The Major Project-II On

EFFECT OF FIBRE LENGTH ON POLYESTER FIBRE REINFORCED SOIL

Submitted In Partial Fulfillment For The Award Of The Degree Of

MASTERS OF TECHNOLOGY

IN

CIVIL ENGINERING

With Specialization In

GEOTECHNICAL ENGINEERING

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2014`

DELHI TECHNOLOGICAL UNIVERSITY, DELHI

CERTIFICATE

This is to certify that the major project-II report entitled "**EFFECT OF FIBRE LENGTH ON POLYESTER FIBRE REINFORCED SOIL**" is a bona fide record of work carried out by Gaurav Gupta(Roll No. 2K12/GTE/06) under my guidance and supervision, during the session 2014 in partial fulfillment of the requirement for the degree of Master of Technology (Geotechnical Engineering) from Delhi Technological University, Delhi.

The work embodied in this major project-II has not been submitted for the award of any other degree to the best of my knowledge.

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ACKNOWLEDGEMENT

As I write this acknowledgement, I must clarify that this is not just a formal acknowledgement but also a sincere note of thanks and regard from my side. I feel a deep sense of gratitude and affection for those who were associated with the project and without whose co-operation and guidance this project could not have been conducted properly.

Words fail me to express my gratitude towards my project guide, **Dr. A. K. Gupta,** Professor, Civil Engineering Department, Delhi Technological University, Delhi for giving me an opportunity to work under his guidance, which really instilled in me the requisite confidence.

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Last but not the least, I would like to thank my family and friends who stimulated me to bring this work to a successful close.

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DECLARATION

I hereby declare that the work being presented in this Project Report entitled "**EFFECT OF FIBRE LENGTH ON POLYESTER FIBRE REINFORCED SOIL** " is a bona fide record of work carried out by me as a part of major project-II in partial fulfillment of the requirement for the degree of Masters of Technology in Geotechnical Engineering.

I have not submitted the matter presented in this report for the award of any degree.

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ABSTRACT

Economy has always been a top consideration factor before carrying out construction of any kind. Achieving higher value of the strength parameters, with a controlled increase in cost of the foreign material leading to an overall decrease in the net construction cost, is always a sign of development.

In the case of geotechnical engineering the idea of inserting fibrous materials in a soil mass in order to improve its mechanical behavior has become very popular. The concept of earth reinforcement is an ancient technique and demonstrated abundantly in nature by animals, birds and the action of tree roots. This reinforcement resists tensile stress developed within the soil mass thereby restricting shear failure. The reinforcement interacts with the soil through friction and adhesion. To improve the mechanical properties of soils, a variety of materials are used for reinforcement e.g. metallic elements, Geo-synthetics etc. Majority of geo-synthetics used in civil engineering application are polymeric in composition.

In this investigation Recron 3s polyester fibre manufactured by Reliance India Ltd., has been used. Polyester Fibres are engineered Micro Fibers with a unique "Triangular" Cross-section shape. In this study 6 mm and 12 mm length polyester fibres were used. Test specimens were prepared with varying percentages of 6 mm and 12 mm polyester fibre (non-reinforced, 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.6%, 0.7%, 0.8%, 0.9% and 1.0%) by the weight of dry soil.Two types of soil, Sandy and Clayey were used in the investigation. 42 modified proctor compaction tests and 129 California Bearing Ratio tests were carried out.

Experimental investigations were undertaken to study the effect of polyester fibre on California Bearing Ratio value of soil. The fibre reinforcement significantly changes and improves the CBR value. The study has shown that there was a gain in California Bearing Ratio value for both types of soil and for both length of fibres. Mathematical Relations were derived using curve-fitting method between percentage gain in California Bearing Ratio value and Amount of polyester fibre added in percentage.

A computer program has been prepared in Visual Basic .Net using Microsoft Visual Studio 2010 which gives us the percentage requirement of fibre addition to obtain to desired gain in California Bearing Ratio Value.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER-1

INTRODUCTION

1.1FIBRE REINFORCED SOIL

1.1.1 INTRODUCTION

Randomly distributed fibre reinforced soil-termed as RDFS is among the latest ground improvement techniques in which fibres of desired quantity and type are added in soil, mixed randomly and arranged in a random position after compaction. RDFS is different from other types of soil reinforcing methods in its orientation. In reinforced earth, the reinforcement in the form of strips, sheets, etc. is laid horizontally at specific intervals and in specific directions, where as in RDFS fibres are mixed randomly in soil thus making a homogeneous mass and maintain the isotropy in strength. Modern geotechnical engineering has focused on the use of planar reinforcement (e.g. metal strips, sheet of synthetic fabrics). However reinforcement of soil with discrete fibres is still a relatively new technique in a geotechnical engineering project.

1.1.2 ADVANTAGES OF FIBRE-REINFORCED SOIL

Randomly distributed fibre reinforced soil (RDFS) offers many advantages as listed below:

- Beneficial for every type of soil (i.e. sand, silt, clay).
- Decreases post peak strength loss.
- Increases shear strength with the maintenance of strength isotropy.
- Improves seismic performance
- Improves ductility
- Reduces swell pressure and shrinkage of expansive soil.
- Great wayto use waste materials such as shredded tires, coir fibres.
- Provide facilitate vegetation development& erosion control.
- No noticeable change in permeability.
- Fibre-reinforcement has been reported to be helpful in eliminating the shallow failure on slope face and thus reducing the cost of maintenance.
- Unlike lime, cement and other chemical stabilization methods, the construction using fibre-reinforcement is not significantly affected by weather conditions.

1.1.3 BASIC MECHANISM OF RDFS

Randomly oriented discrete fibres when placed in soil improve its load-deformation behavior by interacting with the soil particles mechanically through interlocking and surface friction. The function of the interlock or bond is to transfer the stress from the soil to the discrete inclusions by mobilizing the tensile strength of discrete inclusion. Thus fibre reinforcement works as a tension resistance and frictional elements.

1.1.4 DIRECTION OF PLACEMENT

Fibres can be randomly mixed in soil or oriented in a particular direction in soil. In random category, inclusions are mixed with soil and placed within probable shear zone, whereas in oriented category, the inclusions are placed within the soil at specific positions and direction. In geotechnical engineering, the concept of randomly reinforced soil is relatively new.Placing the fibres in field, at some orientation, is a time consuming and a difficult task. In reinforced soil the added material (the geosynthetics sheet, etc.) is layered at a specific position and direction, which may make the soil weak in some other direction. Where as in RDFS, the isotropy in strength is maintained.

1.2POLYESTER FIBER

1.2.1 INTRODUCTION

Polyester is a synthetic fiber derived from air, water, coal and petroleum. Developed in a 20th-century laboratory, polyester fibers are formed from a chemical reaction between an alcohol and an acid. In this reaction, two or more molecules combine to make a large molecule whose structure repeats throughout its length.

1.2.2. PROPERTIES OF POLYESTER FIBRE (As provided by the Supplier)

Material	Polyester
Shape/ Cross Section	Triangular
Effective Diameter	10-40 Microns
Length	6 / 12 millimeters

Specific Gravity	1.31-1.39
Melting Point	150-160^{o}C
Tensile strength	4-6 MPa (Mega Pascal)
Young`s Modulus	>5000 MPa (Mega Pascal)

1.2.3. SHAPE OF POLYESTER FIBRES

Polyester fibres have a unique triangular cross-section, which gives 40% more surface area for bonding compared to other shapes. Polyester fibres are also designed so that the fibre stays uniformly dispersed and dimensionally straight, so as to safe guard against curling and bunching.

1.2.4. WORKING OF POLYESTER FIBRES IN CONCRETE

Polyester fibres when mixed with cement in the concrete batch mixing/ mortar preparation stage, spreads throughout the matrix and gives three-dimensional secondary reinforcement. It also improvesthe workability. The early micro-cracks formed due to heat of hydration, shrinkage and expansion before and post-hardening are avoided by the presence of polyester fibre, which acts as a barrier for further propagation of cracks.

1.2.5. APPLICATIONS OF POLYESTER FIBRE IN CONSTRUCTION

- Plastering
- Roads and pavements
- Hollow blocks and pre-cast
- RCC, PCC like lintel, beam, column, flooring & wall plastering
- Manhole covers, tanks, foundations and tiles

1.2.6. ROLE OF POLYESTER FIBRE IN CONSTRUCTION INDUSTRY

Polyester fibre can be added at a small dosage of 0.25% on the weight of cement, may help in various ways to improve quality of construction as well as raw material, labour, time and money saving.

- Reduces rebound loss - Brings direct savings and gains
- Increases flexibility
- Increased abrasion resistance
- Controls cracking
- Reduces water permeability

1.2.7. USE OF POLYESTER FIBRE IN PLASTERING

- Polyester fibre reduces the rebound loss of material by 50-70%. This result in direct saving of raw material, bringing back the cost of Polyester fibre added, resulting in equal amount of money saving. The faster pace of work and the saving in labour are added cost savings.
- The plaster free from micro-cracks also improves the aesthetics and helps avoid the expense on frequent repainting and repair work.
- Use of Polyester fibre checks plastic and drying shrinkage cracks and plastic settlement cracks.
- It helps in reducing the water seepage through the micro-cracks formed in plaster and thus protects the iron rebar from corrosion.

1.3 NECESSITY OF STUDY

- Higher subgrade strength lowers the thickness of overlying layers hence makes the road construction economical.
- Large types of synthetic fibres are available in market easily at an economical price.
- Placing randomly distributed fibres in soil are easy as compared to the reinforced soil in which the added material (the geosynthetics sheet, etc.) is layered at a specific direction and position, which may keep the soil weaken in some other direction. Where as in ply soil, the isotropy in strength is maintained.

OBJECTIVES OF THE STUDY

- To determine the influence of content of polyester fibre of various lengths (6 mm and 12 mm) on maximum dry density value and optimum moisture content value of various types of soil (sand and clay) by conducting modified proctor compaction test.
- To study the effect of percentage content of polyester fibre of various lengths (6 mm and 12 mm) on California Bearing Ratio value(unsoaked and soaked) of various types of soil (sand and clay).
- To draw a mathematical relation between percentage polyester fibre added and percentage change in maximum dry density value, percentage change in optimum dry density value, percentage change in California bearing ratio value, as compared to the value of the same for virgin soil.
- To determine the optimum dose of polyester fibre for the highest value of California Bearing Ratio that can be obtained of the soil to be used in subgrade layer of the road.
- To develop a software using vb.net which could calculate the required need of polyester fibre to attain the target California Bearing Ratio value by inputs of the observations of the test and the type of soil and fibre.

CHAPTER-2

LITERATURE

REVIEW

Reviews of Literature:

K. Furumoto et al. (2002)have performed experiments on short fiber reinforced soil in order to improve the roughness and strength of soil by adding fibre to the soil. They carried out permeability tests to find out the piping resistance of the fibre-reinforced soil. Large-scale levee model tests were done to find out the applicability of the fiber reinforced soil layer to the river levee structure. It was concludedthat the short fiber reinforced soil layer rises the stability of levee against seepage of flood& rainfall.

Yi Cai et al. (2006)have studied randomly mixedlime &polypropylene fiber in soil so as to achieve better mechanical behavior of soil.Six different fiber (%)-lime (%) content samples were made, 0-0%, 0.2-0%, 0-8%, 0.1-8%, 0.1-6% and 0.2-6% by weight of dry soil. A number of shrinkage tests, swelling tests, unconfined compression tests without load & shear tests were carried out. Addition of polypropylene&lime fibre in the soil decrease the capacity of shrinkage & swelling, increasethe shear strength& compression,&transfer the failure characteristic of soil from brittle failure to ductile failure.

B.V.S. Viswanadham et al. (2009)have worked onthe effect of discrete and randomly distributed geo fibers. These fibres were used to restrain the cracking tendency of clay barrier, subjected to differential settlements, reducing swelling tendency of moist compacted expansive soil, and Efficacy of geofiber-reinforced soil as a fill material. A number of tests were carried-out for finding the influence of geo fibers. Geo fibres having various length and dosages were used. Polyester and propylenegeo fibers were used in there study in three type of soil. The geofiber-reinforced soil is a very efficient method, which helps to restrain cracking of clay barrier at the onset of differential settlements,allows us to use the expansive soil deposits at the construction sites, and to use geofiber reinforced soil as a fill material.

BehzadKalantari et al. (2010)did a model study to stabilize peat soil using cement & polypropylene fibre. California Bearing Ratio test was carried out in order to study the improvement in the mechanical strength of the stabilized.A gain of 22% in unsoaked CBR value &15%in soaked CBR value was observed. With the addition of the polypropylene fibers to the stabilized peat soil with cement, increase in the strength of the stabilized peat soil and considerable amount of uniformity & intactness to the stabilized peat soil was achieved.

Prof.S.Ayyappan et al. (2010)did a study on the influence of length & fibre content on fiber reinforced soil- fly ash specimens. Unconfined compression strength tests and California bearing ratio tests were carried. Polypropylene fibers of various fibre length (6 mm, 12 mm and 24 mm) were used as reinforcement. Soil -fly ash specimens were compacted at maximum dry density with low percentage of reinforcement (0 to 1.50 % of weight). Following conclusions were obtained from this investigation. Addition of randomly distributed fibers increased the unconfined compressive strength of soil fly ash mixtures. Increase in fiber length reduced the contribution to peak compressive strength while increased the contribution to strain energy absorption capacity in all soil fly ash mixtures. Optimum dosage rate of fibre was identified as 1.00 % by dry weight of soil- fly ash, for all soil fly ash mixtures. Maximumgain was achieved by using fiber length equal to12 mmfor soil reinforcement.

G.P. Dall'aqua et al. (2010) have studied the effect of fibre on laterite & kaolinite stabilized with both cement and lime subjected to repeated loading. Crimped monofilament of 12 mm long polypropylene fiber with a diameter of 18 microns was used to reinforce both the soils at concentration of 0.3% stabilized with 4% and 6% of lime and cement. Results show that kaolinite soils reinforced with 0.3% of fibers together stabilized with 6% cement under repeated axial load test deform less than 1% after 3,600 load cycles and could be used in pavement construction.

KalpanaMaheshwari et al. (2011)did a number of model footing tests to find out the feasibility of polypropylene fibers as a reinforcing material. Fibres were added below the footing so as to improve the strength & behavior clayey soil as subsoil for the foundation. In all nine model footing tests on fiber reinforced soil with three different fibers content (0.25%, 0.50%, 1.00%) and three depths of placement of fiber reinforced soil (b/4, b/2, b, where b is width of footing). The actual full-scale load tests with the optimum fiber content (0.50%) and optimum depth of placement of fiber-reinforced soil (b/4) were conducted to verify small-scale laboratory results. The bearing capacity of reinforced soil increased to 250 kN/m^{2}from 64 kN/m^{2}bearing capacity of unreinforced soil.

S. Twinkle et al. (2011) have studied the effect of polypropylene fibre& lime admixture on engineering properties of expansive soil. For lime stabilization in black cotton soil, the optimum moisture content increases and the maximum dry density decreases. Whereas for polypropylene fiber, as the fiber content increases, optimum moisture content increases and maximum dry density decreases. With lime stabilization the liquid limit of soil decreases but plastic limit increases. Thus plasticity index of soil decreases. In California Bearing Ratio, the optimum lime dosage level was noted at 6% lime with a strength increase of about 3.19 times compared to untreated soil. Highest California bearing Ratio was observed at 0.75% for polypropylene fiber reinforced soil and polypropylene plus lime stabilized soil.

H.S. Chore et al. (2011)have studied the effect of fibre length & fibre content on the California Bearing Ration value of soil and to find out the optimum quantity of randomly distributed polypropylene fibers & fly ash. The effect of fibre inclusion on the angle of internal friction of sand as a highway material was also studied. The study shows that there is a remarkable gain in California Bearing Ratio value as well as angle of internal friction due to addition of randomly distributed fibers.

