vertical Strain in micron (10^{-6}) ** Allowable Vertical Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 165.70 59.00

Mu values 0.350.350.35

thicknesses (mm) 200.00 355.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.35:* The output result from IITPAVE in sample B of CBR = 6.61%**

Z	R	epZ	epT	epR
555.00	0.00	0.1788E-03	0.1166E-03	0.9781E-04
555.00L	0.00	0.2938E-03	0.1165E-03	0.9722E-04
555.00	155.00	0.1910E-03	0.1213E-03	0.1089E-03
555.00L	155.00	**0.3122E-03**	0.1213E-03	0.1089E-03

Vertical Strain in micron = **312.2 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 165.70 59.11

Mu values 0.350.350.35

thicknesses (mm) 200.00 355.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.36: **The output result from IITPAVE in sample B of CBR = 6.64%**

Z	R	epZ	epT	epR
555.00	0.00	0.1788E-03	0.1166E-03	0.9781E-04
555.00L	0.00	0.2938E-03	0.1165E-03	0.9722E-04
555.00	155.00	0.1910E-03	0.1213E-03	0.1089E-03
555.00L	155.00	**0.3122E-03**	0.1213E-03	0.1089E-03

Vertical Strain in micron = $\mathbf{312.2 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 193.71 76.72

Mu values 0.350.350.35

thicknesses (mm) 200.00 280.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.37: **The output result from IITPAVE in sample B of CBR = 9.98%**

Z	R	epZ	epT	epR
480.00	0.00	0.1820E-03	0.1150E-03	0.9308E-04
480.00L	0.00	0.2885E-03	0.1150E-03	0.9302E-04
480.00	155.00	0.1959E-03	0.1208E-03	0.1048E-03
480.00L	155.00	**0.3094E-03**	0.1208E-03	0.1048E-03

Vertical Strain in micron = $\mathbf{309.4 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 204.95 86.20

Mu values 0.350.350.35

thicknesses (mm) 200.00 245.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.38: **The output result from IITPAVE in sample B of CBR = 11.97%**

Z	R	epZ	epT	epR
445.00	0.00	0.1859E-03	0.1154E-03	0.9111E-04
445.00L	0.00	0.2888E-03	0.1154E-03	0.9111E-04

455.00	155.00	0.2007E-03	0.1218E-03	0.1027E-03
445.00L	155.00	**0.3106E-03**	0.1218E-03	0.1027E-03

Vertical Strain in micron = **310.6×10^{-6}**

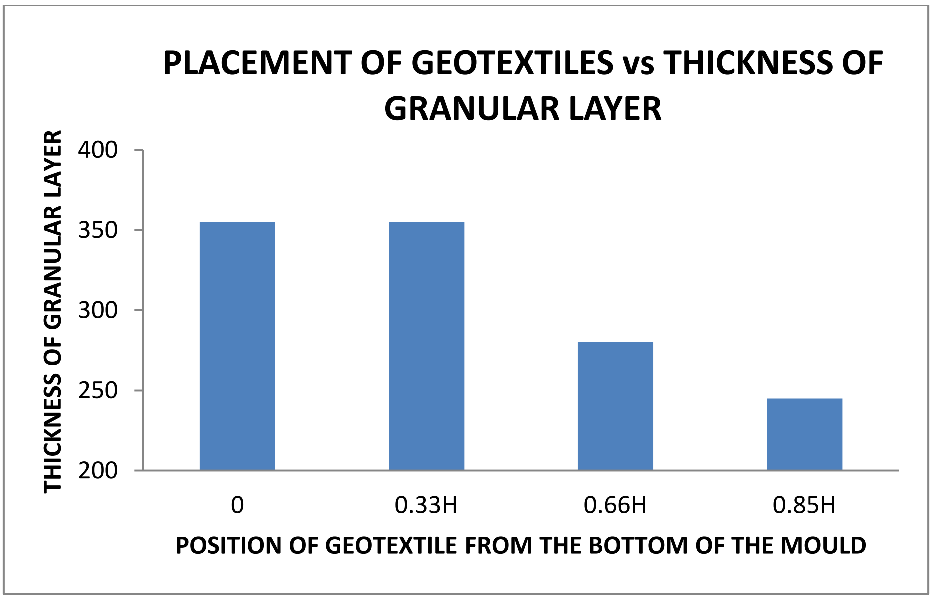

Figure 5.16: **Placement of Geotextiles in sample B with layer of Granular Layer thickness at 90% reliability**

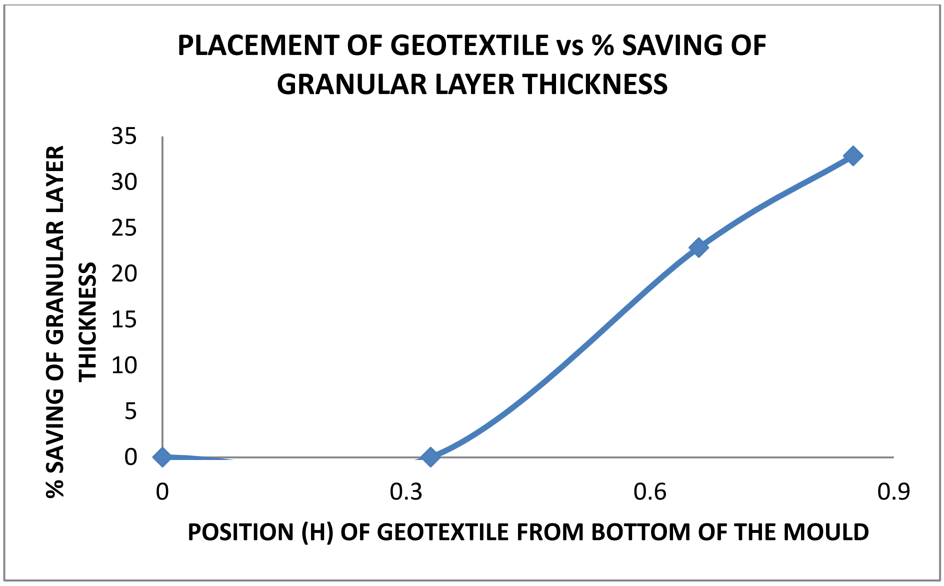

Figure 5.17: **Placement of Geotextiles in sample B with % saving of Granular layer thickness at 90% reliability**

For rutting life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample B, there is a saving of Granular layer thickness are 0%, 22.85% and 32.85% at 90 percent reliability as shown in figure 5.17. Figure 5.16 gives the variation of Granular layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.17 gives the variation of placement of geotextile vs saving (%) of Granular layer thickness.

***Table 5.39:* Pavement Composition for Soil Sample C with geotextiles at different location for Rutting Life 100MSA at 90% reliability**

S.No	Design CBR (%)	Placement of Geotextiles from bottom of the mould	Granular Layer Thickness (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	ε_v*	ε_v**	Rutting Life (MSA)	% Saving in Granular Layer Thickness
1.	12.01	0	245	150	50	445	310	319	100	0
2.	12.85	0.33H	230	150	50	430	312	319	100	5.1
3.	19.12	0.66H	170	150	50	370	307	319	100	31.91

* Vertical Strain in micron (10^{-6})   ** Allowable Vertical Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3
E values (MPa) 3000.00 204.95 86.38
Mu values 0.350.350.35
thicknesses (mm) 200.00 245.00
single wheel load (N) 20000.00
tyre pressure (MPa) 0.56
Dual Wheel

***Table 5.40:* The output result from IITPAVE in sample C of CBR = 12.01%**

Z	R	epZ	epT	epR
445.00	0.00	0.1858E-03	0.1152E-03	0.9099E-04
445.00L	0.00	0.2884E-03	0.1152E-03	0.9100E-04
455.00	155.00	0.2006E-03	0.1217E-03	0.1027E-03
445.00L	155.00	**0.3102E-03**	0.1217E-03	0.1027E-03

Vertical Strain in micron = **310.2 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3
E values (MPa) 3000.00 208.45 90.20
Mu values 0.350.350.35
thicknesses (mm) 200.00 230.00
single wheel load (N) 20000.00
tyre pressure (MPa) 0.56
Dual Wheel

Table 5.41: **The output result from IITPAVE in sample C of CBR = 12.85%**

Z	R	epZ	epT	epR
430.00	0.00	0.1886E-03	0.1159E-03	0.9057E-04
430.00L	0.00	0.2900E-03	0.1159E-03	0.9060E-04
430.00	155.00	0.2040E-03	0.1227E-03	0.1025E-03
430.00L	155.00	**0.3125E-03**	0.1227E-03	0.1025E-03

Vertical Strain in micron = **312.5 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 234.65 116.32

Mu values 0.350.350.35

thicknesses (mm) 200.00 170.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.42: **The output result from IITPAVE in sample C of CBR = 19.12%**

Z	R	epZ	epT	epR
370.00	0.00	0.1949E-03	0.1145E-03	0.8425E-04
370.00L	0.00	0.2843E-03	0.1145E-03	0.8437E-04
370.00	155.00	0.2112E-03	0.1220E-03	0.9506E-03
370.00L	155.00	**0.3072E-03**	0.1220E-03	0.9505E-03

Vertical Strain in micron = **307.2 x 10^{-6}**

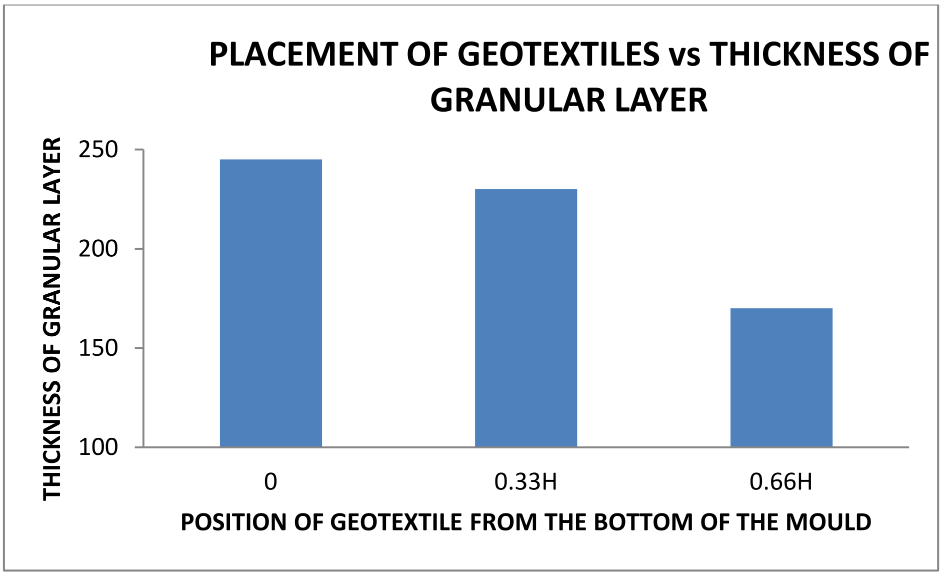

Figure 5.18: **Placement of Geotextiles in sample C with layer of Granular Layer thickness at 90% reliability**

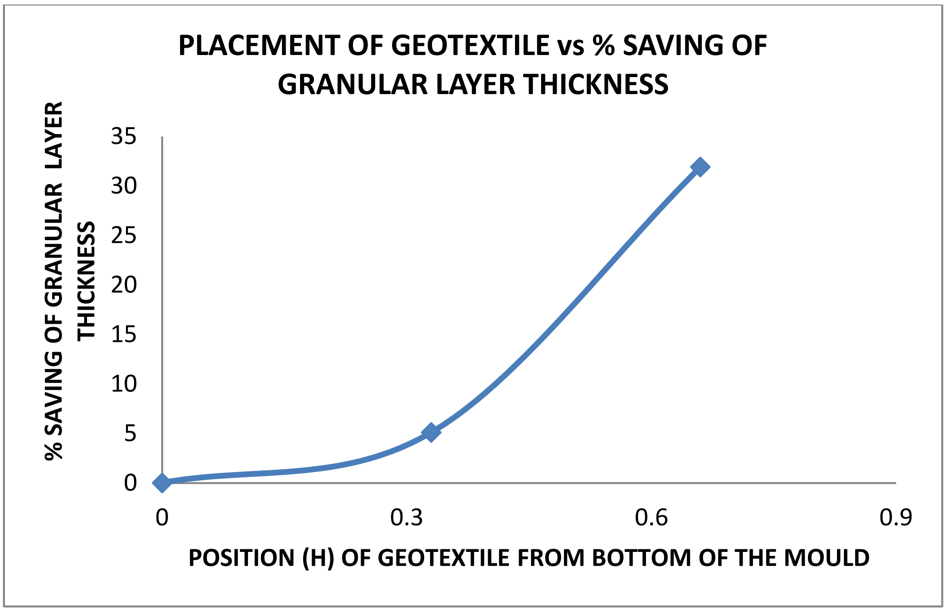

Figure 5.19: **Placement of Geotextiles in sample C with % saving of Granular layer thickness at 90% reliability**

For rutting life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H and 0.66H from the base of the mould in sample C, there is a saving of Granular layer thickness are 5.1% and 31.91% at 90 percent reliability as shown in figure 5.19. Figure 5.18 gives the variation of Granular layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.19 gives the variation of placement of geotextile vs saving (%) of Granular layer thickness.

Table 5.43: **Pavement Composition for Soil Sample A with geotextiles at different location for Rutting Life 100MSA at 80% reliability**

S.No.	Design CBR (%)	Placement of Geotextiles from bottom of the mould	Granular Layer Thickness (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	ε_v*	ε_v**	Rutting Life (MSA)	% Saving in Granular Layer Thickness
1.	3.12	0	545	150	50	745	393	405	100	0
2.	3.28	0.33H	540	150	50	740	383	405	100	0.91
3.	6.14	0.66H	360	150	50	560	382	405	100	33.0
4.	8.17	0.85H	300	150	50	500	389	405	100	44.9

* Vertical Strain in micron (10^{-6}) ** Allowable Vertical Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 106.30 31.20

Mu values 0.350.350.35

thicknesses (mm) 200.00 545.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.44: **The output result from IITPAVE in sample A of CBR = 3.12%**

Z	R	epZ	epT	epR
745.00	0.00	0.2181E-03	0.1524E-03	0.1308E-03
745.00L	0.00	0.3759E-03	0.1512E-03	0.1320E-03
755.00	155.00	0.2293E-03	0.1543E-03	0.1444E-03
745.00L	155.00	**0.3937E-03**	0.1543E-03	0.1444E-03

Vertical Strain in micron = **393.7×10^{-6}**

The input to IITPAVE**:-**

No. of layers

E values (MPa) 1700.00 111.20 32.80

Mu values 0.350.350.35

thicknesses (mm) 200.00 540.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.45:* The output result from IITPAVE in sample A of CBR = 3.28%**

Z	R	epZ	epT	epR
740.00	0.00	0.2124E-03	0.1481E-03	0.1273E-03
740.00L	0.00	0.3655E-03	0.147E-03	0.1287E-03
740.00	155.00	0.2234E-03	0.1503E-03	0.1404E-03
740.00L	155.00	**0.3832E-03**	0.1503E-03	0.1404E-03

Vertical Strain in micron = **383.2 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 158.90 56.22

Mu values 0.350.350.35

thicknesses (mm) 200.00 360.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.46:* The output result from IITPAVE in sample A of CBR = 6.14%**

Z	R	epZ	epT	epR
560.00	0.00	0.2200E-03	0.1449E-03	0.1211E-03
560.00L	0.00	0.3576E-03	0.1449E-03	0.1193E-03
560.00	155.00	0.2347E-03	0.1513E-03	0.1343E-03
560.00L	155.00	**0.3826E-03**	0.1513E-03	0.1344E-03

Vertical Strain in micron = **382.6 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 175.80 67.50

Mu values 0.350.350.35

thicknesses (mm) 200.00 300.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.47:* The output result from IITPAVE in sample A of CBR = 8.17%**

Z	R	epZ	epT	epR
500.00	0.00	0.2264E-03	0.1473E-03	0.1172E-03
500.00L	0.00	0.3614E-03	0.1473E-03	0.1173E-03

500.00	155.00	0.2453E-03	0.1552E-03	0.1332E-03
500.00L	155.00	**0.3896E-03**	0.1552E-03	0.1332E-03

Vertical Strain in micron = **389.6 x 10^{-6}**

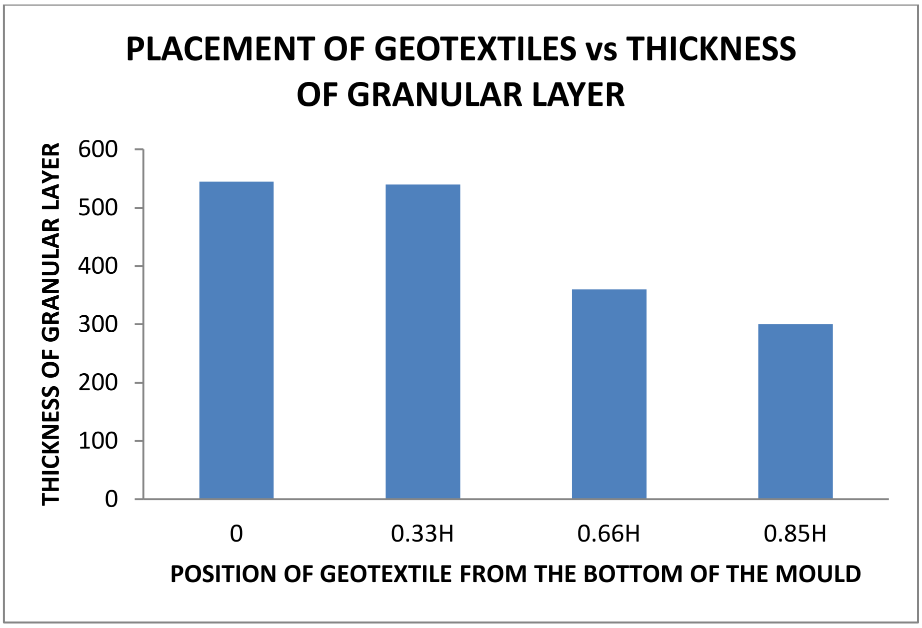

Figure 5.20: **Placement of Geotextiles in sample A with layer of Granular Layer thickness at 80% reliability**

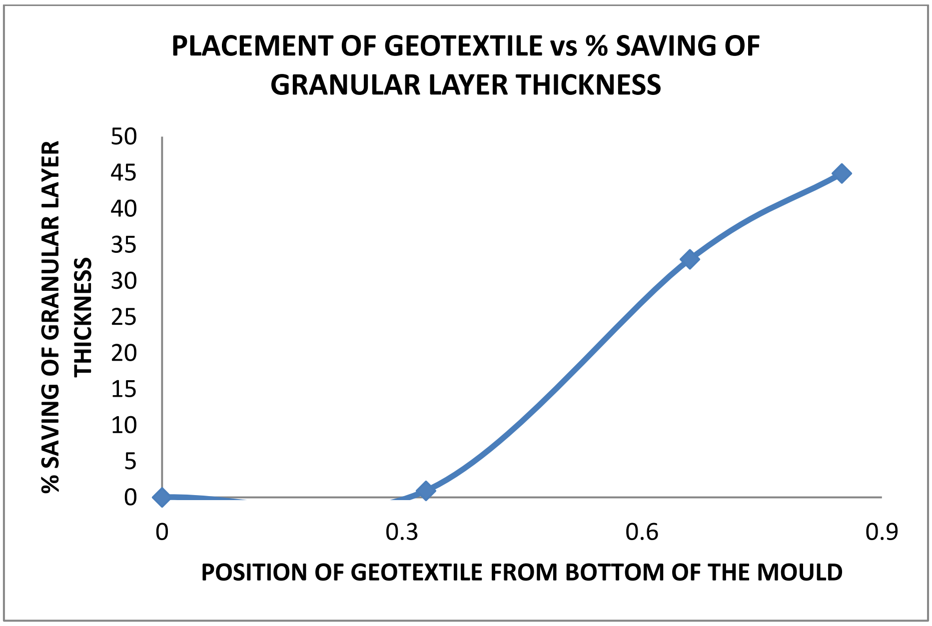

Figure 5.21: **Placement of Geotextiles in sample A with % saving of Granular layer thickness at 80% reliability**

For rutting life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample A, there is a saving of Granular layer thickness are 0.91%, 33.00% and 44.9% at 80 percent reliability as shown in figure 5.21. Figure 5.20 gives the variation of Granular layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.21 gives the variation of placement of geotextile vs saving (%) of Granular layer thickness.