M. Heeralal et al. (2011)have studied the effects of short discrete polypropylene fiber (PP-fiber) on the mechanical behavior& strength of soil and also, soil+ cement kiln dust (CKD) mix. 0.25%, 0.5%, 1.0% of propylene fibre, by weight of the soil,was the proportioning of the soil samples undertaken. Three different percentages ofCKD content (3%,5%,8% by weight of the soil) and unconfined compressive strength, direct shear test and California Bearing Ratio tests were conducted. The inclusion of fiber reinforcement within soil and CKD soil mix caused an increase in the Unconfined Compressive Strength; shear strength and axial strain at failure. Increasing fiber content increases the peak axial stress &decreases the stiffness.

Mona Malekzadeh et al. (2012)have studied the effect of polypropylene fiber on swell and compressibility of expansive soils. Primary swell and secondary swell percentages decreased considerably with addition in fiber addition. The time of primary swell did increased when 0.5% and 0.75% fiber was added, however a significant reduction occurred with 1% fiberaddition. Hydraulic conductivity increased with 0.75% fiber content, while with 1% fibre content a decreasewas observed.

H. P. Singh et al. (2013)has reinforced locally available (Doimukh, Itanagar, Arunachal Pradesh, India) soil with jute fibre. The natural fiber reinforcement causes significant gain in shear strength, tensile strength, and other properties of the soil. The soil samples were prepared at a density equal to its maximum dry density corresponding to their optimum moisture content.The variation in percentage of Jute fiber by dry weight of soil 0.25%, 0.5%, 0.75% and 1%. The lengths of fiber wereadopted as 30 mm, 60 mm and 90 mm having two different diameters, 1 mm and 2 mm for each fiber length. The laboratory California Bearing Ratio value of jute reinforcedsoil was found out.The effects of diameter & length of the fiber on California Bearing Ratio value of soil were also studied. California Bearing Ratiovalue of soil increases with the increase in fiber content.With increasing length and diameter of fiber further California Bearing Ratio value of reinforced soil is further increased being substantial at fiber content of 1 % for 90 mm fiber length with diameter 2 mm.

S.K. Tiwari et al. (2013)have studied the effect (individual & mutual) of randomly distributed fiber reinforcements and cement stabilization on the geotechnical properties of fly ash-soil mixtures. It was observed that the fly ash fiber composite can sustain large axial strain showing high ductility in the composite and results in significant improvement in stress-strain behavior, causing substantial increase in shear strength. The increase in strength and secant modulus, increases as amount of cement increases, but decrease as amount of fly ash increases.The unconfined compressive strength of fly ash-soil blends increases due to addition of cement and fibers.

H.P. Singh (2013) has reinforced locally available (Doimukh, Itanagar, Arunachal Pradesh, India) soil with cotton fibre. The 0.25%, 0.5%, 0.75% and 1%percentage of cotton fiber by dry weight of soil was taken. For every fiber content, soaked &unsoaked California Bearing Ratio tests were conducted.Addition of cotton fibre improved the California Bearing Ratio for both soaked and unsoaked conditions.Substantial increase inCalifornia Bearing Ratio of 112% was obtained at 1% fibre.Optimum fiber content was found to be 1 % by dry weight of soil as sample preparations of soil for CBR test beyond 1 % fiber content was not possible.

CHAPTER-3

MATERIALS USED

3.0 INTRODUCTION

In the following chapter,a description of the materials used in the current investigation has been given. 2 types of soils namely silty sand and clay have been used. 2 types of polyester fibre 6 mm & 12 mm in length have been used.

3.1 POLYESTSER FIBRE AS REINFORCEMENT (http://www.ril.com)

Polyester Fibres are engineered Micro Fibers with a unique “Triangular” Cross-section. It complements Structural Steel in enhancing Concrete’s resistance to Shrinkage Cracking and improves mechanical properties such as Flexural / Split Tensile and Transverse Strengths of Concrete along with the desired improvement in Abrasion and Impact Strengths.

Polyester Fibres of following length have been used in the current investigation.

1. 6 millimeter length
2. 12 millimeter length

Reliance Industry Limited (RIL) has launched polyester fibres under the brand name of “**RECRON ® 3S**” with the objective of improving the quality of plaster and concrete. The Reliance Group, founded by MrDhirubhai H. Ambani, is India's largest business house with total revenues of Rs 65,000 crores. The group's activities span petrochemicals, synthetics fibres, fibre intermediates, gas, power, telecom, etc. Reliance is 4th largest polymer player in the world and our experience and research in Polymer field supports Polyester as better polymer for concrete than polypropylene. Polyester fibre has a unique triangular cross-section, which gives 40% more surface area for bonding compared to other shapes. Polyester fibre is also designed so that the fibre stays dimensionally straight and uniformly dispersed, so as to safe guard against balling, curling and bunching.

The unique triangular shape of Polyester fibre is designed to improve the adhesion in the cement matrix. It also helps in better operability and dispersion, which is key to performance of any secondary reinforcement.

The Polyester fibre retains its performance over a long period of time and does not deteriorate for years.

3.2 PROPERTIES OF POLYESTER FIBRE (As provided by the supplier)

TABLE 1: PROPERTIES OF POLYESTER FIBRE

Material	Polyester
Shape/ Cross Section	Triangular
Effective Diameter	10-40 Microns
Length	6 / 12 millimeters
Specific Gravity	1.31-1.39
Melting Point	150-160^{o}C
Tensile strength	4-6 MPa (Mega Pascal)
Young`s Modulus	>5000 MPa (Mega Pascal)

3.2 SOIL

In the current investigation two types of soil has been used.

- Soil 1 –Sand
- Soil 2 – Clay

3.2.1 SOIL 1 – SAND

The soil sample selected is obtained from a construction site in village Kansal, Punjab. The foreign and vegetative materials were removed.

Following tests have been performed on the virgin soil

- Determination Of Specific Gravity
- Determination Of Liquid Limit
- Determination Of Plastic Limit

- Grain Size Analysis
- Hydrometer Analysis
- Modified Proctor Compaction Test
- California Bearing Ratio Test (3 samples)

1) DETERMINATION OF SPECIFIC GRAVITY

The Specific Gravity of the soil was found out to be **2.68**by density bottle method.

TABLE 2: SPECIFIC GRAVITY TEST OF SAND

Weight of Density Bottle	W1	20.6 grams	20.6 grams	20.6 grams	20.6 grams
Weight of Density Bottle + dry soil	W2	125.6 grams	103.5 grams	130.1 grams	115.1 grams
Weight of Density Bottle + dry soil + water	W3	136.9 grams	142.7 grams	139.6 grams	129.9 grams
Weight of Density Bottle + water	W4	70.8 grams	70.8 grams	70.8 grams	70.8 grams
Specific Gravity	**S.G.**	**2.70**	**2.67**	**2.69**	**2.67**

$$\textit{SPECIFIC GRAVITY}=\frac{\boldsymbol{W2-W1}}{(\boldsymbol{W2-W1})-(\boldsymbol{W3-W4})}$$

$$\textit{AVERAGE SPECIFIC GRAVITY} = \frac{\mathbf{2.70+2.67+2.69+2.67}}{\mathbf{4}}=\mathbf{2.6825}$$

2)DETERMINATION OF LIQUID LIMIT AND PLASTIC LIMIT

Table 3: Atterberg Limits

Liquid Limit	-
Plastic Limit	Thread doesn`t form
Plasticity Index	-

GRAIN SIZE ANALYSIS

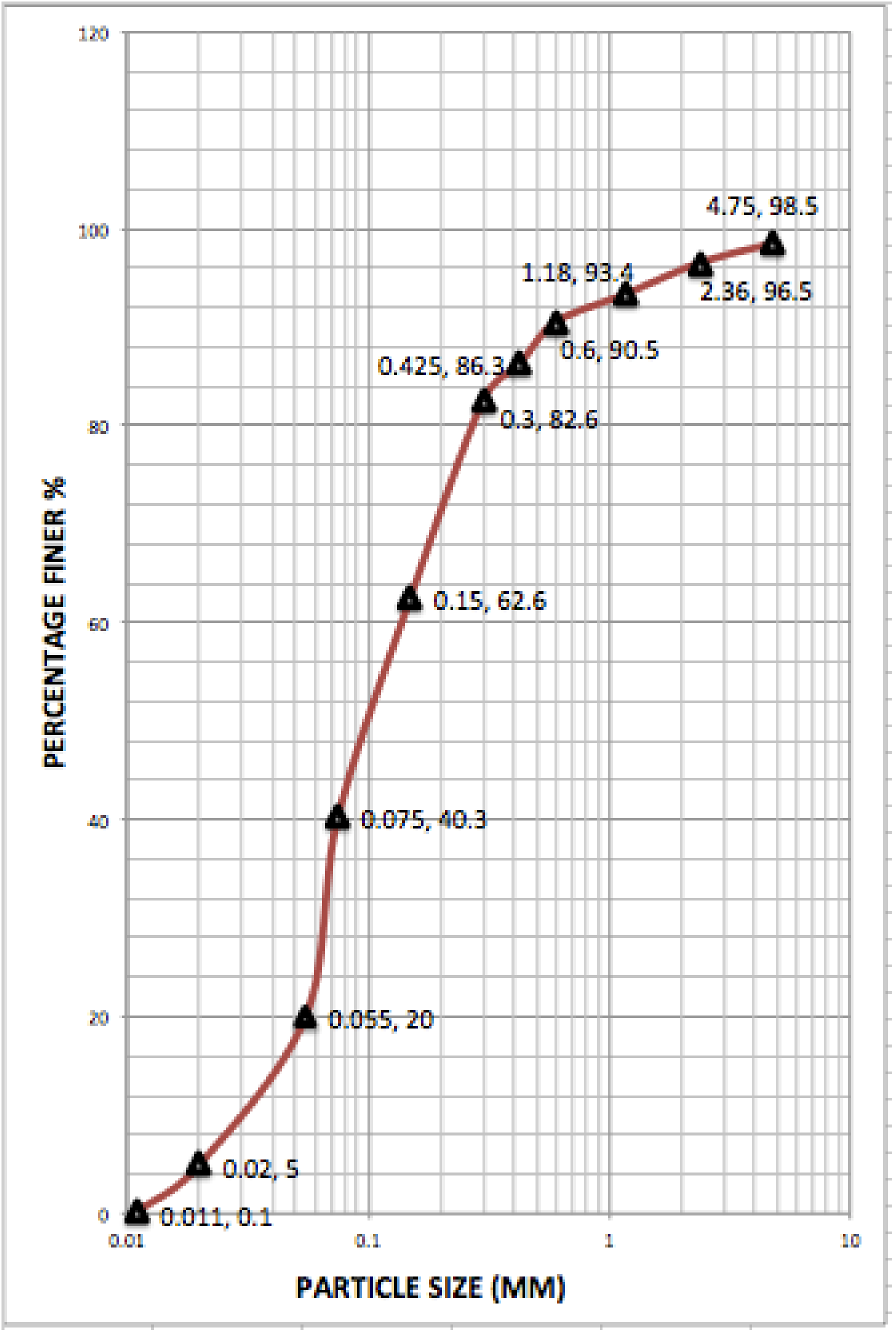


FIGURE 1: GRAIN SIZE ANALYSIS CURVE OF SAND

PERCENTAGE OF SOIL PASSING 4.75 mm SIEVE: 98.5% (> 50%)
PERCENTAGE OF SOIL RETAINED ON .075 mm SIEVE:59.4% (>50%)

Classification as per Indian standard code (IS 2720: 1985 part 4):
Sand with appreciable amount of fines (S.M.) SILTY SAND

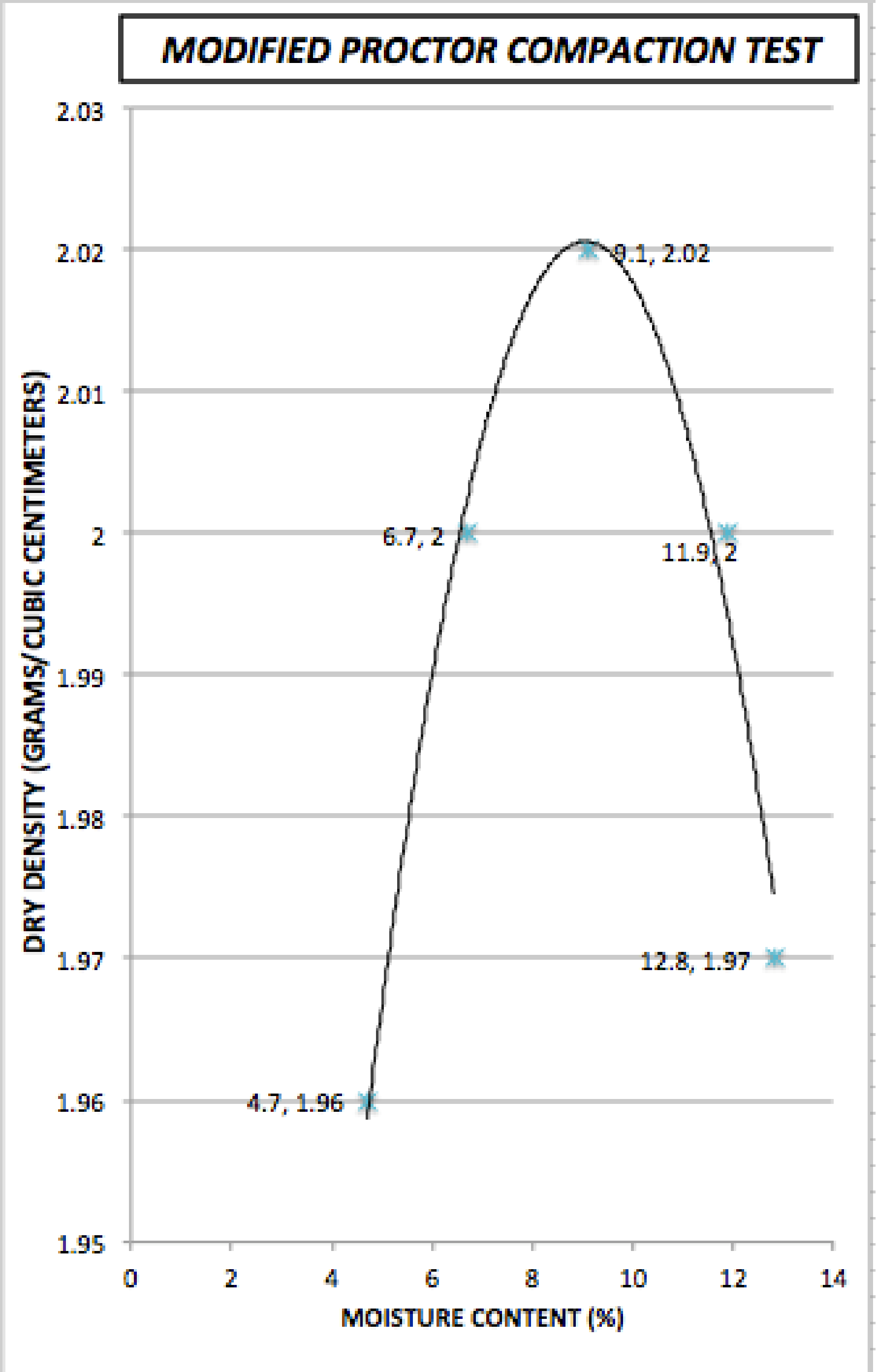


FIGURE 2: MODIFIED PROCTOR COMPACTION TEST OF SAND

Maximum Dry Density	**2.02 grams/ cubic centimeters**
Optimum Moisture Content	**10.1%**