Table 5.48: **Pavement Composition for Soil Sample B with geotextiles at different location for Rutting Life 100MSA at 80% reliability**

S.No.	Design CBR (%)	Placement of Geotextiles from bottom of the mould	Granular Layer Thickness (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	ε_v*	ε_v**	Rutting Life (MSA)	% Saving in Granular Layer Thickness
1.	6.61	0	340	150	50	540	387	405	100	0
2.	6.64	0.33H	335	150	50	535	392	405	100	1.47
3.	9.98	0.66H	260	150	50	460	395	405	100	23.5
4.	11.97	0.85H	230	150	50	430	394	405	100	33.82

* Vertical Strain in micron (10^{-6}) ** Allowable Vertical Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 162.50 59.00

Mu values 0.350.350.35

thicknesses (mm) 200.00 340.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.49: **The output result from IITPAVE in sample B of CBR = 6.61%**

Z	R	epZ	epT	epR
540.00	0.00	0.2227E-03	0.1468E-03	0.1195E-03
540.00L	0.00	0.3615E-03	0.1468E-03	0.1195E-03
540.00	155.00	0.2399E-03	0.1538E-03	0.1350E-03
540.00L	155.00	**0.3878E-03**	0.1538E-03	0.1351E-03

Vertical Strain in micron = **387.8 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 161.70 59.11

Mu values 0.350.350.35

thicknesses (mm) 200.00 335.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.50: **The output result from IITPAVE in sample B of CBR = 6.64%**

Z	R	epZ	epT	epR
535.00	0.00	0.2256E-03	0.1483E-03	0.1208E-03
535.00L	0.00	0.3654E-03	0.1483E-03	0.1208E-03
535.00	155.00	0.2429E-03	0.1556E-03	0.1360E-03
535.00L	155.00	**0.3920E-03**	0.1555E-03	0.1361E-03

Vertical Strain in micron = **392.0 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 187.35 76.72

Mu values 0.350.350.35

thicknesses (mm) 200.00 260.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.51: **The output result from IITPAVE in sample B of CBR = 9.98%**

Z	R	epZ	epT	epR
460.00	0.00	0.2336E-03	0.1494E-03	0.1156E-03
460.00L	0.00	0.3647E-03	0.1494E-03	0.1156E-03
460.00	155.00	0.2542E-03	0.1583E-03	0.1322E-03
460.00L	155.00	**0.3952E-03**	0.1583E-03	0.1322E-03

Vertical Strain in micron = **395.2 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 199.21 86.20

Mu values 0.350.350.35

thicknesses (mm) 200.00 230.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.52: **The output result from IITPAVE in sample B of CBR = 11.97%**

Z	R	epZ	epT	epR
430.00	0.00	0.2375E-03	0.1495E-03	0.1129E-03
430.00L	0.00	0.3636E-03	0.1495E-03	0.1129E-03

430.00	155.00	0.2588E-03	0.1592E-03	0.1290E-03
430.00L	155.00	**0.3948E-03**	0.1592E-03	0.1289E-03

Vertical Strain in micron = **394.8 x 10^{-6}**

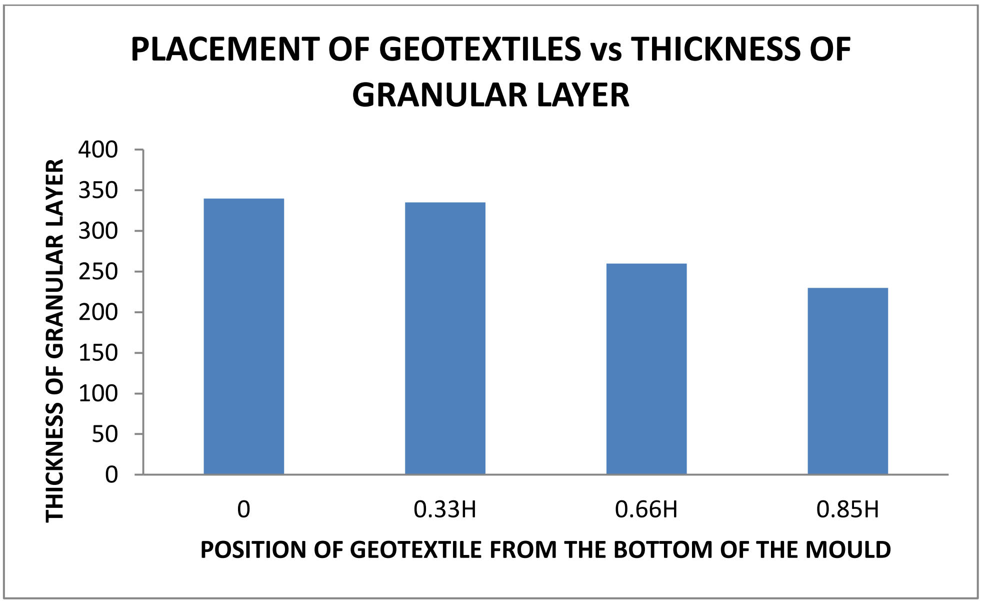

Figure 5.22: **Placement of Geotextiles in sample B with layer of Granular Layer thickness at 80% reliability**

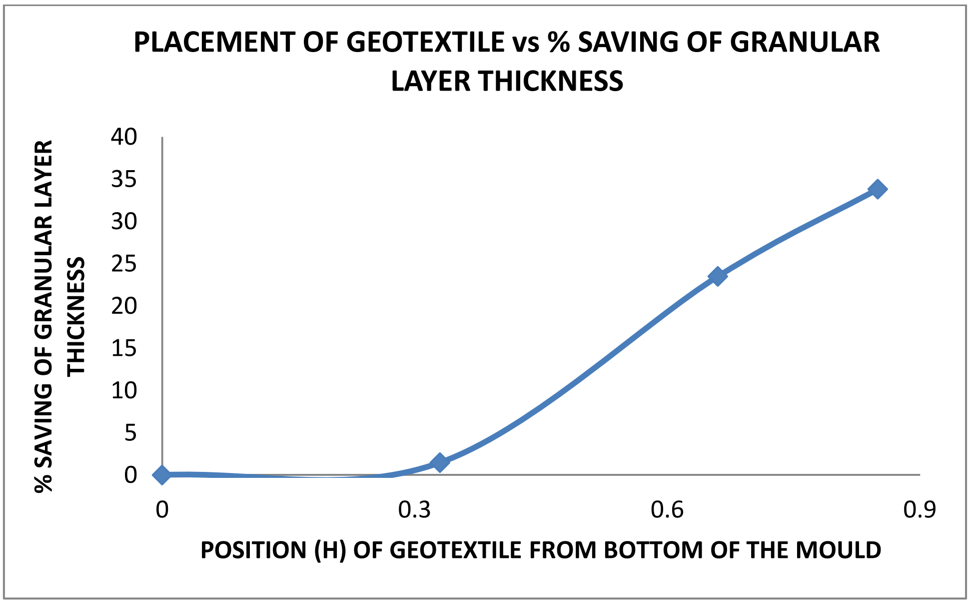

Figure 5.23: **Placement of Geotextiles in sample B with % saving of Granular layer thickness at 80% reliability**

For rutting life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample A, there is a saving of Granular layer thickness are 1.47%, 23.5% and 33.82% at 80 percent reliability as shown in figure 5.23. Figure 5.22 gives the variation of Granular layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.23 gives the variation of placement of geotextile vs saving (%) of Granular layer thickness.

Table 5.53: **Pavement Composition for Soil Sample C with geotextiles at different location for Rutting Life 100MSA at 80% reliability**

S.No.	Design CBR (%)	Placement of Geotextiles from bottom of the mould	Granular Layer Thickness (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	ε_v*	ε_v**	Rutting Life (MSA)	% Saving in Granular Layer Thickness
1.	12.01	0	230	150	50	430	394	405	100	0
2.	12.85	0.33H	220	150	50	420	393	405	100	4.34
3.	19.12	0.66H	160	150	50	360	391	405	100	30.43

* Vertical Strain in micron (10^{-6})   ** Allowable Vertical Strain Values in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 199.60 86.38

Mu values 0.350.350.35

thicknesses (mm) 200.00 230.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.54: **The output result from IITPAVE in sample C of CBR = 12.01%**

Z	R	epZ	epT	epR
430.00	0.00	0.2371E-03	0.1493E-03	0.1127E-03
430.00L	0.00	0.3631E-03	0.1493E-03	0.1127E-03
430.00	155.00	0.2585E-03	0.1590E-03	0.1288E-03
430.00L	155.00	**0.3941E-03**	0.1590E-03	0.1287E-03

Vertical Strain in micron = **394.1 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 204.32 90.20

Mu values 0.350.350.35

thicknesses (mm) 200.00 220.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.55: **The output result from IITPAVE in sample C of CBR = 12.85%**

Z	R	epZ	epT	epR
420.00	0.00	0.2381E-03	0.1490E-03	0.1115E-03
420.00L	0.00	0.3619E-03	0.1490E-03	0.1115E-03
420.00	155.00	0.2598E-03	0.1590E-03	0.1274E-03
420.00L	155.00	**0.3923E-03**	0.1590E-03	0.1274E-03

Vertical Strain in micron = **392.3 x 10^{-6}**

The input from IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 228.31 116.32

Mu values 0.350.350.35

thicknesses (mm) 200.00 160.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.56: **The output result from IITPAVE in sample C of CBR = 19.12%**

Z	R	epZ	epT	epR
360.00	0.00	0.2509E-03	0.1501E-03	0.1048E-03
360.00L	0.00	0.3604E-03	0.1499E-03	0.1050E-03
360.00	155.00	0.2730E-03	0.1610E-03	0.1181E-03
360.00L	155.00	**0.3911E-03**	0.1610E-03	0.1181E-03

Vertical Strain in micron = **391.1 x 10^{-6}**

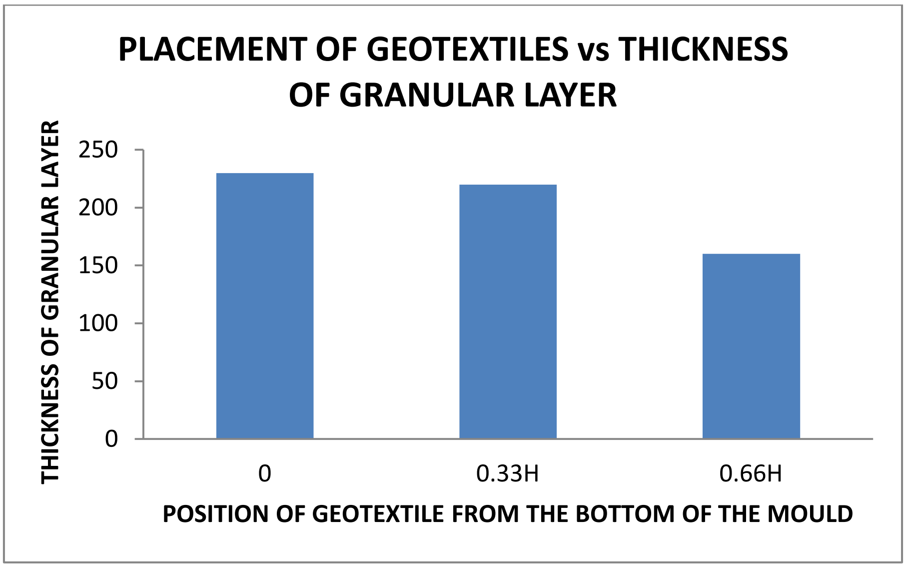

Figure 5.24: **Placement of Geotextiles in sample C with layer of Granular Layer thickness at 80% reliability**

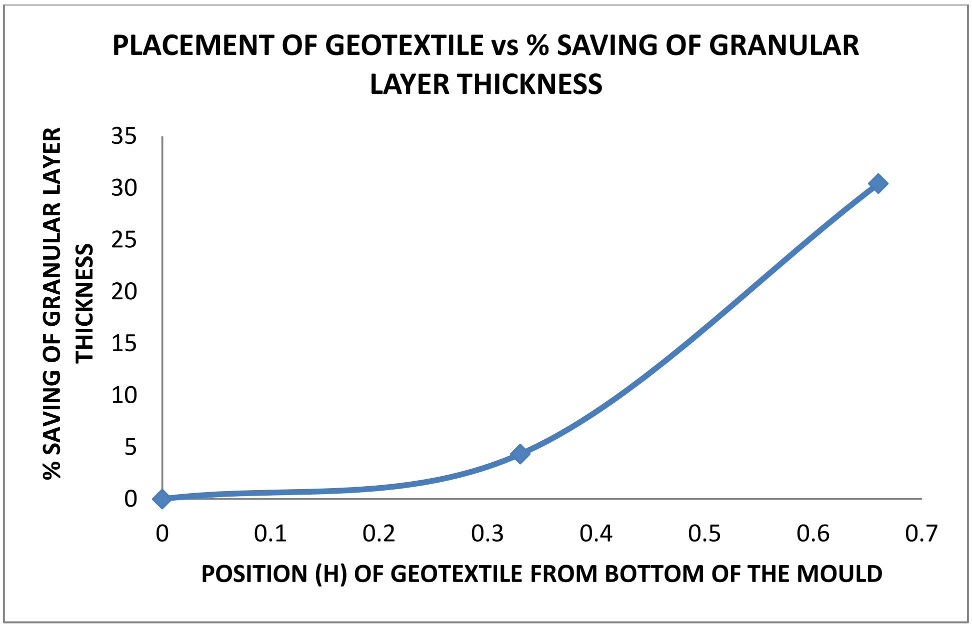

Figure 5.25: **Placement of Geotextiles in sample C with % saving of Granular layer thickness at 80% reliability.**

For rutting life 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H and 0.66H from the base of the mould in sample C, there is a saving of Granular layer thickness are 4.34% and 30.43% at 80 percent reliability as shown in figure 5.25. Figure 5.24 gives the variation of Granular layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.25 gives the variation of placement of geotextile vs saving (%) of Granular layer thickness.