CALIFORNIA BEARING RATIO TEST OF SAND

SAMPLE 1

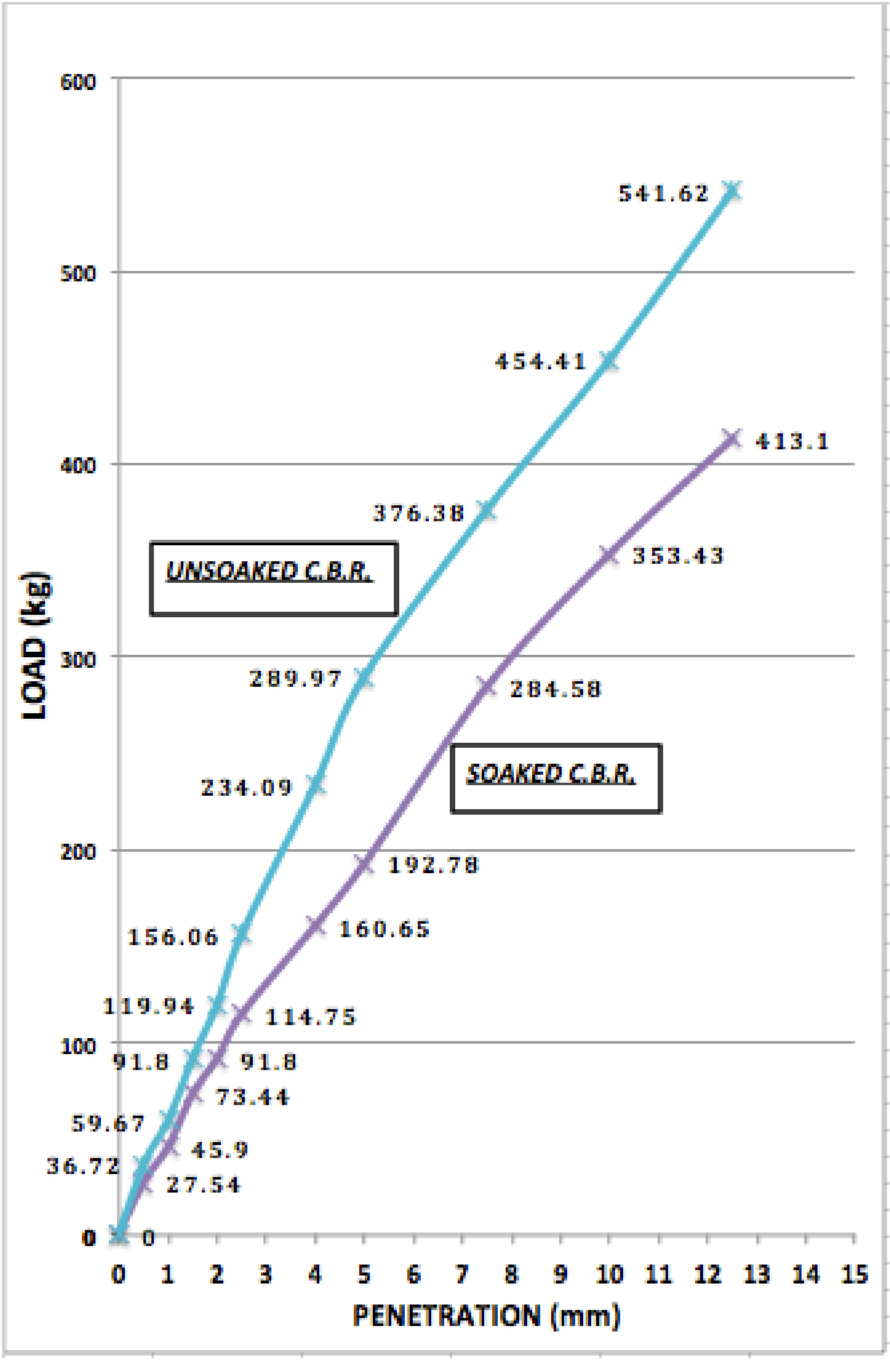


FIGURE 3: CALIFORNIA BEARING RATIO (100% Sand) SAMPLE:1

CALIFORNIA BEARING RATIO TEST OF SAND

SAMPLE 2

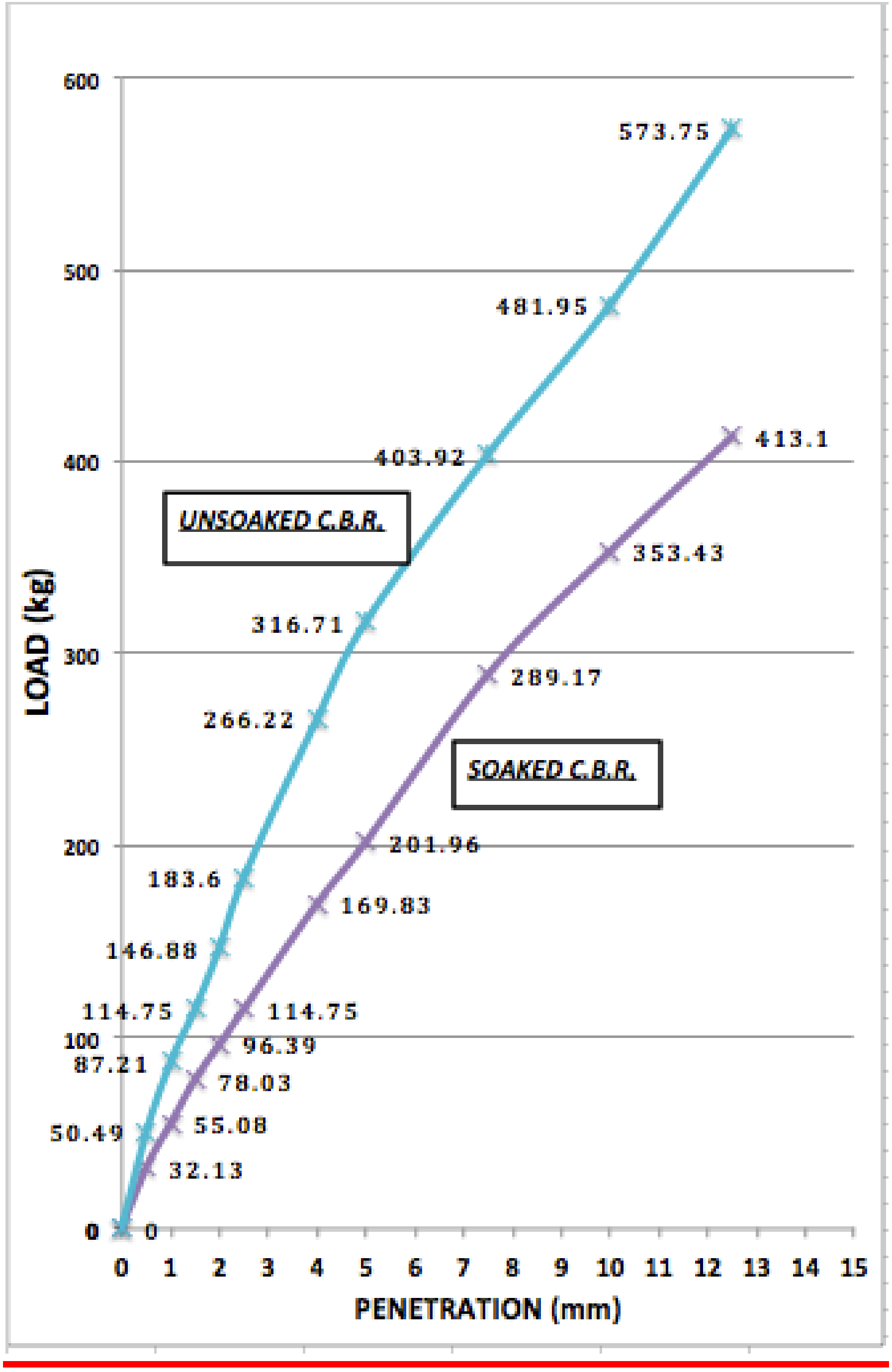


FIGURE 4: CALIFORNIA BEARING RATIO (100% Sand) SAMPLE:2

CALIFORNIA BEARING RATIO TEST OF SAND

SAMPLE 3

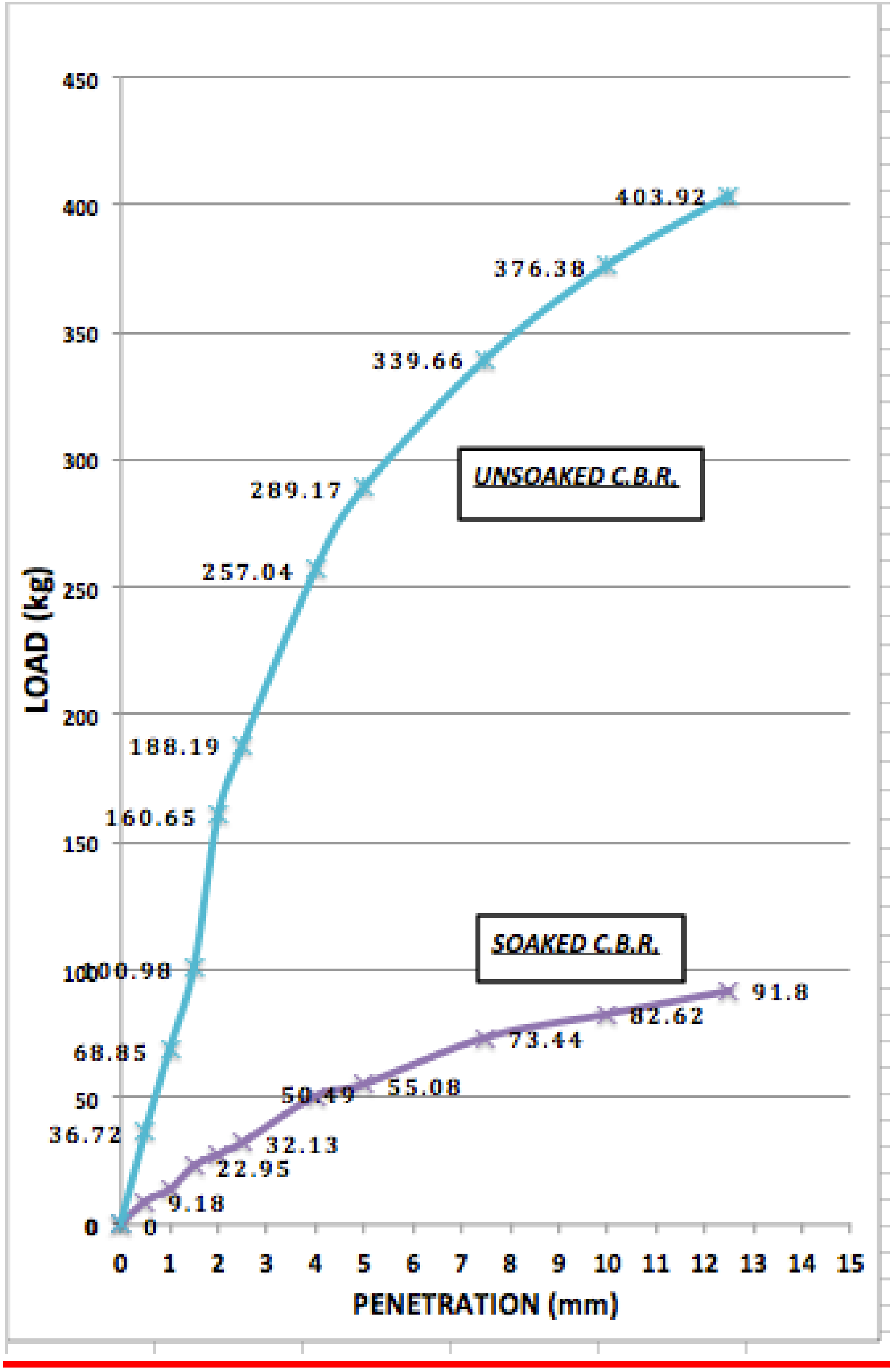


FIGURE 5: CALIFORNIA BEARING RATIO (100% Sand) SAMPLE:3

California Bearing Ratio (100% Sand) Sample: 1

UNSOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	156.06	1370	11.39%
2	5.0	289.97	2055	14.11%

Design value of CBR: 14.11%

SOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	114.75	1370	8.36%
2	5.0	192.78	2055	9.38%

Design value of CBR: 9.38%

California Bearing Ratio (100% Sand) Sample: 2

UNSOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	183.6	1370	13.40%
2	5.0	316.71	2055	15.41%

Design value of CBR: 15.41%

SOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	114.75	1370	8.38%
2	5.0	201.96	2055	9.83%

Design value of CBR: 9.83%

California Bearing Ratio (100% Sand) Sample: 3

UNSOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	156.06	1370	11.39%
2	5.0	289.97	2055	14.11%

Design value of CBR: 14.11%

SOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	110.16	1370	8.04%
2	5.0	188.19	2055	9.16%

Design value of CBR: 9.16%

SUMMARY OF THE TEST RESULTS CARRIED OUT FOR SAND

TABLE 4: SUMMARY OF TEST RESULTS CARRIED OUT FOR SAND.

PROPERTY OF THE SOIL	**RESULT**
Specific Gravity	**2.70**
Liquid Limit	**-**
Plastic Limit	**-**
Plasticity Index	**-**
I.S. Classification	**Silty Sand (SM)**
Maximum Dry Density	**2.02 grams/ cubic centimeters**
Optimum Moisture Content	**10.1%**
Unsoaked CBR value Sample – 1	**14.11 %**
Soaked CBR value Sample – 1	**9.38 %**
Unsoaked CBR value Sample – 2	**15.41 %**
Soaked CBR value Sample – 2	**9.83 %**
Unsoaked CBR value Sample – 3	**14.07 %**
Soaked CBR value Sample – 3	**9.16 %**
Unsoaked CBR value (Average)	**14.81 %**
Soaked CBR value (Average)	**9.46 %**

3.2.2 SOIL 2 – CLAY

The soil sample selected is obtained from a construction site in sector 17, Chandigarh. The foreign and vegetative materials were removed. Following are the results of various test carried out on the soil.

Following tests have been performed on the virgin soil

- Determination Of Specific Gravity
- Determination Of Liquid Limit
- Determination Of Plastic Limit
- Grain Size Analysis
- Hydrometer Analysis
- Modified Proctor Compaction Test
- California Bearing Ratio Test

1) DETERMINATION OF SPECIFIC GRAVITY

The Specific Gravity Of The Soil Was Found Out To Be 2.64 by Density Bottle method.

TABLE 5: SPECIFIC GRAVITY TEST OF CLAY

Weight of Density Bottle	W1	20.6 grams	20.6 grams	20.6 grams	20.6 grams
Weight of Density Bottle + dry soil	W2	120.6 grams	138.5 grams	128.5 grams	114.1 grams
Weight of Density Bottle + dry soil + water	W3	132.7grams	144.2 grams	138.1 grams	128.6 grams
Weight of Density Bottle + water	W4	70.8 grams	70.8 grams	70.8 grams	70.8 grams
Specific Gravity	**S.G.**	**2.63**	**2.65**	**2.66**	**2.62**

$$\textit{SPECIFIC GRAVITY} = \frac{\boldsymbol{W2-W1}}{(\boldsymbol{W2-W1})-(\boldsymbol{W3-W4})}$$

$$\textit{AVERAGE SPECIFIC GRAVITY} = \frac{\mathbf{2.63+2.65+2.66+2.62}}{\mathbf{4}} = \mathbf{2.64}$$

2)DETERMINATION OF LIQUID LIMIT AND PLASTIC LIMIT

TABLE 6: ATTERBERG LIMITS

Liquid Limit	43.1%
Plastic Limit	23.3%
Plasticity Index	19.8%

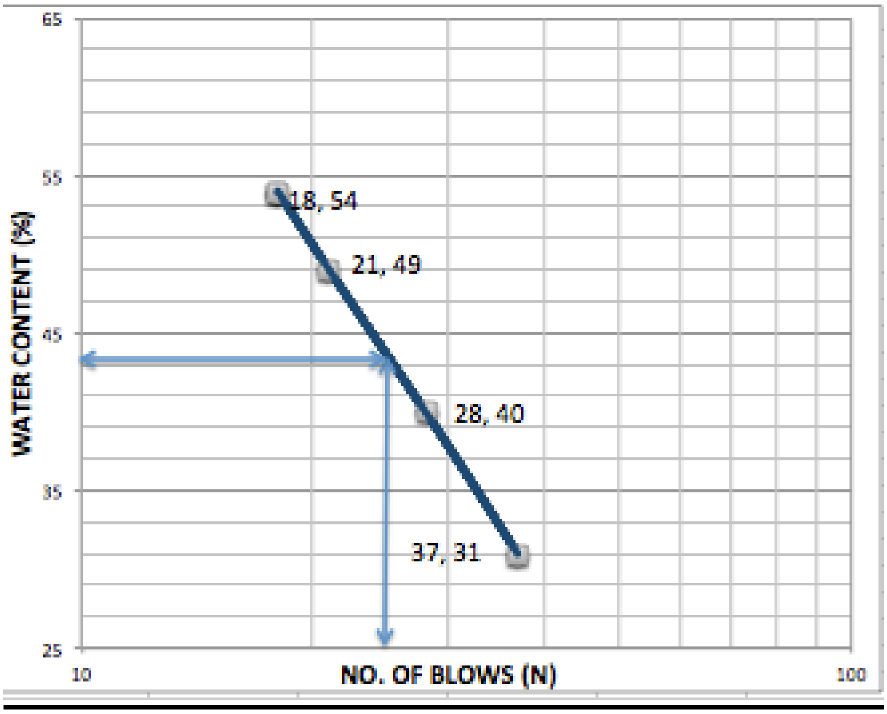


FIGURE 6: DETERMINATION OF LIQUID LIMIT OF CLAY

GRAIN SIZE ANALYSIS

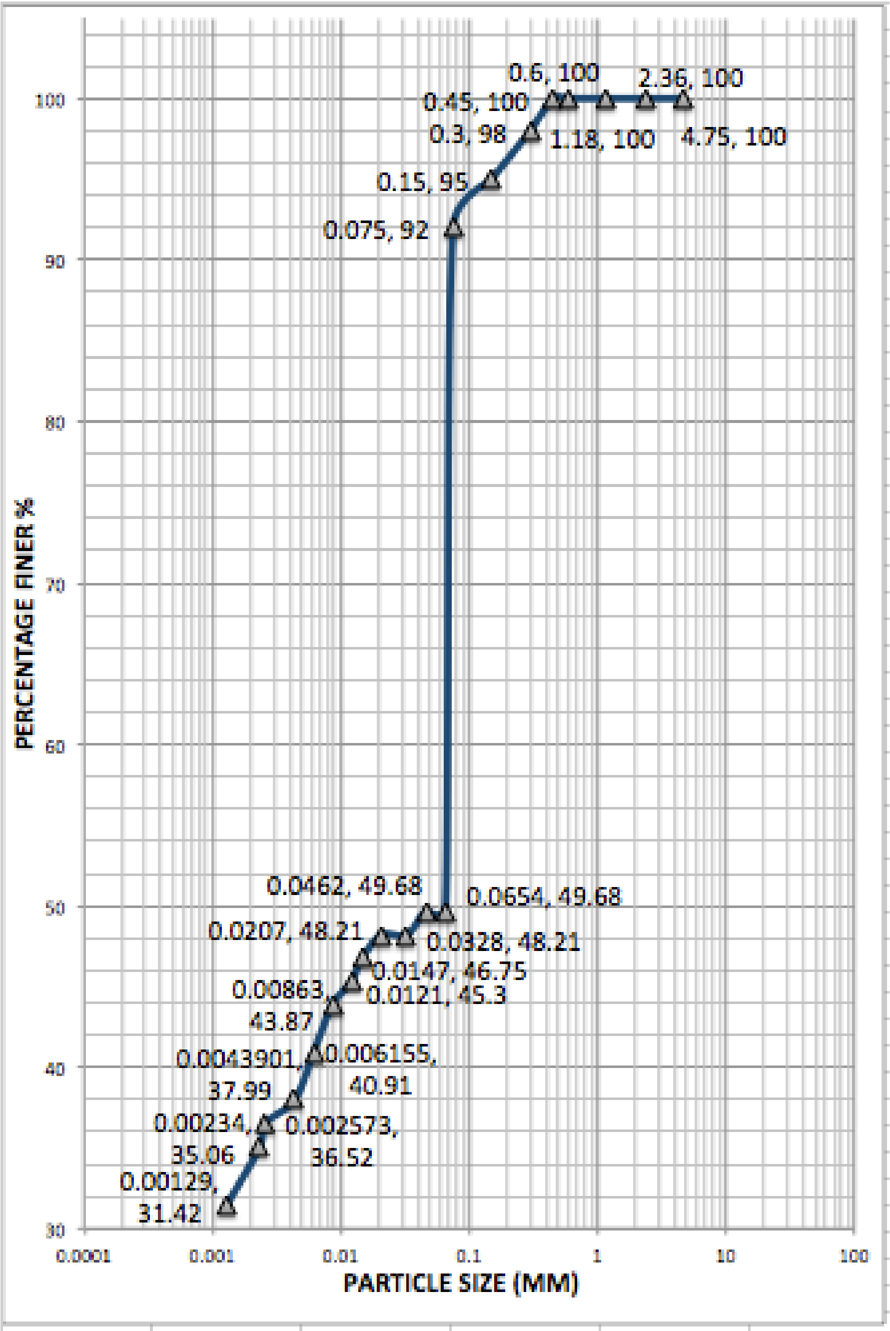


FIGURE 7: GRAIN SIZE ANALYSIS CURVE OF CLAY

PERCENTAGE OF SOIL PASSING 4.75 mm SIEVE: 100% (> 50%)
PERCENTAGE OF SOIL PASSING .075 mm SIEVE: 92% (>50%)
PLASTICITY INDEX: 19.8% (> 7)

Classification As Per Indian Standard Code (Is 2720: 1985 Part 4):
Clay Of Intermediate Plasticity (C.I.)

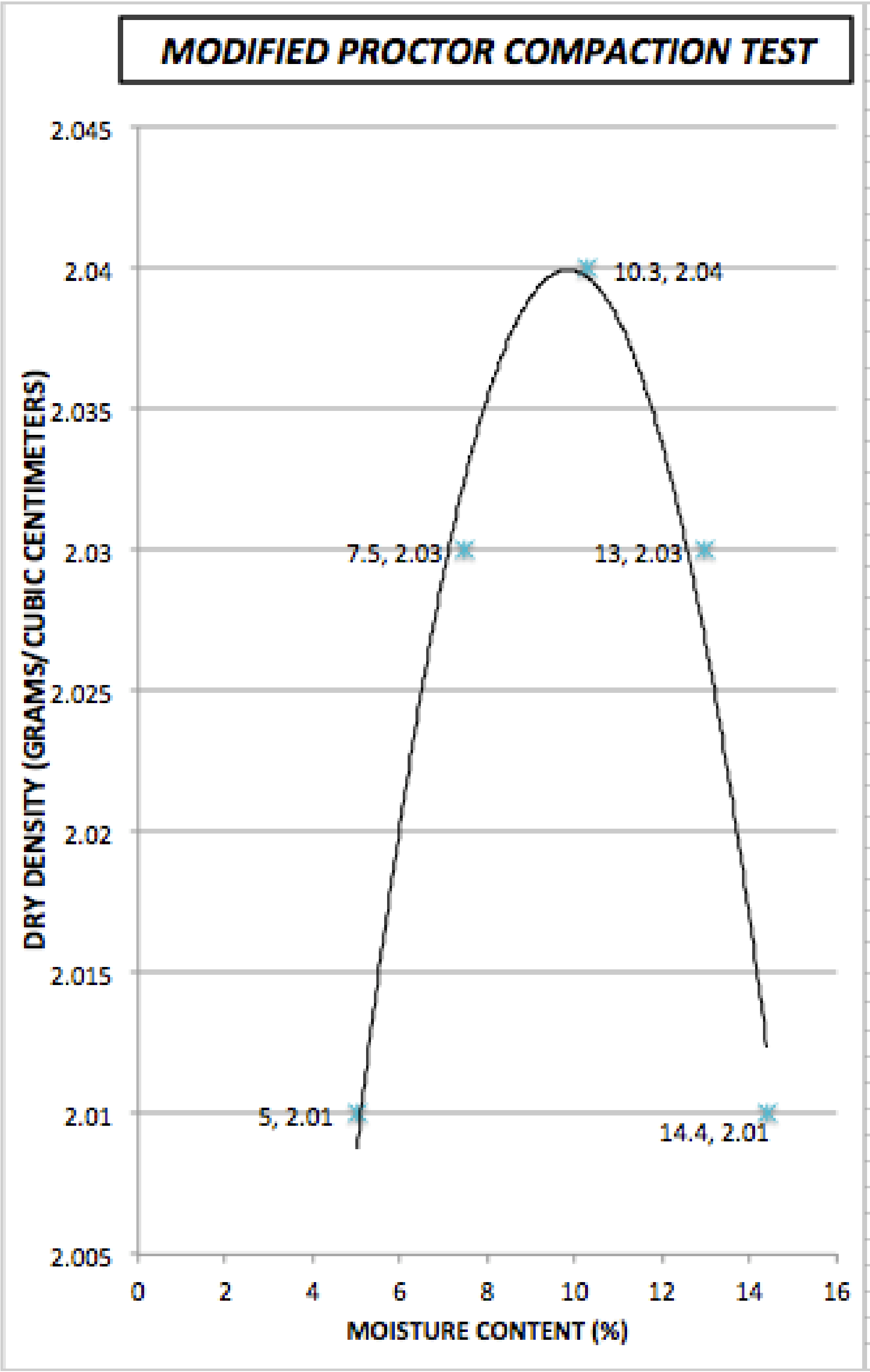


FIGURE 8: MODIFIED PROCTOR COMPACTION TEST OF CLAY

Maximum Dry Density	**2.04 grams/ cubic centimeters**
Optimum Moisture Content	**10.3%**