Table 5.57: **Pavement Composition for Soil Sample A with geotextiles at different location for both Fatigue Life & Rutting Life = 100MSA at 90% reliability in IRC: 37-2012**

S.No.	Design CBR (%)	Placement of Geotextile from bottom the of mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	εv*	εv**	Fatigue Life & Rutting Life(MSA)
1.	3.12	0	375	250	155	50	830	163	170	285	319	100
2.	3.28	0.33H	366	250	151	50	817	164	170	285	319	100
3.	6.14	0.66H	256	250	125	50	681	164	170	267	319	100
4.	8.17	0.85H	200	250	115	50	615	165	170	277	319	100

εt* = Horizontal strain value in micron (10^{-6}), εt** = Allowable horizontal strain value in micron (10^{-6}),

εv* = Vertical strain value in micron (10^{-6}) εv** = Allowable vertical strain value in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 113.00 31.20

Mu values 0.350.350.35

thicknesses (mm) 205.00 625.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.58: **The output result from IITPAVE in sample A of CBR = 3.12%**

Z	R	epZ	epT	epR
205.00	0.00	0.1518E-03	0.1564E-03	0.1070E-03
205.00L	0.00	0.4064E-03	0.1564E-03	0.1070E-03
205.00	155.00	0.1425E-03	0.1631E-03	0.8313E-04
205.00L	155.00	0.3968E-03	**0.1631E-03**	0.8313E-04
830.00	0.00	0.1572E-03	0.1054E-03	0.1024E-03
830.00L	0.00	0.2760E-03	0.1089E-03	0.9893E-04
830.00	155.00	0.1633E-03	0.1633E-03	0.1055E-03
830.00L	155.00	**0.2858E-03**	0.1109E-03	0.1055E-03

Horizontal Strain in micron = **163.1 x 10^{-6}** & Vertical Strain in micron = **285.8 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 118.00 32.80

Mu values 0.350.350.35

thicknesses (mm) 201.00 616.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.59: **The output result from IITPAVE in sample A of CBR = 3.28%**

Z	R	epZ	epT	epR
201.00	0.00	0.1538E-03	0.1582E-03	0.1078E-03
201.00L	0.00	0.4108E-03	0.1582E-03	0.1078E-03
201.00	155.00	0.1431E-03	0.1648E-03	0.8158E-04
201.00L	155.00	0.3988E-03	**0.1648E-03**	0.8158E-04
817.00	0.00	0.1570E-03	0.1101E-03	0.9702E-03
817.00L	0.00	0.2750E-03	0.1071E-03	0.1001E-04
817.00	155.00	0.1633E-03	0.1109E-03	0.1051E-03
817.00L	155.00	**0.2853E-03**	0.1109E-03	0.1052E-03

Horizontal Strain in micron = **164.8 x 10^{-6}** & Vertical Strain in micron = **285.3 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 185.00 56.22

Mu values 0.350.350.35

thicknesses (mm) 175.00 506.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.60: **The output result from IITPAVE in sample A of CBR = 6.14%**

Z	R	epZ	epT	epR
175.00	0.00	0.1589E-03	0.1596E-03	0.1052E-03
175.00L	0.00	0.4065E-03	0.1596E-03	0.1052E-03
175.00	155.00	0.1358E-03	0.1640E-03	0.5935E-04
175.00L	155.00	0.3712E-03	**0.1640E-03**	0.5935E-04
681.00	0.00	0.1485E-03	0.1022E-03	0.8830E-03
681.00L	0.00	0.2535E-03	0.1023E-03	0.8824E-04
681.00	155.00	0.1574E-03	0.1054E-03	0.9741E-03
681.00L	155.00	**0.2677E-03**	0.1054E-03	0.9738E-03

Horizontal Strain in micron = **164.0 x 10^{-6}** & Vertical Strain in micron = **267.7 x 10^{-6}**

The input to IITPAVE:-

No. of layers 3

E values (MPa) 3000.00 211.00 67.50

Mu values 0.350.350.35

thicknesses (mm) 165.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.61: **The output result from IITPAVE in sample A of CBR = 8.17%**

Z	R	epZ	epT	EpR
165.00	0.00	0.1636E-03	0.1625E-03	0.1065E-03
165.00L	0.00	0.4116E-03	0.1625E-03	0.1065E-03
165.00	155.00	0.1340E-03	0.1656E-03	0.5087E-04
165.00L	155.00	0.3642E-03	**0.1656E-03**	0.5087E-04
165.00	0.00	0.1537E-03	0.1059E-03	0.8801E-04
165.00L	0.00	0.2607E-03	0.1059E-03	0.8863E-04
165.00	155.00	0.1656E-03	0.1099E-03	0.9971E-04
165.00L	155.00	**0.2777E-03**	0.1099E-03	0.9970E-04

Horizontal Strain in micron = **165.6×10^{-6}** & Vertical Strain in micron = **277.7×10^{-6}**

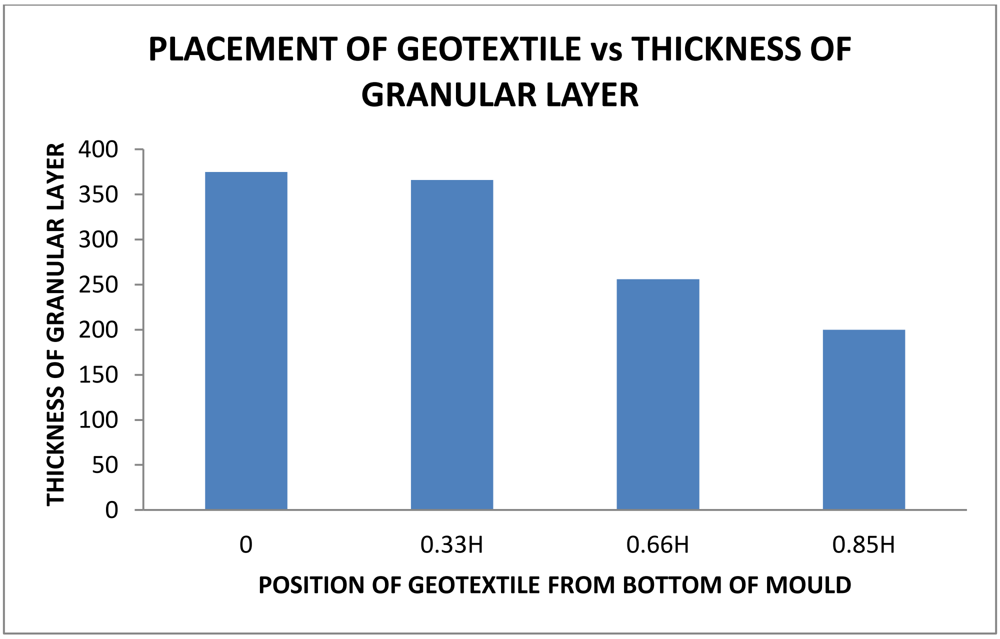

Figure 5.26: **Placement of Geotextiles in sample A with Granular Layer thickness at 90% reliability**

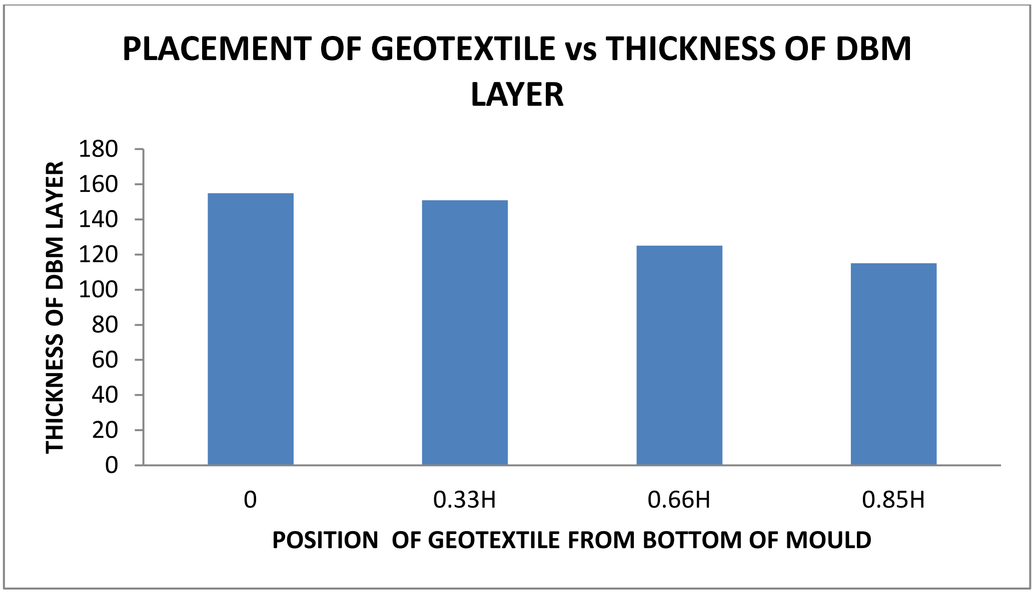

Figure 5.27: **Placement of Geotextiles in sample A with DBM Layer thickness at 90% reliability**

For both rutting life and fatigue 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample A, there is a saving of Granular layer thickness and Dense Bituminous Macadam Layer at 90 percent reliability as shown in figure 5.26 and 5.27. Figure 5.26 gives the variation of Granular layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.27 gives the variation of thickness of DBM layer in pavement vs position of geotextile at different depths from the base of the mould. There is also saving of total thickness of the road crust when the geotextile are placed at different depths.