CALIFORNIA BEARING RATIO TEST OF CLAY

SAMPLE 1

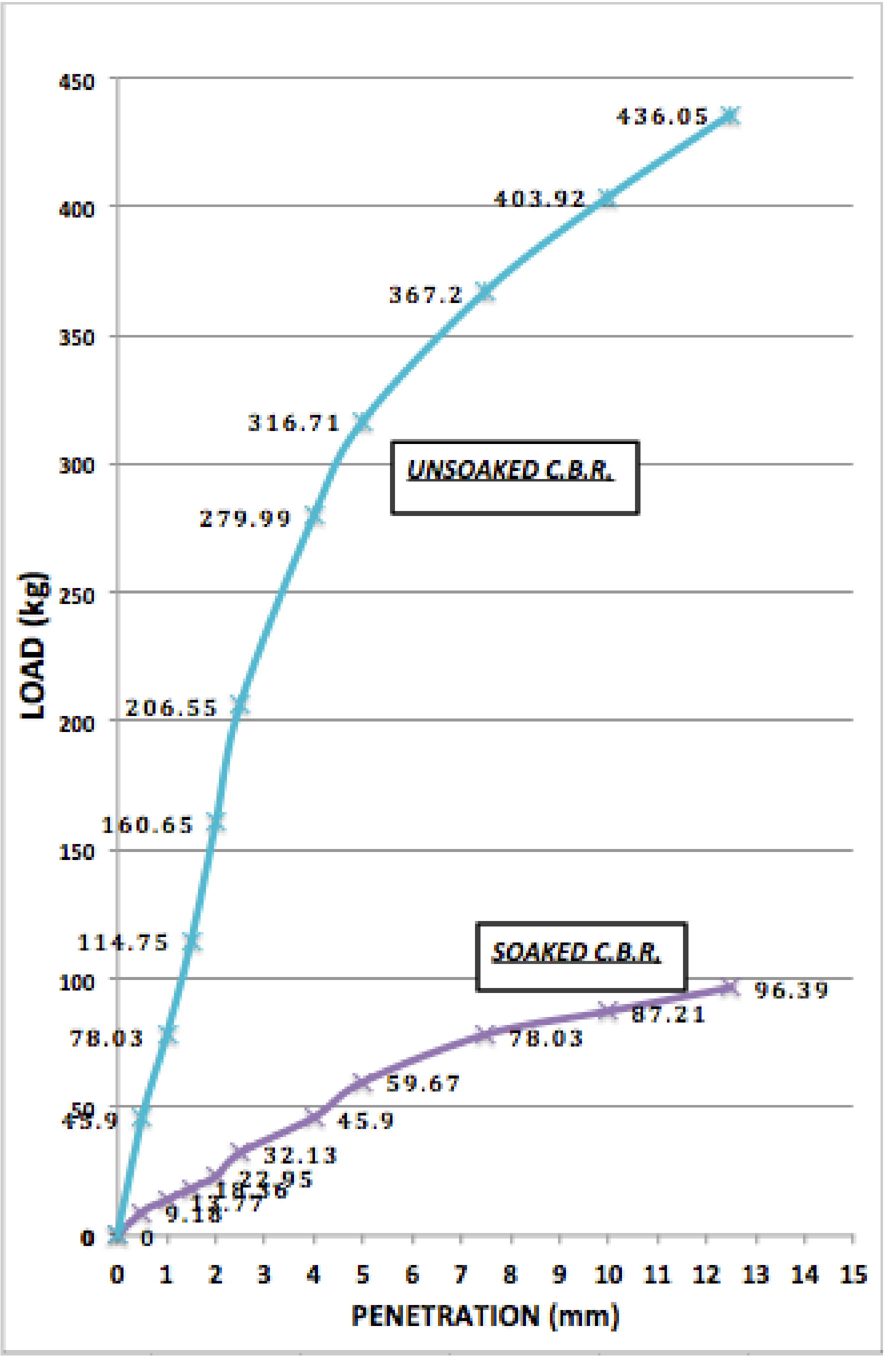


FIGURE 9: CALIFORNIA BEARING RATIO (100% CLAY) SAMPLE: 1

CALIFORNIA BEARING RATIO TEST OF CLAY

SAMPLE 2

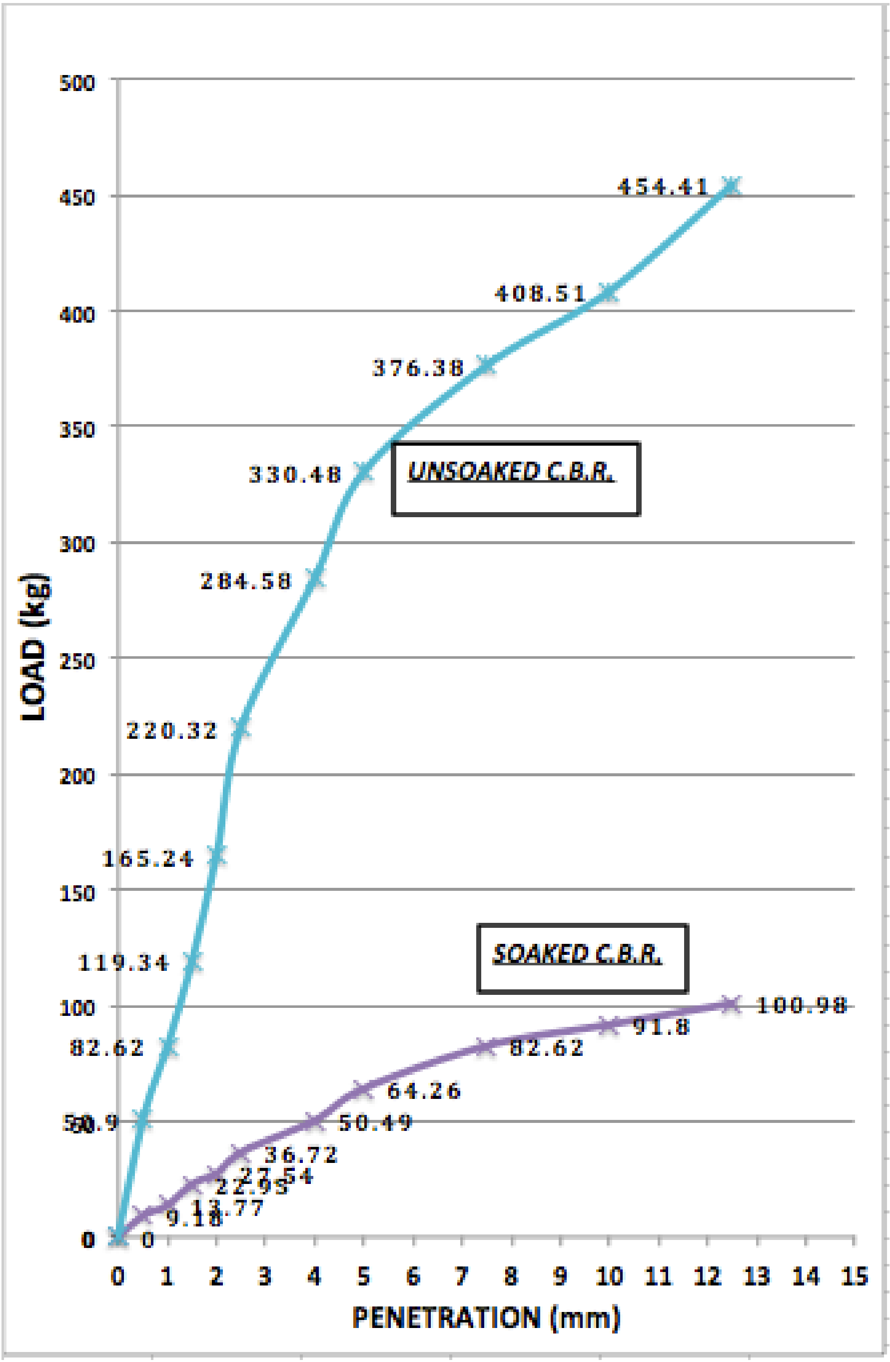


FIGURE 10: CALIFORNIA BEARING RATIO (100% CLAY) SAMPLE: 2

CALIFORNIA BEARING RATIO TEST OF CLAY

SAMPLE 3

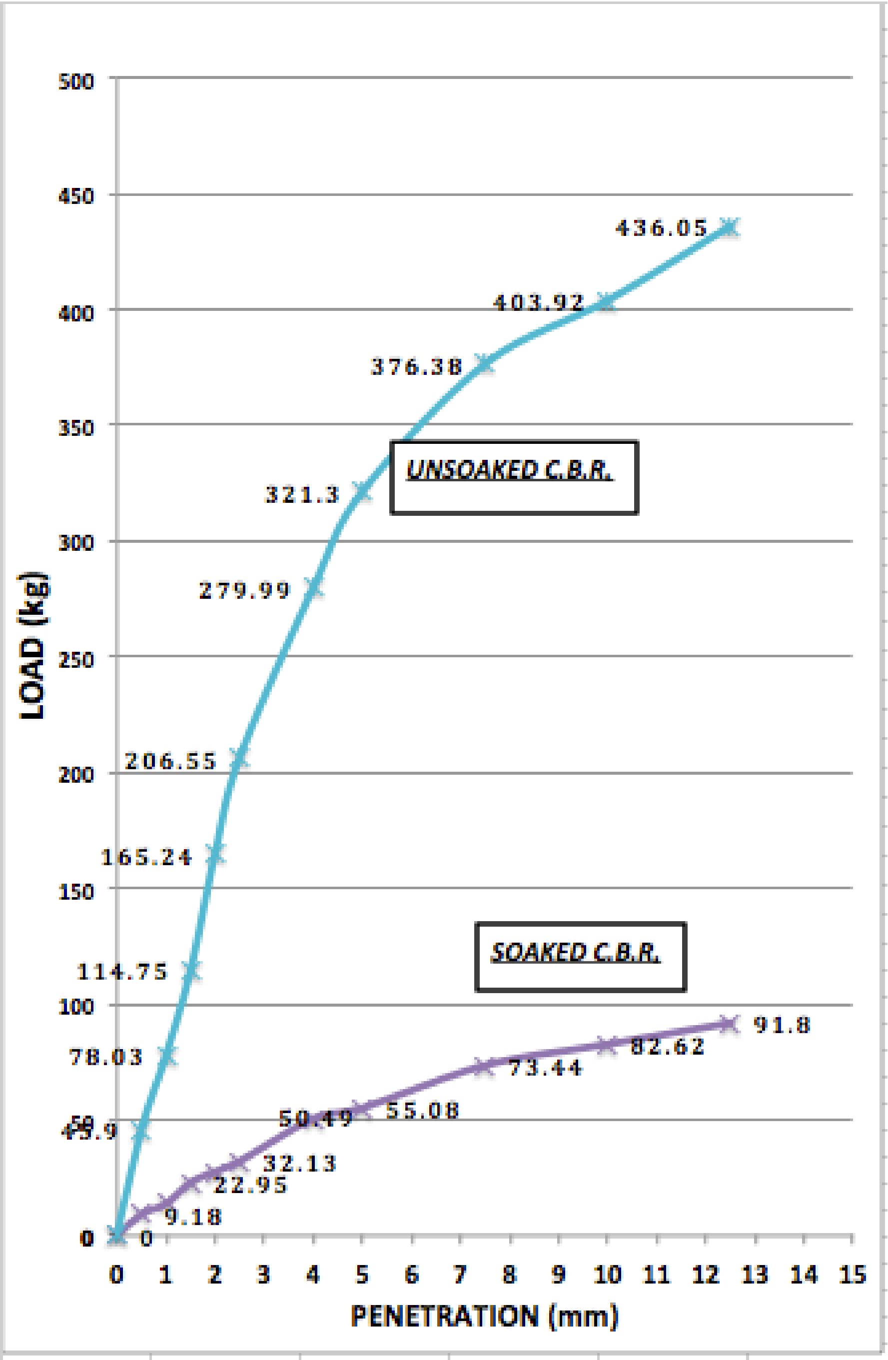


FIGURE 11: CALIFORNIA BEARING RATIO (100% CLAY) SAMPLE: 3

California Bearing Ratio (100% Clay) Sample: 1

UNSOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	206.55	1370	15.08%
2	5.0	316.71	2055	15.41%

Design value of CBR: 15.41%

SOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	32.13	1370	2.35%
2	5.0	59.67	2055	2.90%

Design value of CBR: 2.90%

California Bearing Ratio (100% Clay) Sample: 2

UNSOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	220.32	1370	16.08%
2	5.0	330.48	2055	16.08%

Design value of CBR: 16.08%

SOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	36.72	1370	2.68%
2	5.0	64.26	2055	3.13%

Design value of CBR: 3.13%

California Bearing Ratio (100% Clay) Sample: 3

UNSOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	206.55	1370	15.08%
2	5.0	321.3	2055	15.64%

Design value of CBR: 15.64%

SOAKED CBR

S. No.	Penetration of the piston (mm)	Load taken by sample	Standard load (Kg)	CBR value
1	2.5	32.13	1370	2.36%
2	5.0	55.08	2055	2.68%

Design value of CBR: 2.68%

SUMMARY OF THE TEST RESULTS CARRIED OUT FOR CLAY

TABLE 7: SUMMARY OF TEST RESULTS CARRIED OUT OF CLAY.

PROPERTY OF THE SOIL	RESULT
Specific Gravity	**2.63**
Liquid Limit	**43.1%**
Plastic Limit	**23.3%**
Plasticity Index	**19.8%**
I.S. Classification	**Clay of Intermediate Plasticity (C.I.)**
Maximum Dry Density	**2.04 grams/cubic centimeters**
Optimum Moisture Content	**10.3%**
Unsoaked CBR value Sample – 1	**2.90 %**
Soaked CBR value Sample – 1	**15.41 %**
Unsoaked CBR value Sample – 2	**3.13 %**
Soaked CBR value Sample – 2	**16.08 %**
Unsoaked CBR value Sample – 3	**2.68 %**
Unsoaked CBR value Sample – 1	**15.64 %**
Soaked CBR value (Average)	**2.90 %**
Unsoaked CBR value (Average)	**15.71 %**

CHAPTER-4

EXPERIMENTAL PROGRAMME

4.0 INTRODUCTION

In the following chapter description of methodology and experimental Programme has been given. Description of the procedure of the various tests has been stated. Details on proportioning ratio of various fibre in various soils are given.

4.1 TESTS CARRIED OUT FOR THE INVESTIGATION

Following tests have been carried out on various soils and various types of fibre.

- **Modified Proctor Compaction Test**
- **California Bearing Ratio Test**

4.2 METHODOLOGY

Modified Proctor Compaction Test

- This test is carried out on soil to determine the maximum dry density of soil and optimum moisture content of the soil.
- Effect of addition of fibre has been observed on the change in values of maximum dry density and optimum moisture content.
- A total of 40 modified proctor tests have been carried out.

California Bearing Ratio Test

- This test is carried out to determine the strength of the subgrade soil. CBR tests are carried out on Remoulded samples of soil at 97% of maximum dry density and optimum moisture content.
- CBR tests are performed strictly according to IS 2720: part 16.
- According to IRC 37:2012, the reproducibility of the CBR results is dependent on a number of factors and a wide variation in values can be expected.

- Therefore in order to avoid errors, at least three samples should be tested on each type of soil at same density and moisture content. To weed out erratic results, permissible maximum variation within the CBR values from three specimens is indicated below when the variation is more than the permissible variation, the design CBR should be the average of test results from at least six samples not three.

TABLE 8: PERMISSIBLE VARIATION IN CBR VALUE

CBR (Percentage)	Maximum Variation in CBR value
5	± 1
5-10	± 2
11-30	± 3
31 and above	± 5

- If the California Bearing Ratio Value of the subgrade is more than the minimum requirement for the sub-base, no sub-base is required.
- In the current investigation, improvement of California bearing ratio value of subgrade soil has been achieved by adding polyester fibre in various percentages by weight of soil as shown in the following tables.
- California Bearing Ratio test samples have been made at 97% of maximum dry density of soil and at moisture content equal to the optimum moisture content of the soil.

TABLE 9: TESTS FOR SILTY SAND WITH 6 mm POLYESTER FIBRE

S.No.	Type of soil (I. S. Classification)	Length of fibre	%age of fibre	Test Carried Out	Test Carried Out
1.	SM- Sand with appreciable amount of fines (Silt)	6 mm	0.05% 0.1 %	Modified proctor compaction test	California bearing ratio test (3samples)
2.	SM- Sand with appreciable amount of fines (Silt)	6 mm	0. 2 %	Modified proctor compaction test	California bearing ratio test (3samples)
3.	SM- Sand with appreciable amount of fines (Silt)	6 mm	0.3 %	Modified proctor compaction test	California bearing ratio test (3samples)
4.	SM- Sand with appreciable amount of fines (Silt)	6 mm	0.4 %	Modified proctor compaction test	California bearing ratio test (3samples)
5.	SM- Sand with appreciable amount of fines (Silt)	6 mm	0.5 %	Modified proctor compaction test	California bearing ratio test (3samples)
6.	SM- Sand with appreciable amount of fines (Silt)	6 mm	0.6 %	Modified proctor compaction test	California bearing ratio test (3samples)
7.	SM- Sand with appreciable amount of fines (Silt)	6 mm	0.7 %	Modified proctor compaction test	California bearing ratio test (3samples)
8.	SM- Sand with appreciable amount of fines (Silt)	6 mm	0.8 %	Modified proctor compaction test	California bearing ratio test (3samples)
9.	SM- Sand with appreciable amount of fines (Silt)	6 mm	0.9 %	Modified proctor compaction test	California bearing ratio test (3samples)
10.	SM- Sand with appreciable amount of fines (Silt)	6 mm	1.0 %	Modified proctor compaction test	California bearing ratio test (3samples)

TABLE 10: TESTS FOR SILTY SAND WITH 12 mm POLYESTER FIBRE

S.No.	Type of soil (I. S. Classification)	Length of fibre	%age of fibre	Test Carried Out	Test Carried Out
1.	SM- Sand with appreciable amount of fines (Silt)	12 mm	0.1 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)
2.	SM- Sand with appreciable amount of fines (Silt)	12 mm	0.2 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)
3.	SM- Sand with appreciable amount of fines (Silt)	12 mm	0.3 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)
4.	SM- Sand with appreciable amount of fines (Silt)	12 mm	0.4 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)
5.	SM- Sand with appreciable amount of fines (Silt)	12 mm	0.5 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)
6.	SM- Sand with appreciable amount of fines (Silt)	12 mm	0.6 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)
7.	SM- Sand with appreciable amount of fines (Silt)	12 mm	0.7 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)
8.	SM- Sand with appreciable amount of fines (Silt)	12 mm	0.8 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)
9.	SM- Sand with appreciable amount of fines (Silt)	12 mm	0.9 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)
10.	SM- Sand with appreciable amount of fines (Silt)	12 mm	1.0 %	Modified Proctor Compaction Test	California Bearing Ratio Test (3samples)

TABLE 11: TESTS FOR CLAY WITH 6 mm POLYESTER FIBRE

S.No.	Type of soil (I. S. Classification)	Length of fibre	%age of fibre	Test Carried out	Test Carried out
1.	CI-Clay of intermediate plasticity.	6 mm	0.05% 0.1 %	Modified proctor compaction test	California bearing ratio test (3samples)
2.	CI-Clay of intermediate plasticity.	6 mm	0.2 %	Modified proctor compaction test	California bearing ratio test (3samples)
3.	CI-Clay of intermediate plasticity.	6 mm	0.3 %	Modified proctor compaction test	California bearing ratio test (3samples)
4.	CI-Clay of intermediate plasticity.	6 mm	0.4 %	Modified proctor compaction test	California bearing ratio test (3samples)
5.	CI-Clay of intermediate plasticity.	6 mm	0.5 %	Modified proctor compaction test	California bearing ratio test (3samples)
6.	CI-Clay of intermediate plasticity.	6 mm	0.6 %	Modified proctor compaction test	California bearing ratio test (3samples)
7.	CI-Clay of intermediate plasticity.	6 mm	0.7 %	Modified proctor compaction test	California bearing ratio test (3samples)
8.	CI-Clay of intermediate plasticity.	6 mm	0.8 %	Modified proctor compaction test	California bearing ratio test (3samples)
9.	CI-Clay of intermediate plasticity.	6 mm	0.9 %	Modified proctor compaction test	California bearing ratio test (3samples)
10.	CI-Clay of intermediate plasticity.	6 mm	1.0 %	Modified proctor compaction test	California bearing ratio test (3samples)

TABLE 12: TESTS FOR CLAY WITH 12 mm POLYESTER FIBRE

S.No.	Type of soil (I. S. Classification)	Length of fibre	%age of fibre	Test Carried out	Test Carried out
1.	CI-Clay of intermediate plasticity.	12 mm	0.1 %	Modified proctor compaction test	California bearing ratio test (3samples)
2.	CI-Clay of intermediate plasticity.	12 mm	0.2 %	Modified proctor compaction test	California bearing ratio test (3samples)
3.	CI-Clay of intermediate plasticity.	12 mm	0.3 %	Modified proctor compaction test	California bearing ratio test (3samples)
4.	CI-Clay of intermediate plasticity.	12 mm	0.4 %	Modified proctor compaction test	California bearing ratio test (3samples)
5.	CI-Clay of intermediate plasticity.	12 mm	0.5 %	Modified proctor compaction test	California bearing ratio test (3samples)
6.	CI-Clay of intermediate plasticity.	12 mm	0.6 %	Modified proctor compaction test	California bearing ratio test (3samples)
7.	CI-Clay of intermediate plasticity.	12 mm	0.7 %	Modified proctor compaction test	California bearing ratio test (3samples)
8.	CI-Clay of intermediate plasticity.	12 mm	0.8 %	Modified proctor compaction test	California bearing ratio test (3samples)
9.	CI-Clay of intermediate plasticity.	12 mm	0.9 %	Modified proctor compaction test	California bearing ratio test (3samples)
10.	CI-Clay of intermediate plasticity.	12 mm	1.0 %	Modified proctor compaction test	California bearing ratio test (3samples)

CHAPTER-5

RESULTS AND ANALYSIS

5.0 INTRODUCTION

In the following chapter, variations in results have been shown of the various tests that have been carried out.