Table 5.62: **Pavement Composition for Soil Sample B with geotextiles at different location for both Fatigue & Rutting Life = 100MSA at 90% reliability in IRC: 37-2012**

S.No.	Design CBR (%)	Placement of Geotextile from bottom the of mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	εv*	εv**	Fatigue Life & Rutting Life(MSA)
1.	6.61	0	245	250	123	50	668	163	170	267	319	100
2.	6.64	0.33H	245	250	123	50	668	163	170	266	319	100
3.	9.98	0.66H	200	250	115	50	610	160	170	258	319	100
4.	11.97	0.85H	200	250	110	50	600	160	170	247	319	100

εt* = Horizontal strain value in micron (10^{-6}), εt** = Allowable horizontal strain value in micron (10^{-6}),

εv* = Vertical strain value in micron (10^{-6}) εv** = Allowable vertical strain value in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 192.00 59.00

Mu values 0.350.350.35

thicknesses (mm) 173.00 495.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.63: **The output result from IITPAVE in sample B of CBR = 6.61%**

Z	R	epZ	EpT	epR
173.00	0.00	0.1592E-03	0.1594E-03	0.1049E-03
173.00L	0.00	0.4054E-03	0.1594E-03	0.1049E-03
173.00	155.00	0.1348E-03	0.1636E-03	0.5717E-04
173.00L	155.00	0.3678E-03	**0.1636E-03**	0.5717E-04
668.00	0.00	0.1482E-03	0.1019E-03	0.8758E-04
668.00L	0.00	0.2523E-03	0.1017E-03	0.8777E-04
668.00	155.00	0.1575E-03	0.1052E-03	0.9694E-04
668.00L	155.00	**0.2670E-03**	0.1052E-03	0.9693E-04

Horizontal Strain in micron = **163.6×10^{-6}** & Vertical Strain in micron = **267.0×10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 193.00 59.11

Mu values 0.350.350.35

thicknesses (mm) 173.00 495.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.64: **The output result from IITPAVE in sample B of CBR = 6.64%**

Z	R	epZ	epT	epR
173.00	0.00	0.1589E-03	0.1591E-03	0.1046E-03
173.00L	0.00	0.4043E-03	0.1591E-03	0.1046E-03
173.00	155.00	0.1345E-03	0.1633E-03	0.5692E-04
173.00L	155.00	0.3667E-03	**0.1633E-03**	0.5692E-04
668.00	0.00	0.1477E-03	0.1016E-03	0.8752E-04
668.00L	0.00	0.2518E-03	0.1017E-03	0.8735E-04
668.00	155.00	0.1570E-03	0.1050E-03	0.9672E-04
668.00L	155.00	**0.2664E-03**	0.1050E-03	0.9670E-04

Horizontal Strain in micron = **163.3 x 10^{-6}** & Vertical Strain in micron = **266.4 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 240.00 76.72

Mu values 0.350.350.35

thicknesses (mm) 160.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.65: **The output result from IITPAVE in sample B of CBR = 9.98%**

Z	R	epZ	epT	epR
160.00	0.00	0.1614E-03	0.1583E-03	0.1026E-03
160.00L	0.00	0.4012E-03	0.1583E-03	0.1026E-03
160.00	155.00	0.1281E-03	0.1604E-03	0.4214E-04
160.00L	155.00	0.3467E-03	**0.1604E-03**	0.4214E-04
610.00	0.00	0.1430E-03	0.9866E-03	0.8151E-04
610.00L	0.00	0.2406E-03	0.9875E-03	0.8082E-04
610.00	155.00	0.1540E-03	0.1026E-03	0.9258E-04
610.00L	155.00	**0.2581E-03**	0.1026E-03	0.9257E-04

Horizontal Strain in micron = **160.4 x 10^{-6}** & Vertical Strain in micron = **258.1 x 10^{-6}**

The input to IITPAVE:-

No. of layers 3

E values (MPa) 3000.00 269.00 86.20

Mu values 0.350.350.35

thicknesses (mm) 150.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.66: **The output result from IITPAVE in sample B of CBR = 11.97%**

Z	R	epZ	epT	EpR
150.00	0.00	0.1659E-03	0.1601E-03	0.1034E-03
150.00L	0.00	0.4097E-03	0.1601E-03	0.1033E-03
150.00	155.00	0.1241E-03	0.1604E-03	0.3060E-04
150.00L	155.00	0.3397E-03	**0.1604E-03**	0.3060E-04
600.00	0.00	0.1368E-03	0.9499E-03	0.7767E-04
600.00L	0.00	0.22993E-03	0.9500E-03	0.7633E-04
600.00	155.00	014805E-03	0.9893E-03	0.8858E-04
600.00L	155.00	**0.2477E-03**	0.9893E-03	0.8859E-04

Horizontal Strain in micron = **160.4 x 10^{-6}** & Vertical Strain in micron = **247.7 x 10^{-6}**

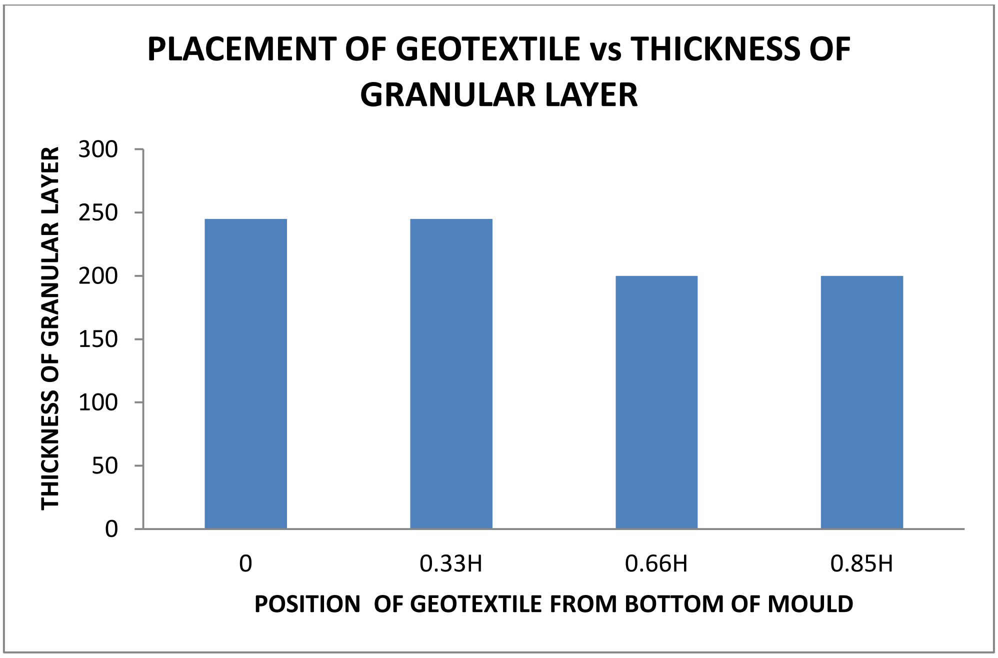

Figure 5.28: **Placement of Geotextiles in sample B with Granular Layer thickness at 90% reliability**

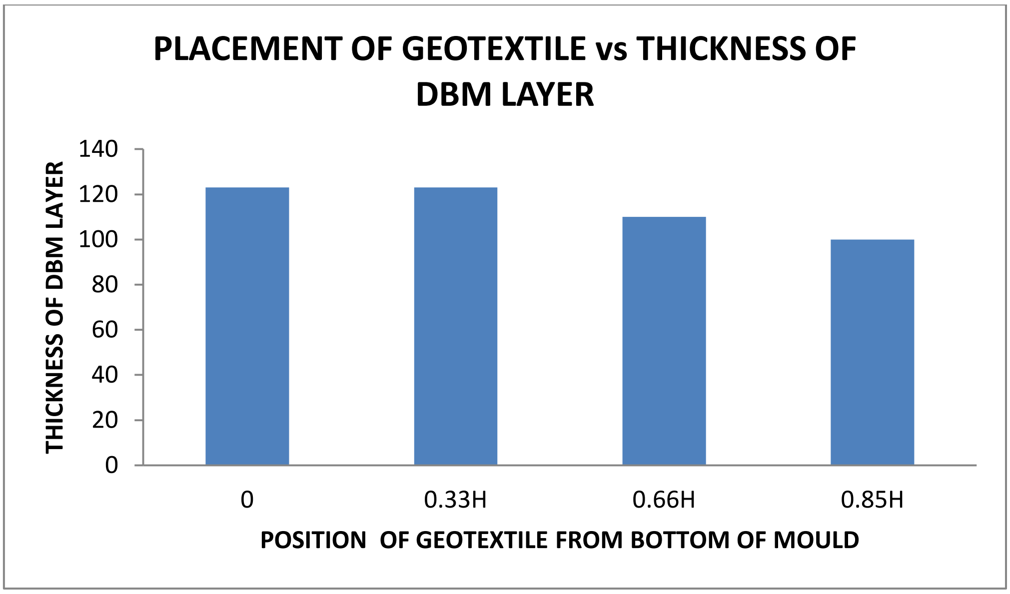

Figure 5.29: **Placement of Geotextiles in sample B with DBM Layer thickness at 90% reliability**

For both rutting life and fatigue 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample B, there is a saving of Granular layer thickness and Dense Bituminous Macadam Layer at 90 percent reliability as shown in figure 5.28 and 5.29. Figure 5.28 gives the variation of Granular layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.29 gives the variation of thickness of DBM layer in pavement vs position of geotextile at different depths from the base of the mould. There is also saving of total thickness of the road crust when the geotextile are placed at different depths.

Table 5.67: **Pavement Composition for Soil Sample C with geotextiles at different location for both Fatigue & Rutting Life = 100MSA at 90% reliability in IRC: 37-2012**

S.No.	Design CBR (%)	Placement of Geotextile from bottom the of mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	εv*	εv**	Fatigue Life & Rutting Life(MSA)
1.	12.01	0	200	250	100	50	600	160	170	247	319	100
2.	12.85	0.33H	200	250	95	50	595	161	170	244	319	100
3.	19.12	0.66H	200	250	75	50	575	160	170	218	319	100

εt* = Horizontal strain value in micron (10^{-6}), εt** = Allowable horizontal strain value in micron (10^{-6}),

εv* = Vertical strain value in micron (10^{-6}) εv** = Allowable vertical strain value in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 270.00 86.20

Mu values 0.350.350.35

thicknesses (mm) 150.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.68: **The output result from IITPAVE in sample C of CBR = 12.01%**

Z	R	epZ	epT	epR
150.00	0.00	0.1657E-03	0.1598E-03	0.1032E-03
150.00L	0.00	0.4090E-03	0.1598E-03	0.1032E-03
150.00	155.00	0.1238E-03	0.1601E-03	0.3042E-04
150.00L	155.00	0.3388E-03	**0.1601E-03**	0.3042E-04
600.00	0.00	0.1379E-03	0.9498E-03	0.7896E-04
600.00L	0.00	0.2318E-03	0.9498E-03	0.7928E-04
600.00	155.00	01477E-03	0.9884E-03	0.8850E-04
600.00L	155.00	**0.2474E-03**	0.9884E-03	0.8850E-04

Horizontal Strain in micron = **160.1 x 10^{-6}** & Vertical Strain in micron = **247.4 x 10^{-6}**

The input from IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 282.00 90.20

Mu values 0.350.350.35

thicknesses (mm) 145.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.69: **The output result from IITPAVE in sample C of CBR = 12.85%**

Z	R	epZ	epT	epR
145.00	0.00	0.1689E-03	0.1617E-03	0.1044E-03
145.00L	0.00	0.4164E-03	**0.1617E-03**	0.1043E-03
145.00	155.00	0.1223E-03	0.1609E-03	0.2480E-04
145.00L	155.00	0.3376E-03	0.1609E-03	0.2480E-04
595.00	0.00	0.1362E-03	0.9394E-03	0.7765E-04
595.00L	0.00	0.2281E-03	0.9397E-03	0.7743E-04
595.00	155.00	0.1461E-03	0.9795E-03	0.8738E-04
595.00L	155.00	**0.2447E-03**	0.9795E-03	0.8737E-04

Horizontal Strain in micron = $\mathbf{161.7 \times 10^{-6}}$ & Vertical Strain in micron = $\mathbf{244.7 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 3000.00 364.00 116.32

Mu values 0.350.350.35

thicknesses (mm) 125.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.70: **The output result from IITPAVE in sample C of CBR = 19.12%**

Z	R	epZ	epT	epR
125.00	0.00	0.1772E-03	**0.1601E-03**	0.1048E-03
125.00L	0.00	0.4271E-03	0.1601E-03	0.1048E-03
125.00	155.00	0.1070E-03	0.1542E-03	0.6070E-05
575.00L	155.00	0.3046E-03	0.1542E-03	0.6070E-05
575.00	0.00	0.1205E-03	0.8415E-03	0.6779E-04
575.00L	0.00	0.2021E-03	0.8411E-03	0.6772E-04
575.00	155.00	01302E-03	0.8810E-03	0.7715E-04
575.00L	155.00	**0.2181E-03**	0.8810E-03	0.7716E-04

Horizontal Strain in micron = $\mathbf{160. \times 10^{-6}}$ & Vertical Strain in micron = $\mathbf{218.1 \times 10^{-6}}$

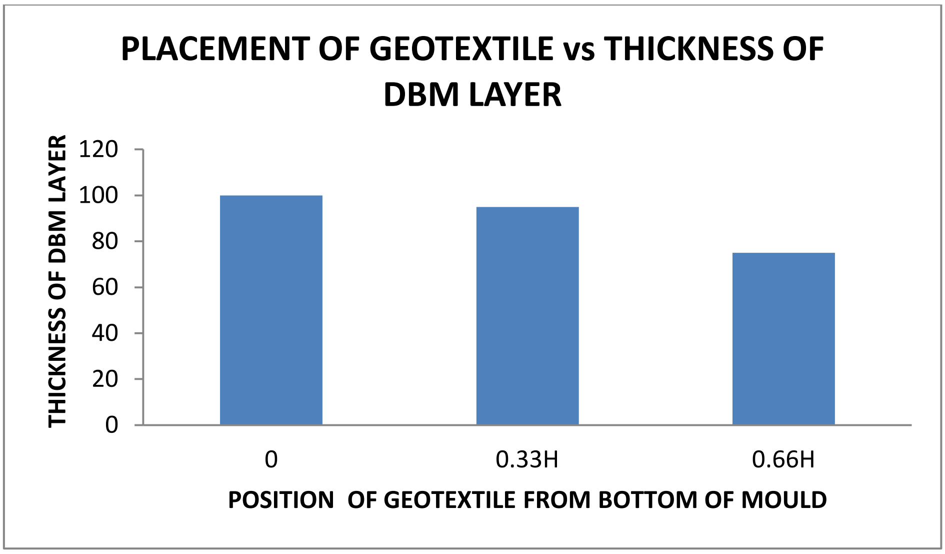

Figure 5.30: **Placement of Geotextiles in sample C with DBM Layer thickness at 90% reliability**

For both rutting life and fatigue 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H and 0.66H from the base of the mould in sample C, there is a saving of Dense Bituminous Macadam Layer at 90 percent reliability as shown in figure 5.30. Figure 5.30 gives the variation of thickness of DBM layer in pavement vs position of geotextile at different depths from the base of the mould. There is also saving of total thickness of the road crust when the geotextile are placed at different depths.

***Table 5.71:* Pavement Composition for Soil Sample A with geotextiles at different location for both Fatigue & Rutting Life = 100MSA at 80% reliability in IRC: 37-2001**

S.No.	Design CBR (%)	Placement of Geotextile from bottom the of mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	εv*	εv**	Fatigue Life & Rutting Life(MSA)
1.	3.12	0	375	250	190	50	865	191	198	287	405	100
2.	3.28	0.33H	370	250	185	50	855	193	198	285	405	100
3.	6.14	0.66H	256	250	155	50	711	188	198	267	405	100
4.	8.17	0.85H	200	250	140	50	610	192	198	281	405	100

εt* = Horizontal strain value in micron (10^{-6}), εt** = Allowable horizontal strain value in micron (10^{-6}),

εv* = Vertical strain value in micron (10^{-6}) εv** = Allowable vertical strain value in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 113.00 31.20

Mu values 0.350.350.35

thicknesses (mm) 240.00 625.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.72:* The output result from IITPAVE in sample A of CBR = 3.12%**

Z	R	epZ	epT	epR
240.00	0.00	0.1818E-03	0.1816E-03	0.1213E-03
240.00L	0.00	0.4438E-03	0.1816E-03	0.1213E-03
240.00	155.00	0.1771E-03	0.1919E-03	0.1018E-03
240.00L	155.00	0.4430E-03	**0.1919E-03**	0.1018E-03
865.00	0.00	0.1586E-03	0.1208E-03	0.8943E-04
865.00L	0.00	0.2777E-03	0.1129E-03	0.9735E-04
865.00	155.00	0.1650E-03	0.1125E-03	0.1068E-03
865.00L	155.00	**0.2878E-03**	0.1124E-03	0.1068E-03

Horizontal Strain in micron = **191.9×10^{-6}** & Vertical Strain in micron = **287.8×10^{-6}**

The input to IITPAVE:-

No. of layers 3

E values (MPa) 1700.00 118.40 32.80

Mu values 0.350.350.35

thicknesses (mm) 235.00 620.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.73: **The output result from IITPAVE in sample A of CBR = 3.28%**

Z	R	epZ	epT	epR
235.00	0.00	0.1841E-03	0.1834E-03	0.1218E-03
235.00L	0.00	0.4484E-03	0.1834E-03	0.1218E-03
235.00	155.00	0.1777E-03	0.1935E-03	0.9941E-04
235.00L	155.00	0.4444E-03	**0.1935E-03**	0.9941E-04
855.00	0.00	0.1572E-03	0.9670E-03	0.1115E-03
855.00L	0.00	0.2749E-03	0.1085E-03	0.9965E-04
855.00	155.00	0.1632E-03	0.1115E-03	0.1053E-03
855.00L	155.00	**0.2850E-03**	0.1116E-03	0.1053E-03

Horizontal Strain in micron = $\mathbf{193.5 \times 10^{-6}}$ & Vertical Strain in micron = $\mathbf{285.0 \times 10^{-6}}$

The input to IITPAVE:-

No. of layers 3

E values (MPa) 1700.00 185.00 56.22

Mu values 0.350.350.35

thicknesses (mm) 205.00 506.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.74: **The output result from IITPAVE in sample A of CBR = 6.14%**

Z	R	epZ	epT	epR
205.00	0.00	0.1920E-03	0.1813E-03	0.1161E-03
205.00L	0.00	0.4366E-03	0.1813E-03	0.1161E-03
205.00	155.00	0.1689E-03	0.1886E-03	0.7138E-04
205.00L	155.00	0.4060E-03	**0.1886E-03**	0.7138E-04
711.00	0.00	0.1487E-03	0.1014E-03	0.8976E-04
711.00L	0.00	0.2535E-03	0.1026E-03	0.8855E-04
711.00	155.00	0.1578E-03	0.1060E-03	0.9771E-04
711.00L	155.00	**0.2679E-03**	0.1060E-03	0.9767E-04

Horizontal Strain in micron = $\mathbf{188.6 \times 10^{-6}}$ & Vertical Strain in micron = $\mathbf{267.9 \times 10^{-6}}$

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 185.00 56.22

Mu values 0.350.350.35

thicknesses (mm) 205.00 506.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.75: **The output result from IITPAVE in sample A of CBR = 8.17%**

Z	R	epZ	epT	epR
190.00	0.00	0.2001E-03	0.1868E-03	0.1190E-03
190.00L	0.00	0.4503E-03	0.1868E-03	0.1190E-03
190.00	155.00	0.1684E-03	0.1923E-03	0.5912E-04
190.00L	155.00	0.4013E-03	**0.1923E-03**	0.5911E-04
610.00	0.00	0.1567E-03	0.1079E-03	0.8969E-04
610.00L	0.00	0.2636E-03	0.1078E-03	0.8981E-04
610.00	155.00	0.1683E-03	0.1121E-03	0.1013E-03
610.00L	155.00	**0.2818E-03**	0.1120E-03	0.1013E-03

Horizontal Strain in micron = **192.3×10^{-6}** & Vertical Strain in micron = **281.8×10^{-6}**

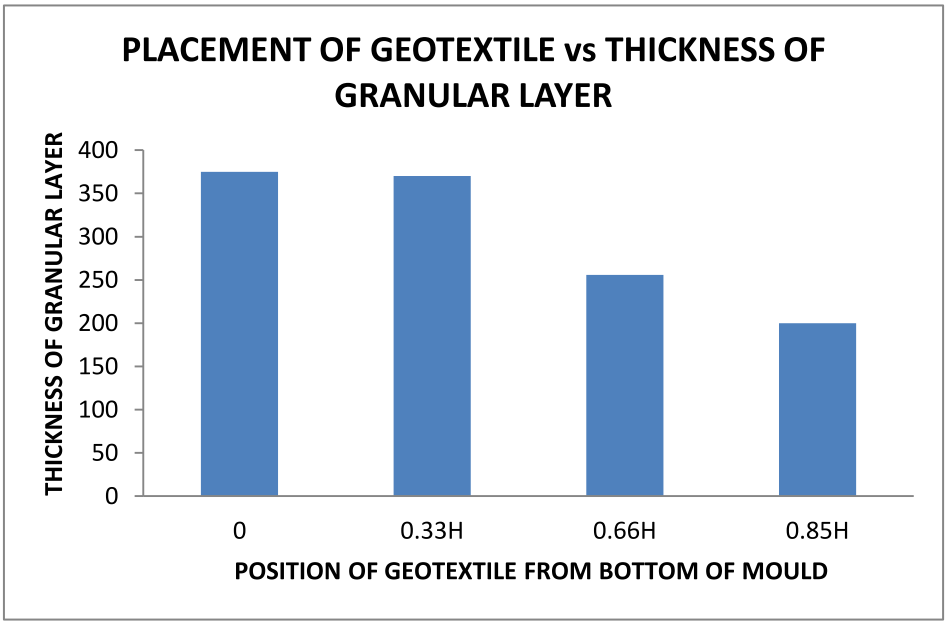

Figure 5.31: **Placement of Geotextiles in sample A with Granular Layer thickness at 80% reliability**