This chapter consists of 4 sub-chapters namely,

- **Chapter 5.1:** Graphs showing variation in Modified Proctor Compaction Test results.
- **Chapter 5.2:** Graphs showing variation in California Bearing Ratio Test results.
- **Chapter 5.3:** Graphs showing the effect of fibre length on various tests that have been carried out.
- **Chapter 5.4:** Graphs showing mathematical relation between percentage gain of California bearing ratio and amount of polyester fibre (in percentage) required to attain that gain in strength of CBR value.

Graphs showing variation of results have been provided for each test. Initially results for sand are stated followed by clay. For each type of soil, first 6 mm fibres test results are shown and then 12 mm fibre test results.

5.1 Graphs Showing Variation In Modified Proctor Compaction Test Results

In this chapter following graphs have been shown

- Figure 12: Variation of Maximum Dry Density of Sand with 6 mm Polyester Fibre
- Figure 13: Variation of Optimum Moisture Content of Sand with 6 mm Polyester Fibre
- Figure 14: Variation of Maximum Dry Density of Sand with 12 mm Polyester Fibre
- Figure 15: Variation of Optimum Moisture Content of Sand with 12 mm Polyester Fibre
- Figure 16: Variation of Maximum Dry Density of Clay with 6 mm Polyester Fibre
- Figure 17: Variation of Optimum Moisture Content of Clay with 6 mm Polyester Fibre
- Figure 18: Variation of Maximum Dry Density of Clay with 12 mm Polyester Fibre
- Figure 19: Variation of Optimum Moisture Content of Clay with 12 mm Polyester Fibre

5.1.1 Effect of fibre length on Maximum Dry Density of Sand

On addition of fibre to sand, there was and initial rise in the maximum dry density of soil followed by a fall.

For 6 mm length fibre, the maximum value of 2.07-grams/ cu. Centimeter was observed at 0.3% polyester fibre. The least value of 2.00-grams/ cu. Centimeter was observed at 1.0% polyester fibre.

For 12 mm length fibre, the maximum value of 2.06-grams/ cu. Centimeter was observed at 0.3% polyester fibre. The least value of 1.99-grams/ cu. Centimeter was observed at 1.0% polyester fibre.

5.1.2 Effect of fibre length on Optimum Moisture Content of Sand

On addition of fibre to sand, there was and gradually rise in the optimum moisture content of soil.

For 6 mm length fibre, the maximum value of 12.2% optimum moisture content was observed at 1.0% polyester fibre.

For 12 mm length fibre, the maximum value of 12.4% optimum moisture content was observed at 1.0% polyester fibre.

TABLE 13: VARIATION OF MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT OF SAND WITH PERCENTAGE FIBRE CONTENT (6 mm)

S. No.	Percentage of fibre	Maximum Dry Density (grams/cu. centimeter)	Optimum Moisture Content (%)
1	0.0%	2.02	9.1
2	0.1%	2.04	9.2
3	0.2%	2.05	9.4
4	0.3%	2.07	9.6
5	0.4%	2.06	9.9
6	0.5%	2.06	10.2
7	0.6%	2.04	10.5
8	0.7%	2.03	10.9
9	0.8%	2.03	11.3
10	0.9%	2.01	11.8
11	1.0%	2.00	12.2

VARIATION OF MAXIMUM DRY DENSITY OF SAND WITH 6 mmPOLYESTER FIBRE

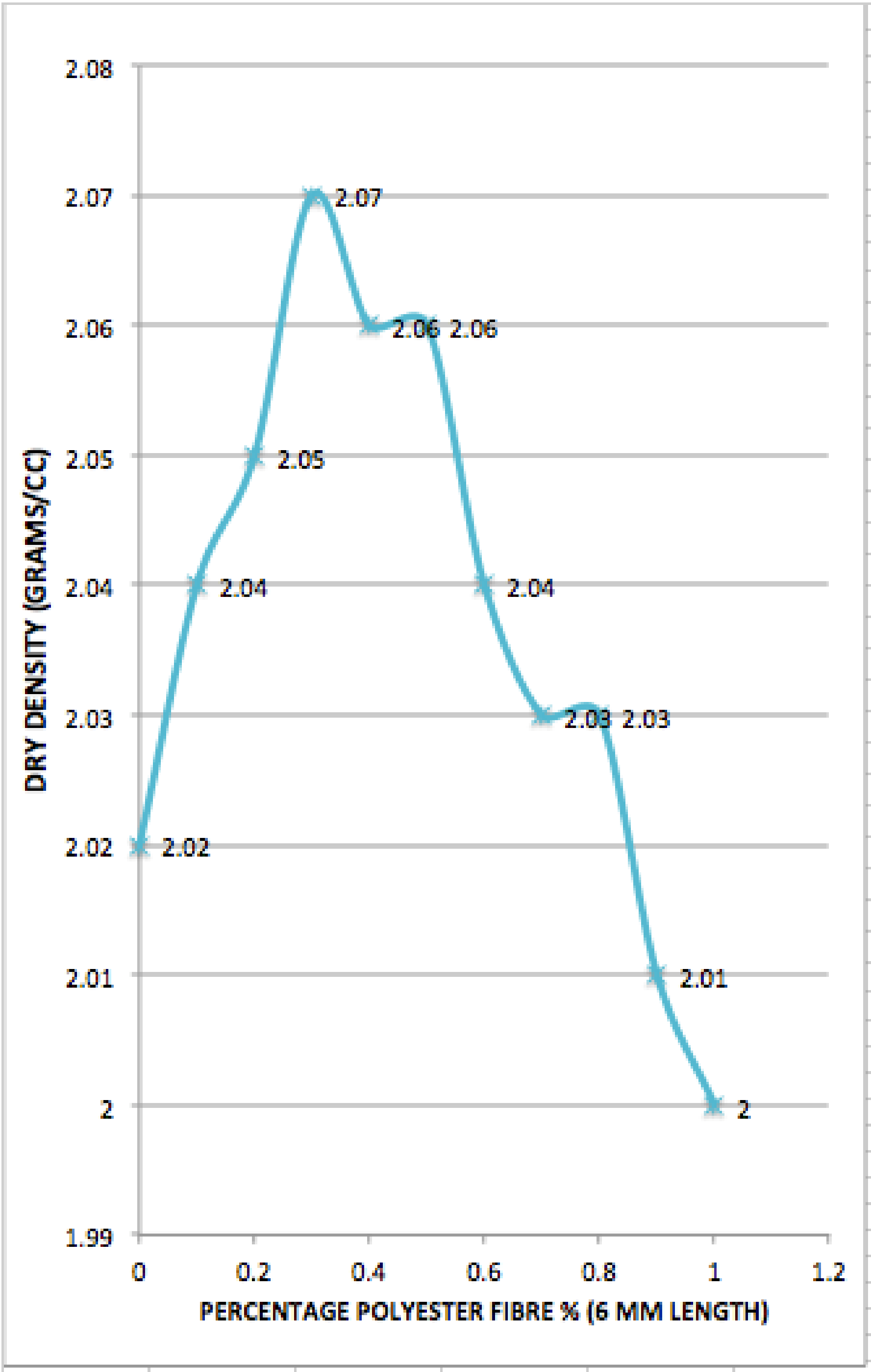


FIGURE 12: VARIATION OF MAXIMUM DRY DENSITY OF SAND WITH 6 mmPOLYESTER FIBRE

VARIATION OF OPTIMUM MOISTURE CONTENT OF SAND WITH 6 mmPOLYESTER FIBRE

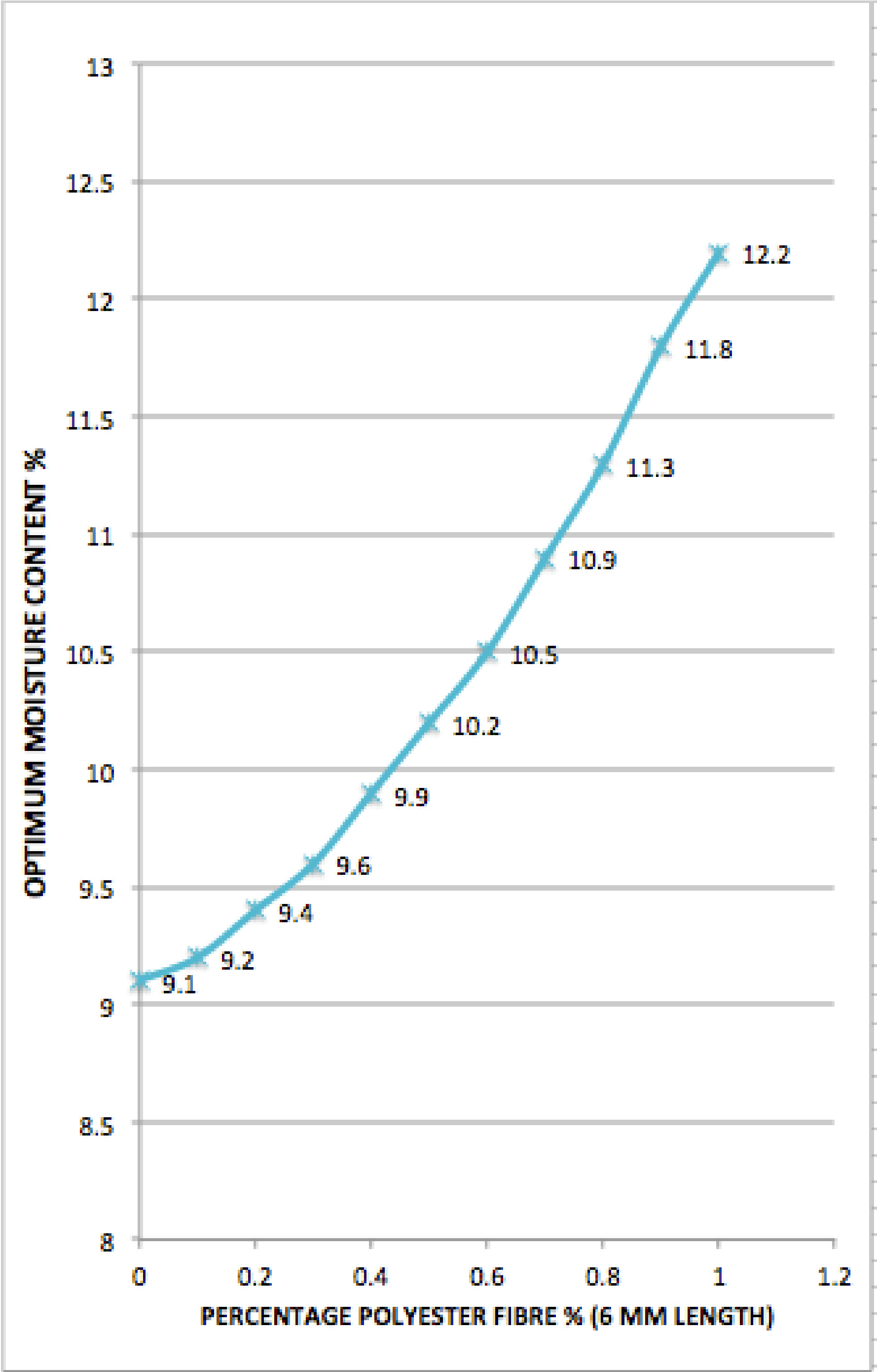


FIGURE 13: VARIATION OF OPTIMUM MOISTURE CONTENT OF SAND WITH 6 mmPOLYESTER FIBRE

TABLE 14: VARIATION OF MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT OF SAND WITH PERCENTAGE FIBRE CONTENT (12 mm)

S. No.	Percentage of fibre	Maximum Dry Density (grams/cu. centimeter)	Optimum Moisture Content (%)
1	0.0%	2.02	9.1
2	0.1%	2.04	9.3
3	0.2%	2.05	9.5
4	0.3%	2.06	9.7
5	0.4%	2.04	10.0
6	0.5%	2.04	10.3
7	0.6%	2.02	10.6
8	0.7%	2.02	11.0
9	0.8%	2.01	11.4
10	0.9%	1.99	11.9
11	1.0%	1.99	12.4