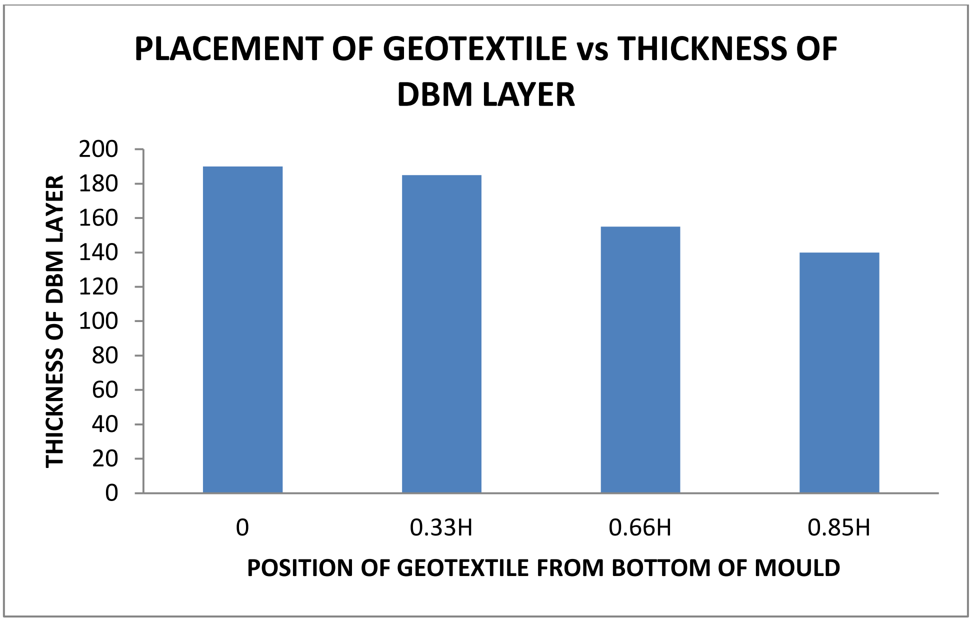

Figure 5.32: **Placement of Geotextiles in sample A with DBM Layer thickness at 80% reliability**

For both rutting life and fatigue 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample A, there is a saving of Granular layer thickness and Dense Bituminous Macadam Layer at 80 percent reliability as shown in figure 5.31 and 5.32. Figure 5.31 gives the variation of Granular layer thickness in pavement vs position of geotextile at different depths from the base of the mould. Figure 5.32 gives the variation of thickness of DBM layer in pavement vs position of geotextile at different depths from the base of the mould. There is also saving of total thickness of the road crust when the geotextile are placed at different depths

Table 5.76: **Pavement Composition for Soil Sample B with geotextiles at different location for both Fatigue & Rutting Life = 100MSA at 80% reliability in IRC: 37-2001**

S.No.	Design CBR (%)	Placement of Geotextile from bottom the of mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	εv*	εv**	Fatigue Life & Rutting Life(MSA)
1.	6.61	0	245	250	145	50	690	195	197	275	405	100
2.	6.64	0.33H	245	250	145	50	690	194	197	275	405	100
3.	9.98	0.66H	200	250	130	50	630	188	197	265	405	100
4.	11.97	0.85H	200	250	125	50	625	181	197	247	405	100

εt* = Horizontal strain value in micron (10^{-6}), εt** = Allowable horizontal strain value in micron (10^{-6}),

εv* = Vertical strain value in micron (10^{-6}) εv** = Allowable vertical strain value in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 192.00 59.00

Mu values 0.350.350.35

thicknesses (mm) 195.00 495.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.77: **The output result from IITPAVE in sample B of CBR = 6.61%**

Z	R	epZ	epT	epR
195.00	0.00	0.1996E-03	0.1891E-03	0.1204E-03
195.00L	0.00	0.4579E-03	0.1891E-03	0.1204E-03
195.00	155.00	0.1720E-03	0.1954E-03	0.6620E-04
195.00L	155.00	0.4165E-03	**0.1954E-03**	0.6620E-04
690.00	0.00	0.1529E-03	0.1053E-03	0.9058E-04
690.00L	0.00	0.2600E-03	0.1058E-03	0.8999E-04
690.00	155.00	0.1629E-03	0.1093E-03	0.1002E-03
690.00L	155.00	**0.2758E-03**	0.1093E-03	0.1002E-03

Horizontal Strain in micron = **195.4×10^{-6}** & Vertical Strain in micron = **275.8×10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 193.00 59.11

Mu values 0.350.350.35

thicknesses (mm) 195.00 495.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.78: **The output result from IITPAVE in sample B of CBR = 6.64%**

Z	R	epZ	epT	epR
195.00	0.00	0.1992E-03	0.1886E-03	0.1201E-03
195.00L	0.00	0.4567E-03	0.1886E-03	0.1201E-03
195.00	155.00	0.1716E-03	0.1949E-03	0.6588E-04
195.00L	155.00	0.4075E-03	**0.1949E-03**	0.6588E-04
690.00	0.00	0.1524E-03	0.1061E-03	0.8932E-04
690.00L	0.00	0.2594E-03	0.1052E-03	0.9020E-04
690.00	155.00	0.1624E-03	0.1091E-03	0.1000E-03
690.00L	155.00	**0.2752E-03**	0.1091E-03	0.1000E-03

Horizontal Strain in micron = **194.9 x 10^{-6}** & Vertical Strain in micron = **275.2 x 10^{-6}**

The input from IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 240.00 76.72

Mu values 0.350.350.35

thicknesses (mm) 180.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.79: **The output result from IITPAVE in sample B of CBR = 9.98%**

Z	R	epZ	epT	epR
180.00	0.00	0.2035E-03	0.1850E-03	0.1176E-03
180.00L	0.00	0.4503E-03	0.1851E-03	0.1176E-03
180.00	155.00	0.1629E-03	0.1887E-03	0.4582E-04
180.00L	155.00	0.3860E-03	**0.1887E-03**	0.4582E-04
630.00	0.00	0.1472E-03	0.1022E-03	0.8347E-04
630.00L	0.00	0.2477E-03	0.1023E-03	0.8337E-04
630.00	155.00	0.1588E-03	0.1061E-03	0.9527E-04
630.00L	155.00	**0.2659E-03**	0.1061E-03	0.9528E-04

Horizontal Strain in micron = **188.7 x 10^{-6}** & Vertical Strain in micron = **265.9 x 10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 269.00 86.20

Mu values 0.350.350.35

thicknesses (mm) 175.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

***Table 5.80:* The output result from IITPAVE in sample B of CBR = 11.97%**

Z	R	epZ	epT	epR
175.00	0.00	0.2018E-03	0.1788E-03	0.1137E-03
175.00L	0.00	0.4375E-03	0.1788E-03	0.1136E-03
175.00	155.00	0.1560E-03	0.1811E-03	0.3579E-04
175.00L	155.00	0.3646E-03	**0.1811E-03**	0.3579E-04
625.00	0.00	0.1334E-03	0.9503E-03	0.7275E-04
625.00L	0.00	0.2226E-03	0.9498E-03	0.7280E-04
625.00	155.00	0.1479E-03	0.9899E-03	0.8843E-04
625.00L	155.00	**0.2475E-03**	0.9898E-03	0.8844E-04

Horizontal Strain in micron = **181.1×10^{-6}** & Vertical Strain in micron = **247.5×10^{-6}**

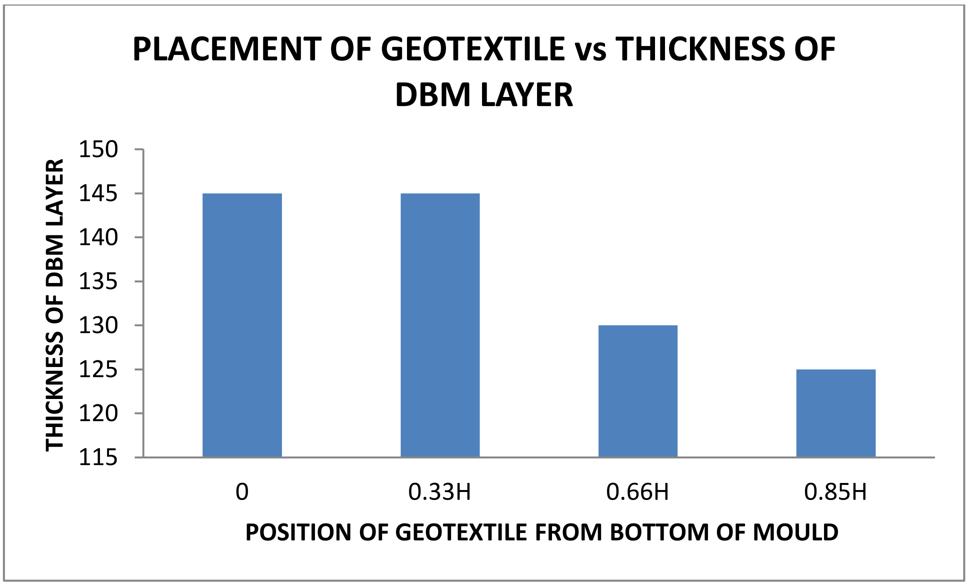

***Figure 5.33:* Placement of Geotextiles in sample B with DBM Layer thickness at 80% reliability**

For both rutting life and fatigue 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H, 0.66H and 0.85H from the base of the mould in sample B, there is a saving of Dense Bituminous Macadam Layer at 80 percent reliability as shown in figure 5.33. Figure 5.33 gives the variation of thickness of DBM layer in pavement vs position of geotextile at different depths from the base of the mould. There is also saving of total thickness of the road crust when the geotextile are placed at different depths.