VARIATION OF MAXIMUM DRY DENSITY OF SAND WITH 12 mmPOLYESTER FIBRE

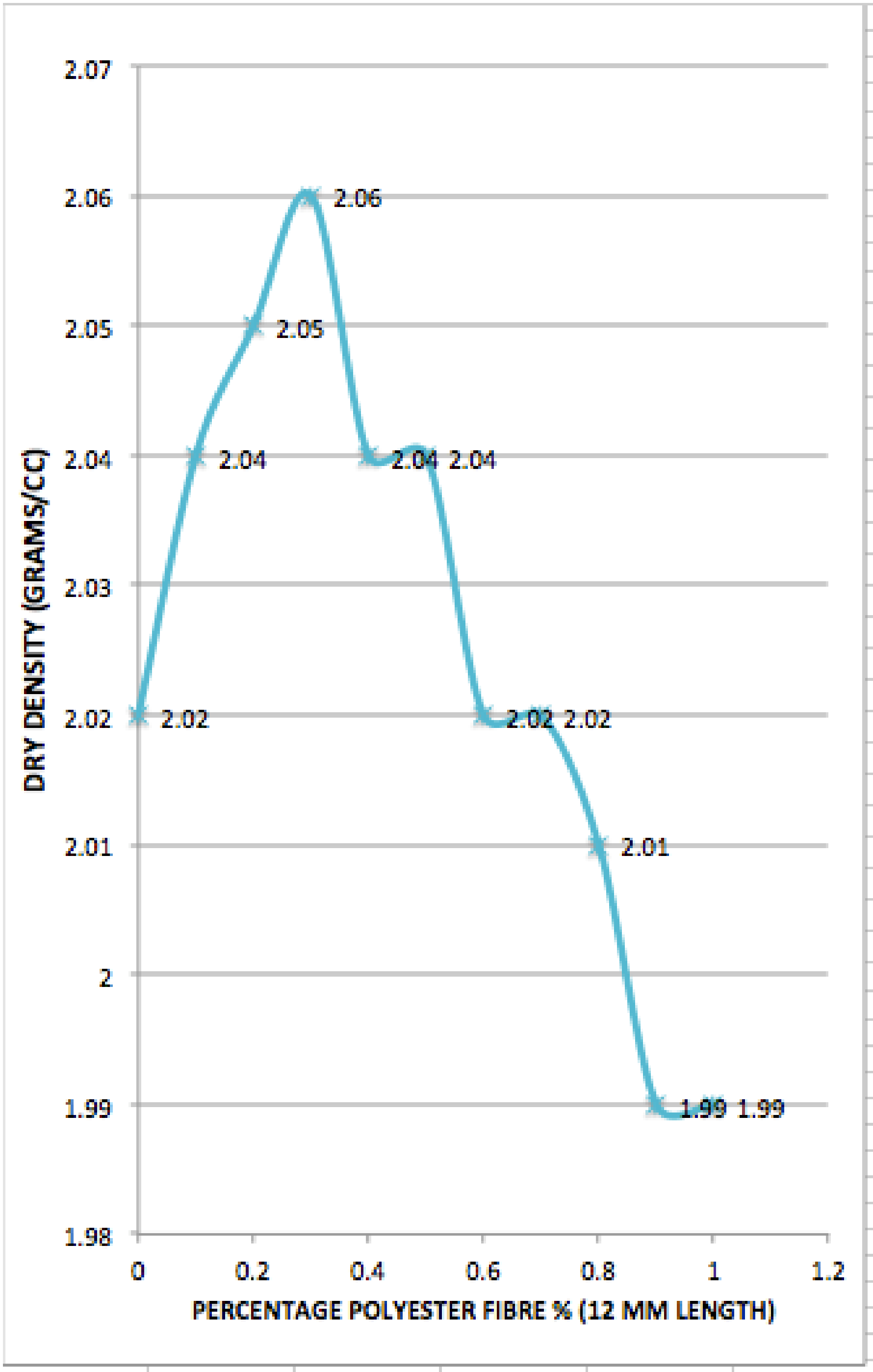


FIGURE 14: VARIATION OF MAXIMUM DRY DENSITY OF SAND WITH 12 mmPOLYESTER FIBRE

VARIATION OF OPTIMUM MOISTURE CONTENT OF SAND WITH 12 mmPOLYESTER FIBRE

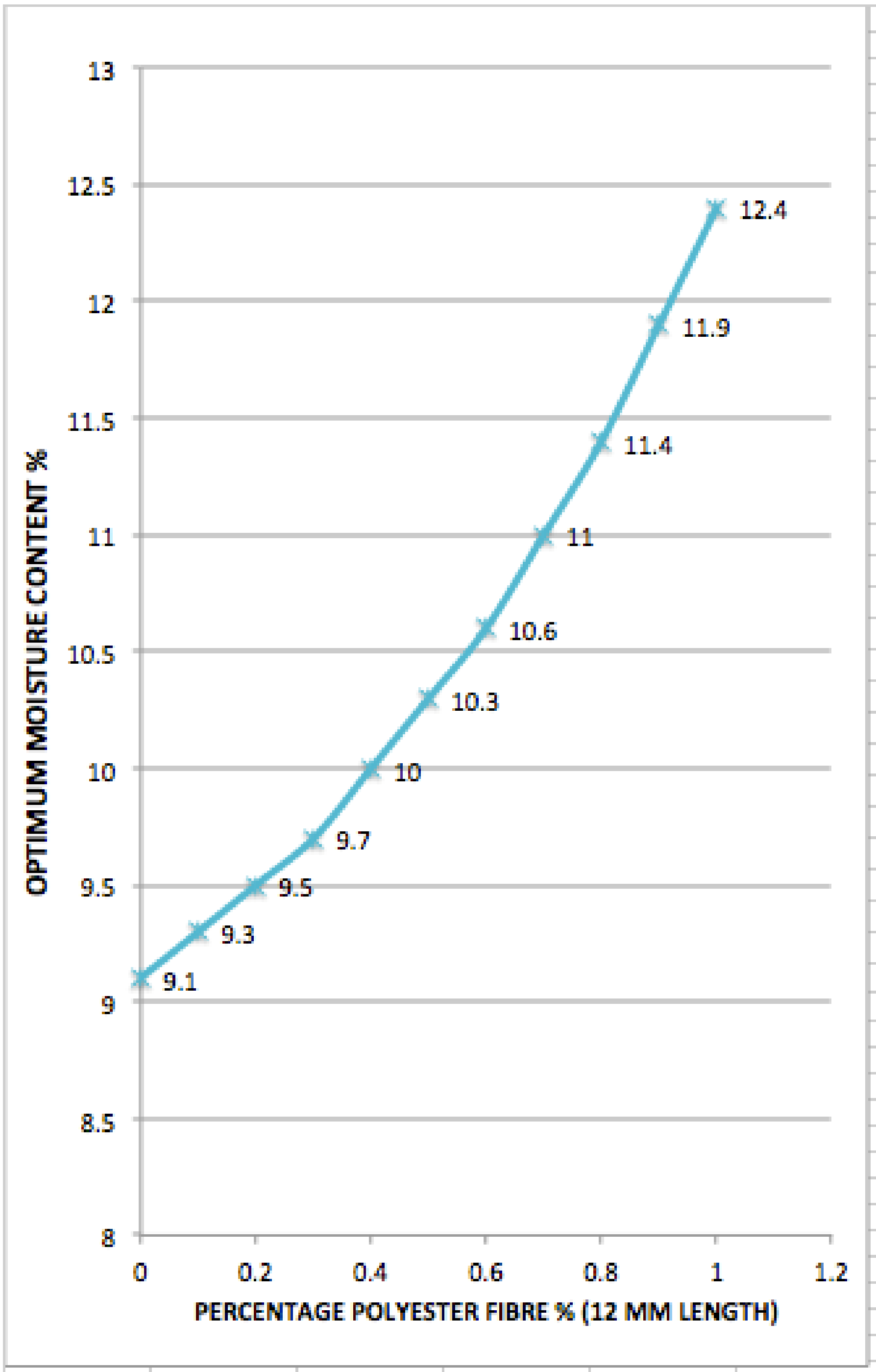


FIGURE 15: VARIATION OF OPTIMUM MOISTURE CONTENT OF SAND WITH 12 mmPOLYESTER FIBRE

5.1.3 Effect of fibre length on Maximum Dry Density of Clay

On addition of fibre to clay, there was no change in the maximum dry density for a few initial proportions of polyester fibre. There was a small fall in maximum dry density when higher proportions of fibre were added.

For 6 mm length fibre, the maximum value of 2.04-grams/ cu. Centimeter was observed at 0.0% polyester fibre. There was no change in the maximum dry density of soil upto addition of fibre of 0.4% by weight. The maximum dry density fell to 2.03-grams/ cu. Centimeter for 0.5%, 0.6%, and 0.7% of polyester fibre. The maximum dry density fell to 2.02-grams/ cu. Centimeter for 0.8%, 0.9%, and 1.0% of polyester fibre.

For 12 mm length fibre, the maximum value of 2.04-grams/ cu. Centimeter was observed at 0.0% polyester fibre. There was no change in the maximum dry density of soil upto addition of fibre of 0.3% by weight. The maximum dry density fell to 2.03-grams/ cu. Centimeter for 0.4%, 0.5%, and 0.6% of polyester fibre. The maximum dry density fell to 2.02-grams/ cu. Centimeter for 0.7% and 0.8% of polyester fibre. The maximum dry density fell to 2.01-grams/ cu. Centimeter for 0.9% and 1.0% of polyester fibre.

5.1.4 Effect of fibre length on Optimum Moisture Content of Clay

On addition of fibre to clay, there was and small gradually rise in the optimum moisture content of soil.

For 6 mm length fibre, the maximum value of 11.4% optimum moisture content was observed at 1.0% polyester fibre.

For 12 mm length fibre, the maximum value of 11.5% optimum moisture content was observed at 1.0% polyester fibre.

TABLE 15: VARIATION OF MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT OF CLAY WITH PERCENTAGE FIBRE CONTENT (6 mm)

S. No.	Percentage of fibre	Maximum Dry Density (grams/cu. centimeter)	Optimum Moisture Content (%)
1	0.0%	2.04	10.3
2	0.1%	2.04	10.4
3	0.2%	2.04	10.5
4	0.3%	2.04	10.5
5	0.4%	2.04	10.6
6	0.5%	2.03	10.7
7	0.6%	2.03	10.8
8	0.7%	2.03	10.9
9	0.8%	2.02	11.0
10	0.9%	2.02	11.2
11	1.0%	2.02	11.4

VARIATION OF MAXIMUM DRY DENSITY OF CLAY WITH 6 mmPOLYESTER FIBRE

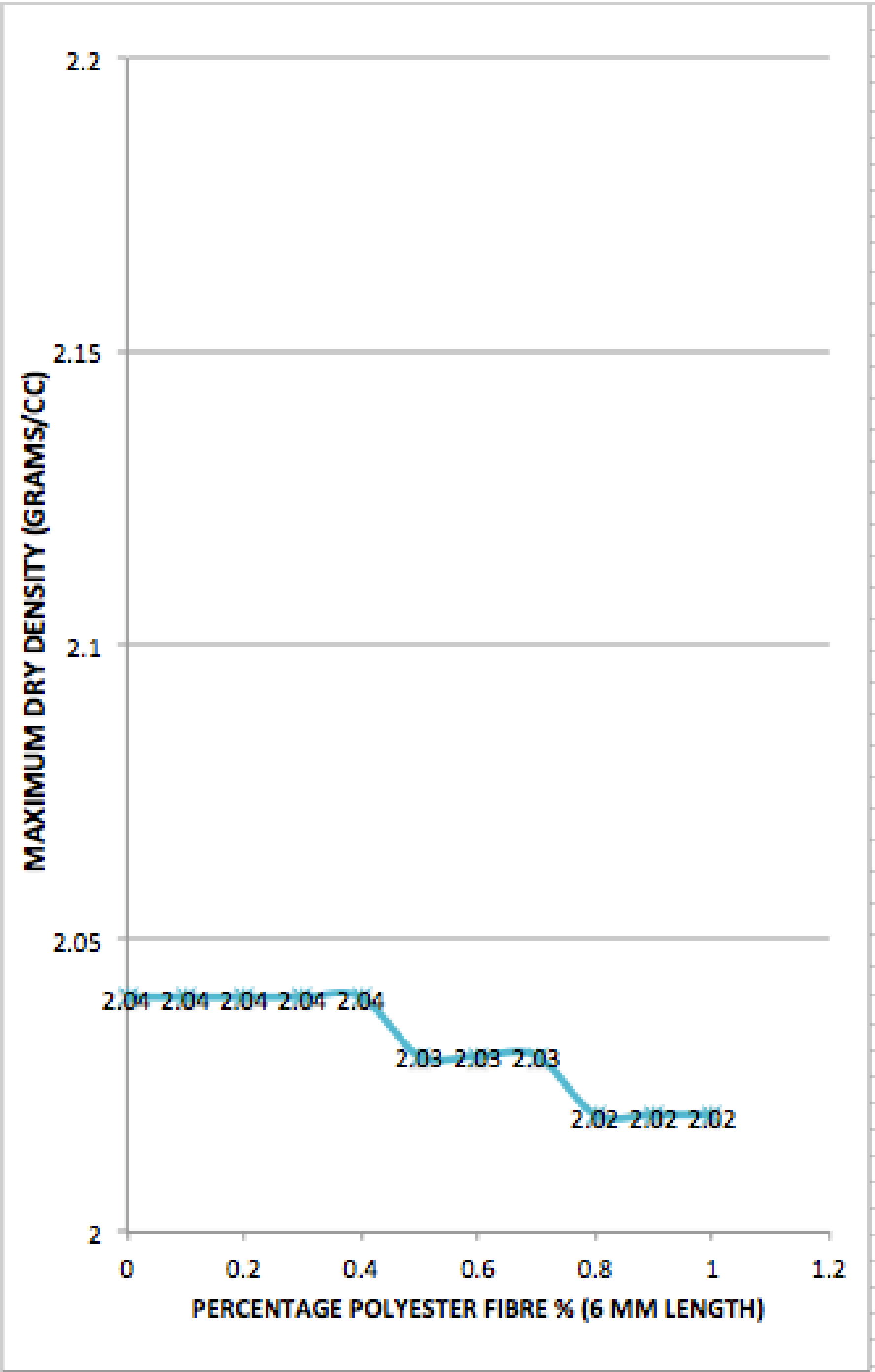


FIGURE 16: VARIATION OF MAXIMUM DRY DENSITY OF CLAY WITH 6 mmPOLYESTER FIBRE

VARIATION OF OPTIMUM MOISTURE CONTENT OF CLAY WITH 6 mmPOLYESTER FIBRE

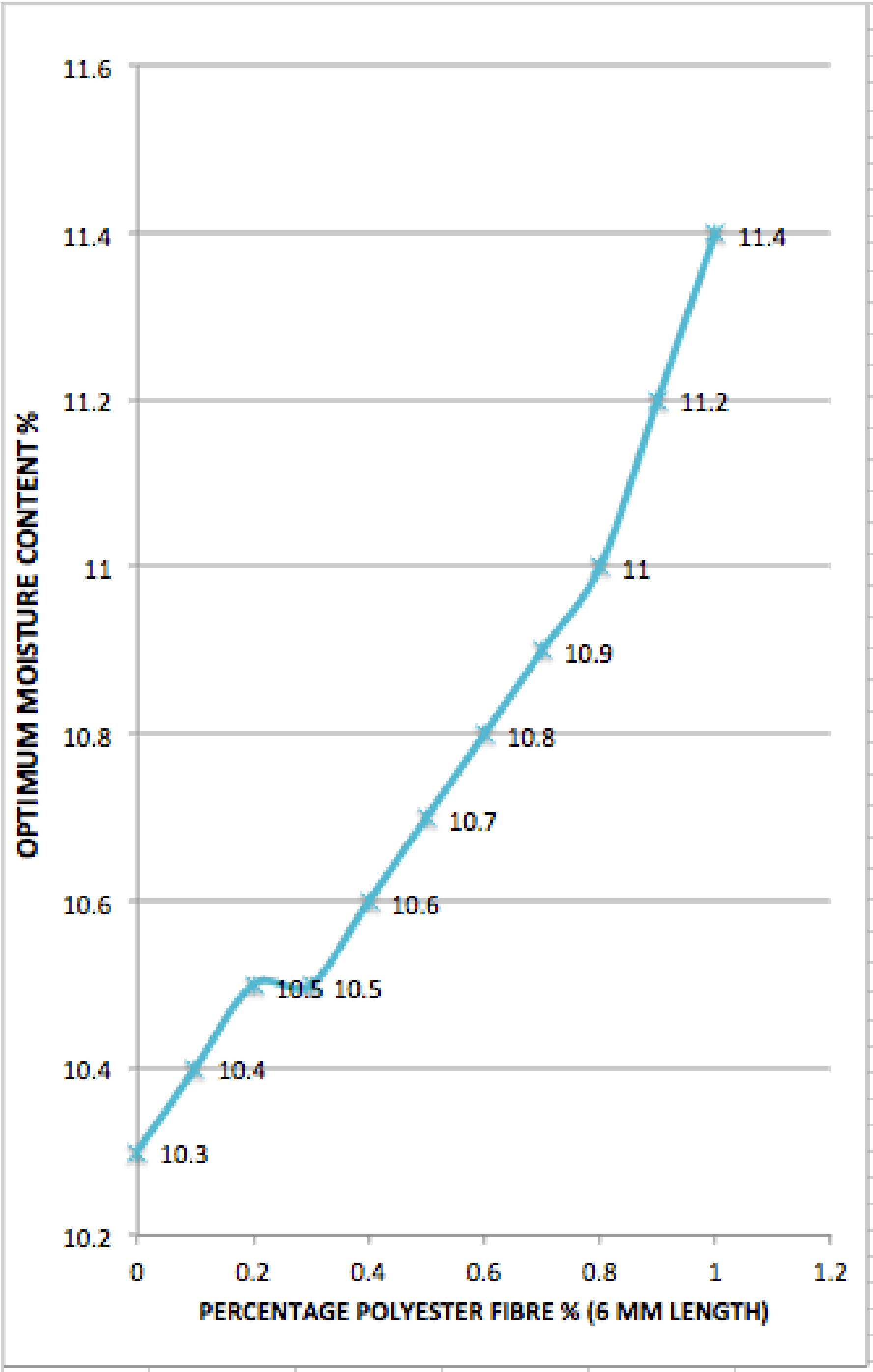


FIGURE 17: VARIATION OF OPTIMUM MOISTURE CONTENT OF CLAY WITH 6 mmPOLYESTER FIBRE

TABLE 16: VARIATION OF MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT OF CLAY WITH PERCENTAGE FIBRE CONTENT (12 mm)

S. No.	Percentage of fibre	Maximum Dry Density (grams/cu. centimeter)	Optimum Moisture Content (%)
1	0.0%	2.04	10.3
2	0.1%	2.04	10.4
3	0.2%	2.04	10.5
4	0.3%	2.04	10.6
5	0.4%	2.03	10.7
6	0.5%	2.03	10.8
7	0.6%	2.03	10.9
8	0.7%	2.02	10.9
9	0.8%	2.02	11.1
10	0.9%	2.01	11.3
11	1.0%	2.01	11.5