Table 5.81: **Pavement Composition for Soil Sample C with geotextiles at different location for both Fatigue & Rutting Life = 100MSA at 80% reliability in IRC: 37-2001**

S.No.	Design CBR (%)	Placement of Geotextile from bottom the of mould	GSB (mm)	WMM (mm)	DBM (mm)	BC (mm)	Total Thickness (mm)	εt*	εt**	εv*	εv**	Fatigue Life & Rutting Life(MSA)
1.	12.01	0	200	250	125	50	625	180	197	246	405	100
2.	12.85	0.33H	200	250	125	50	625	176	197	238	405	100
3.	19.12	0.66H	200	250	115	50	615	167	197	209	405	100

εt* = Horizontal strain value in micron (10^{-6}), εt** = Allowable horizontal strain value in micron (10^{-6}),

εv* = Vertical strain value in micron (10^{-6}) εv** = Allowable vertical strain value in micron (10^{-6})

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 272.00 86.38

Mu values 0.350.350.35

thicknesses (mm) 175.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.82: **The output result from IITPAVE in sample C of CBR = 12.01%**

Z	R	epZ	epT	epR
175.00	0.00	0.2010E-03	0.1779E-03	0.1128E-03
175.00L	0.00	0.4347E-03	0.1779E-03	0.1128E-03
175.00	155.00	0.1552E-03	0.1800E-03	0.3520E-04
175.00L	155.00	0.3618E-03	**0.1800E-03**	0.3520E-04
625.00	0.00	0.1330E-03	0.9470E-03	0.7581E-04
625.00L	0.00	0.2312E-03	0.9462E-03	0.7734E-04
625.00	155.00	0.1468E-03	0.9858E-03	0.8805E-04
625.00L	155.00	**0.2465E-03**	0.9858E-03	0.8805E-04

Horizontal Strain in micron = **180.0×10^{-6}** & Vertical Strain in micron = **246.5×10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 282.00 90.20

Mu values 0.350.350.35

thicknesses (mm) 175.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.83: **The output result from IITPAVE in sample C of CBR = 12.85%**

Z	R	epZ	epT	epR
175.00	0.00	0.1984E-03	0.1740E-03	0.1067E-03
175.00L	0.00	0.4258E-03	0.1740E-03	0.1105E-03
175.00	155.00	0.1525E-03	0.1761E-03	0.3314E-04
175.00L	155.00	0.3528E-03	**0.1761E-03**	0.3314E-04
625.00	0.00	0.1312E-03	0.9162E-03	0.7179E-04
625.00L	0.00	0.2202E-03	0.9157E-03	0.7215E-04
625.00	155.00	0.1424E-03	0.9541E-03	0.8515E-04
625.00L	155.00	**0.2385E-03**	0.9541E-03	0.8515E-04

Horizontal Strain in micron = **176.1×10^{-6}** & Vertical Strain in micron = **238.5×10^{-6}**

The input to IITPAVE**:-**

No. of layers 3

E values (MPa) 1700.00 364.00 116.32

Mu values 0.350.350.35

thicknesses (mm) 155.00 450.00

single wheel load (N) 20000.00

tyre pressure (MPa) 0.56

Dual Wheel

Table 5.84: **The output result from IITPAVE in sample B of CBR = 19.12%**

Z	R	epZ	epT	epR
155.00	0.00	0.2065E-03	0.1676E-03	0.1071E-03
155.00L	0.00	0.4216E-03	**0.1676E-03**	0.1071E-03
155.00	155.00	0.1374E-03	0.1640E-03	0.3264E-04
155.00L	155.00	0.3112E-03	0.1640E-03	0.3264E-04
605.00	0.00	0.1137E-03	0.8037E-03	0.6380E-04
605.00L	0.00	0.1940E-03	0.8040E-03	0.6314E-04
605.00	155.00	0.1248E-03	0.8415E-03	0.7393E-04
605.00L	155.00	**0.2093E-03**	0.8415E-03	0.7393E-04

Horizontal Strain in micron = **167.6×10^{-6}** & Vertical Strain in micron = **209.3×10^{-6}**

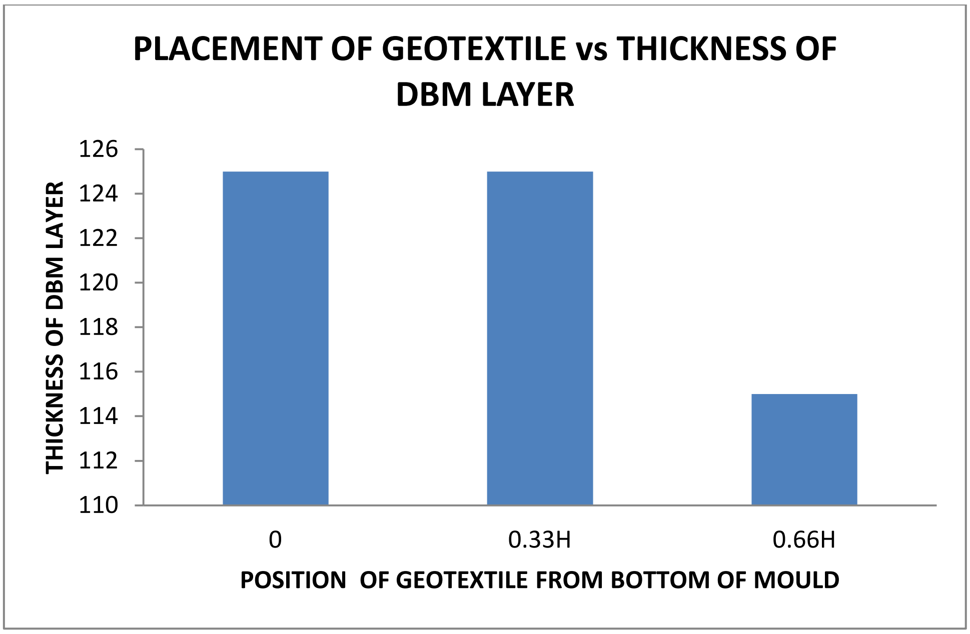

Figure 5.34: **Placement of Geotextiles in sample C with DBM Layer thickness at 80% reliability**

For both rutting life and fatigue 100 MSA, when the geotextiles are placed at different depths i.e. 0.33H and 0.66H from the base of the mould in sample C, there is a saving of Dense Bituminous Macadam Layer at 80 percent reliability as shown in figure 5.34. Figure 5.34 gives the variation of thickness of DBM layer in pavement vs position of geotextile at different depths from the base of the mould. There is also saving of total thickness of the road crust when the geotextile are placed at different depths.

5.4 Cost Analysis:-

Cost analysis has been done for road having 1 km length, 7.5 m width as shown in Table: 5.85.

Table 5.85: **Cost Analysis**

S.No.	Description	Layers	Layer Thickness (mm)	Cost of layer/m^3 (Rs.)	Total Cost of layer/Km (Rs.)
1.	Soil Sample with CBR= 3.12% for Fatigue life = 100MSA	GSB	200	1397	20,95,500
		WMM	250	2413	45,24,375
		DBM	165	11049	1,36,73,138
		BC	50	12065	45,24,375
		Total Cost of Road per Km (Rs.)			**2,48,17,388**
2.	Soil Sample with geotextile is placed at 0.85H from the bottom of the mould	GSB	200	1397	20,95,500
		WMM	250	2413	45,24,375
		DBM	118	11049	97,78,365
		BC	50	12065	45,24,375
		Cost of Geotextile and its Laying @60/sq. mtr			45,00,00
		Total Cost of Road per Km (Rs.)			**2,13,72,615**
3.	Soil Sample with CBR= 3.2% for Rutting life = 100MSA	GSB+WMM	590	1905	84,29,625
		DBM	150	11049	1,24,30,125
		BC	50	12065	45,24,375
		Total Cost of Road per Km (Rs.)			**2,53,84,125**
4.	Soil Sample with geotextile is placed at 0.85H from the bottom of the mould	GSB+WMM	315	1905	45,00,562
		DBM	150	11049	1,24,30,125
		BC	50	12065	45,24,375
		Cost for Geotextile and its Laying @60/sq. mtr			4,50,000
		Total Cost of Road per Km (Rs.)			**2,19,05,062**
5.	Soil Sample with CBR= 3.2% for Fatigue & Rutting life = 100MSA at 90% reliability	GSB	375	1397	39,29,063
		WMM	250	2413	45,24,375
		DBM	155	11049	1,28,44,463
		BC	50	12065	45,24,375
		Total Cost of Road per Km (Rs.)			**2,58,22,276**

6.	Soil Sample with geotextile is placed at 0.85H for Rutting & Fatigue life= 100MSA at 90% reliability	GSB	200	1397	20,95,500
		WMM	250	2413	45,24,375
		DBM	115	11049	95,29,762
		BC	50	12065	45,24,375
		Cost of Geotextile and its Laying @60/sq. mtr			4,50,000
		Total Cost of Road per Km (Rs.)			**2,11,24,012**
7.	Soil Sample with CBR= 3.2% for Fatigue & Rutting life = 100MSA at 80% reliability	GSB	375	1397	39,29,063
		WMM	250	2413	45,24,375
		DBM	190	11049	1,57,44,825
		BC	50	12065	45,24,375
		Total Cost of Road per Km (Rs.)			**2,87,22,638**
8.	Soil Sample with geotextile is placed at 0.85H for Rutting & Fatigue life= 100MSA at 80% reliability	GSB	200	1397	20,95,500
		WMM	250	2413	45,24,375
		DBM	140	11049	1,16,01,450
		BC	50	12065	45,24,375
		Cost of Geotextile and its Laying @60/sq. mtr			4,50,000
		Total Cost of Road per Km (Rs.)			**2,31,95,700**

CHAPTER- 06
CONCLUSIONS

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

1. In weak & soft subgrade soil, non-woven geotextiles increases the penetration resistance resulting in higher value of CBR, when the geotextiles are placed at varying depths.
2. The percentage increase in the CBR value is 161%, 80.27% and 85.05%, when the geotextiles are placed at 0.85H from the bottom of the mould in single layer in sample A, B and C under soaked condition.
3. Sandy soil with geotextiles can be used as sub-base material in the pavement design, as its CBR value is 22.23%, as according to IRC 37-2012, the minimum value of CBR for subbase material used in bituminous pavement is 20%. This type of application can lead to lot of savings in the aggregate consumed for the WBM / WMM layers construction and can thus lead to development of sustainable and green highways.
4. The fatigue and rutting life increased when the geotextile is placed at different depths in various samples A, B and C at 80% and 90% reliability.
5. The percentage reduction in the DBM thickness for fatigue life of 100MSA in sample A is 2.5%, 2.19% & 30.73% at 80 percent and 3.03%, 21.2% & 28.4% at 90% reliability. In sample B, the percentage reduction in DBM layer thickness is 1.2%, 17.41% & 25.8% at 80 percent and 0%, 17.9% & 25.7% at 90% reliability whereas sample C, the percentage reduction in DBM layer thickness is 2.6%, & 26.54% at 80 percent and 3.15%, & 24.2% at 90% reliability, when the geotextile is placed at 0.33H, 0.66H & 0.85H from the bottom of the mould.
6. The percentage reduction in Granular layer (GSB + WMM) thickness for the rutting life of 100MSA in sample A is 0.91%, 33% & 44.9% at 80 percent and 2.6%, 36.7% & 46.08% at 90% reliability. In sample B, the percentage reduction in Granular layer thickness is 1.47%, 23.5% & 33.82% at 80 percent and 0%, 22.85% & 32.85% at 90% reliability whereas sample C, the percentage reduction in Granular layer thickness is 4.34% & 30.43% at 80 percent and 5.1% & 31.91% at 90% reliability, when the geotextile is placed at 0.33H, 0.66H & 0.85H from the bottom of the mould.
7. The percentage reduction in total layer thickness for the fatigue & rutting life of 100MSA in sample A is 1.56%, 17.95% & 25.9%. In sample B, the percentage reduction in total layer thickness is 0%, 8.6% & 10.17%, whereas sample C, the

percentage reduction in total layer thickness is 0.84% & 4.17% at 90 percent reliability in IRC: 37-2012.

8. The percentage reduction in total layer thickness for the fatigue & rutting life of 100MSA in sample A is 11.156%, 17.80% & 29.47%. In sample B, the percentage reduction in total layer thickness is 0%, 8.7% & 9.42% whereas sample C, the percentage reduction of total layer thickness is 0% & 1.61% at 80 percent reliability in IRC: 37-2001.
9. The pavement construction cost per km for two lane national highway is reduced upto 18.19% and 19.24% for both rutting and fatigue life 100MSA at 90% & 80% reliability, when the geotextile is placed in subgrade soil.

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