VARIATION OF MAXIMUM DRY DENSITY Ob F CLAY

WITH 12 mm POLYESTER FIBRE

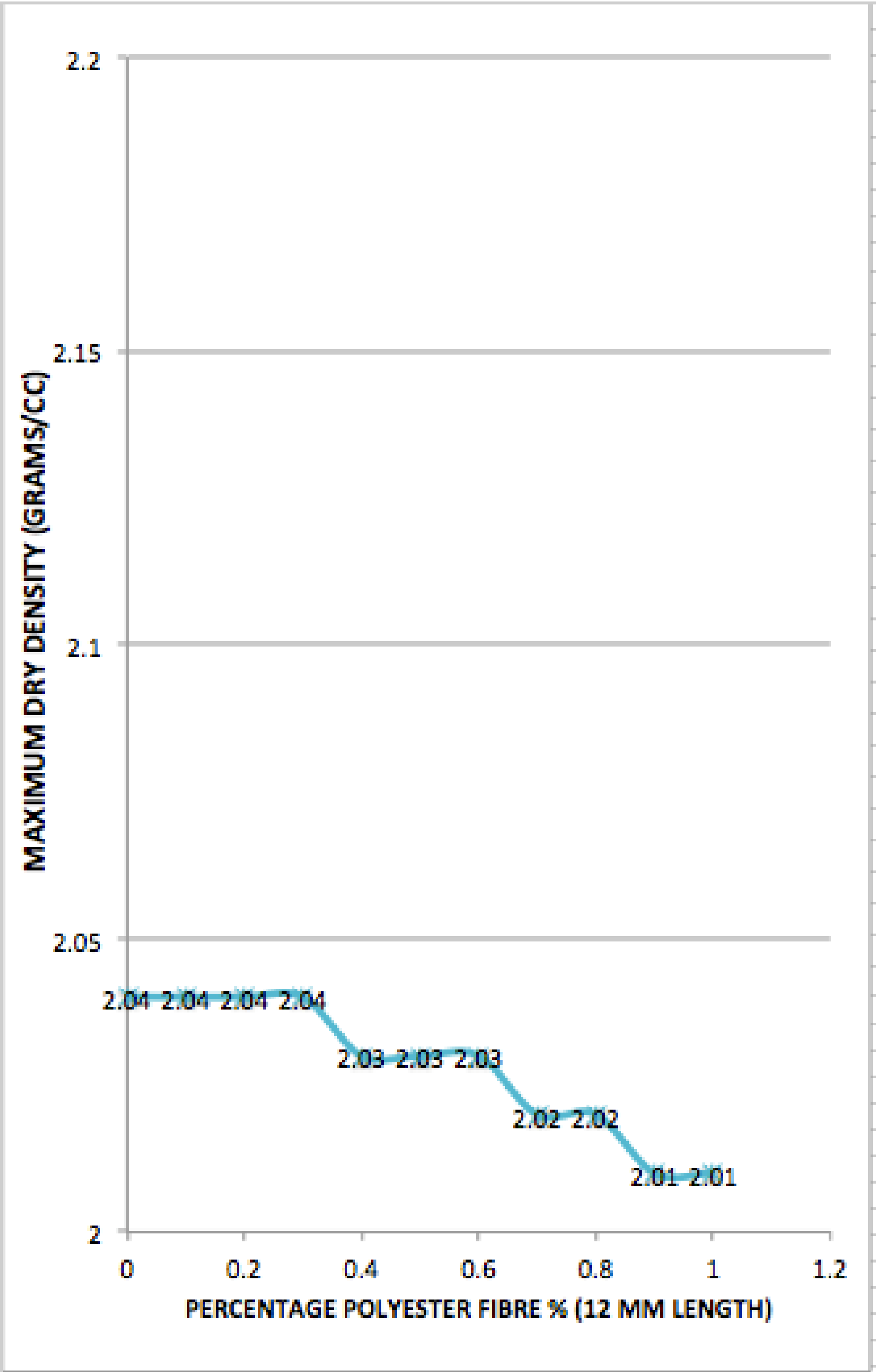


FIGURE 18: VARIATION OF MAXIMUM DRY DENSITY OF CLAY

WITH 12 mm POLYESTER FIBRE

VARIATION OF OPTIMUM MOISTURE CONTENT OF CLAY WITH 12 mm POLYESTER FIBRE

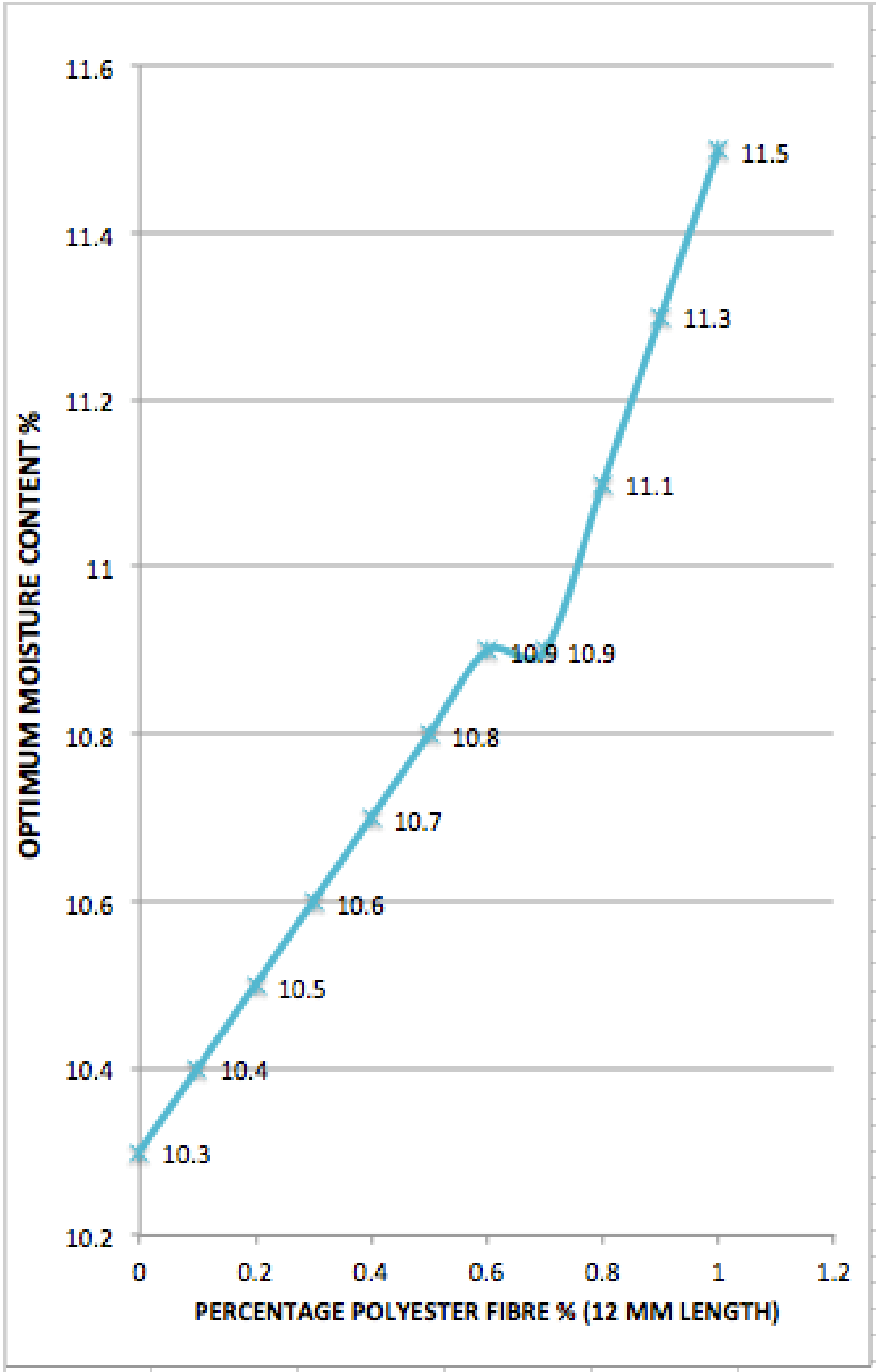


FIGURE 19: VARIATION OF OPTIMUM MOISTURE CONTENT OF CLAY WITH 12 mm POLYESTER FIBRE

5.2 Graphs Showing Variation In California Bearing Ratio Test Results

In this chapter following graphs have been shown

- Figure 20,21,22,23: Variation of California Bearing Ratio of Sand with 6 mm polyester fibre, Sample-1, 2, 3, design curve.
- Figure 24,25,26,27: Variation of California Bearing Ratio of Sand with 12 mm polyester fibre, Sample-1, 2, 3, design curve.
- Figure 28,29,30,31: Variation of California Bearing Ratio of Clay with 6 mm polyester fibre, Sample-1, 2, 3, design curve.
- Figure 32,33,34,35: Variation of California Bearing Ratio of Clay with 12 mm polyester fibre, Sample-1, 2, 3, design curve.

5.2.1 Effect of fibre length on California Bearing Ratio of Sand

- **6 mm fibre**

  California Bearing Ratio of sand increased steeply from 0% polyester fibre to 0.1% fibre. Highest average value of **soaked CBR, 25.87 %** was obtained at 0.1% fibre content. Highest average value of **unsoaked CBR, 40.35 %** was obtained at 0.1% fibre. On further increase in fibre content there was a gradual fall in the CBR value, giving the lowest value at 1.0% fibre content. Lowest average value of **soaked CBR, 14.38 %** was obtained at 1.0% fibre. Lowest average value of **unsoaked CBR, 25.78 %** was obtained at 1.0% fibre. Additional test was carried out at 0.05% fibre to confirm the proportion of highest CBR value.
- **12 mm fibre**

  California Bearing Ratio of sand increased gradually from 0% polyester fibre to 0.4% fibre content. Highest average value of **soaked CBR, 36.78 %** was obtained at 0.4% fibre. Highest average value of **unsoaked CBR, 55.54 %** was obtained at 0.4% fibre. On further increase in fibre content there was a gradual fall in the CBR value, giving the lowest value at 1.0% fibre content. Lowest average value of **soaked CBR, 22.78 %** was obtained at 1.0% fibre. Lowest average value of **unsoaked CBR, 35.08%** was obtained at 1.0% fibre.

TABLE 17: Variation of Soaked value of California Bearing Ratio of Sandwith 6 mm Polyester Fibre

S. No.	% fibre	CBR-sample 1 %	CBR-sample 2 %	CBR-sample 3 %	Average CBR %	Maximum Permissible Variation in CBR value
1	0.0%	9.38	9.83	9.16	9.46	±2%
2	0.05%	22.33	20.77	22.11	21.74	±3%
3	0.1%	27.70	24.12	25.78	25.87	±3%
4	0.2%	26.43	23.68	25.08	25.06	±3%
5	0.3%	25.46	22.55	23.95	23.99	±3%
6	0.4%	24.12	22.11	22.55	22.93	±3%
7	0.5%	23.01	20.77	21.27	21.68	±3%
8	0.6%	22.33	18.99	20.38	20.57	±3%
9	0.7%	20.10	18.76	19.03	19.30	±3%
10	0.8%	18.99	16.75	17.69	17.81	±3%
11	0.9%	16.96	14.96	16.34	16.09	±3%
12	1.0%	15.41	13.18	14.55	14.38	±3%

TABLE 18: Variation of Unsoaked value of California Bearing Ratio of Sand with 6 mm Polyester Fibre

S. No.	% fibre	CBR-sample 1 %	CBR-sample 2 %	CBR-sample 3 %	Average CBR %	Maximum Permissible Variation in CBR value
1	0.0%	14.96	15.41	14.07	14.81	±3%
2	0.05%	28.14	27.7	27.92	27.91	±3%
3	0.1%	41.32	39.53	40.20	40.35	±5%
4	0.2%	40.20	39.09	39.85	39.71	±5%
5	0.3%	39.53	37.74	38.42	38.56	±5%
6	0.4%	38.19	36.63	37.08	37.30	±5%
7	0.5%	36.85	35.06	35.78	35.90	±5%
8	0.6%	35.51	33.95	34.17	34.54	±5%
9	0.7%	34.17	31.94	32.61	32.90	±5%
10	0.8%	31.71	29.25	30.82	30.59	±5%
11	0.9%	29.93	27.70	28.14	28.59	±3%
12	1.0%	27.91	24.12	25.30	25.78	±3%

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF SAND WITH POLYESTER FIBRE (6 mm), SAMPLE-1

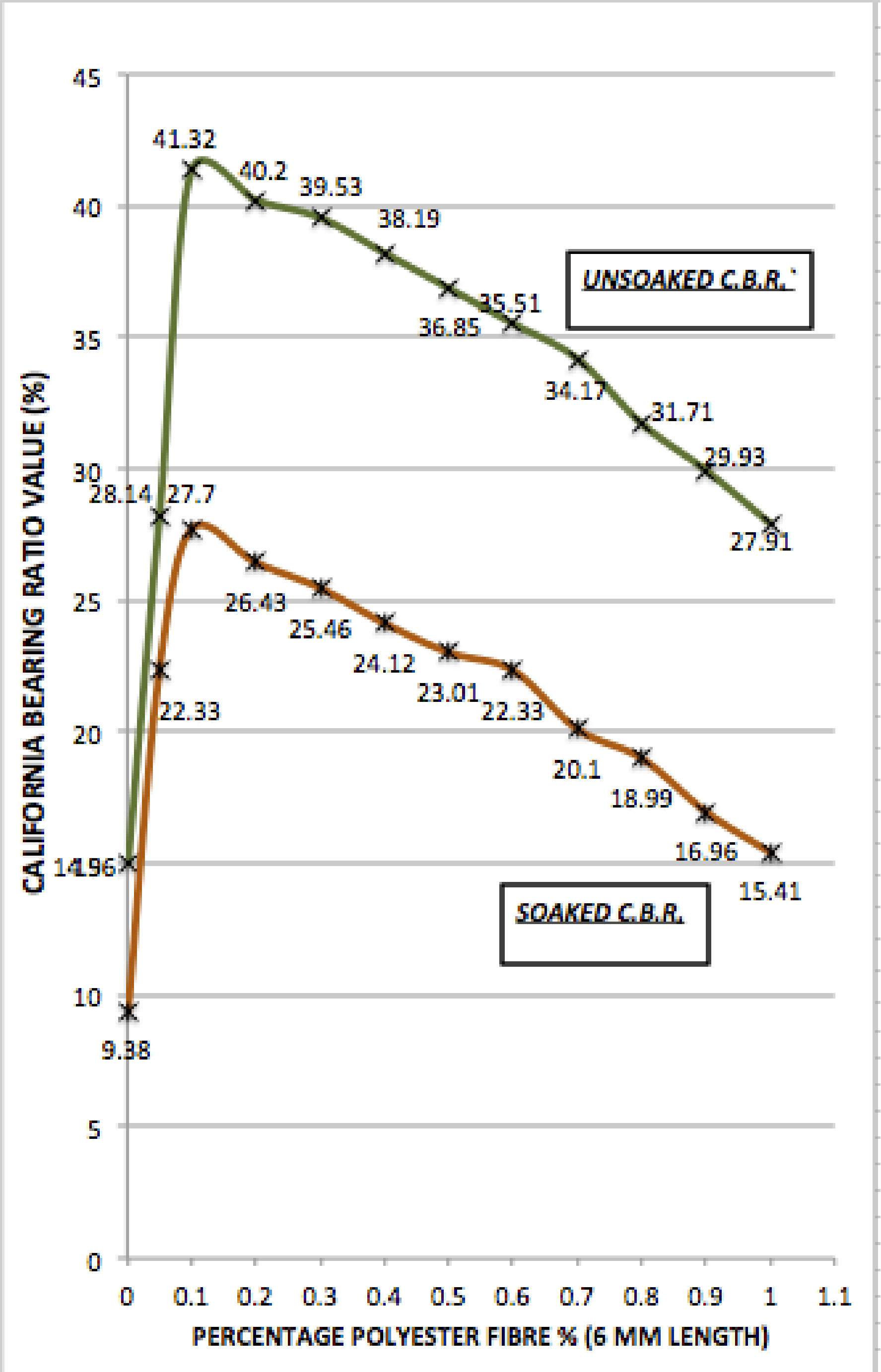


FIGURE 20: VARIATION OF CALIFORNIA BEARING RATIO OF SAND WITH 6mmPOLYESTER FIBRE SAMPLE-1

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF SAND WITH POLYESTER FIBRE (6 mm), SAMPLE-2

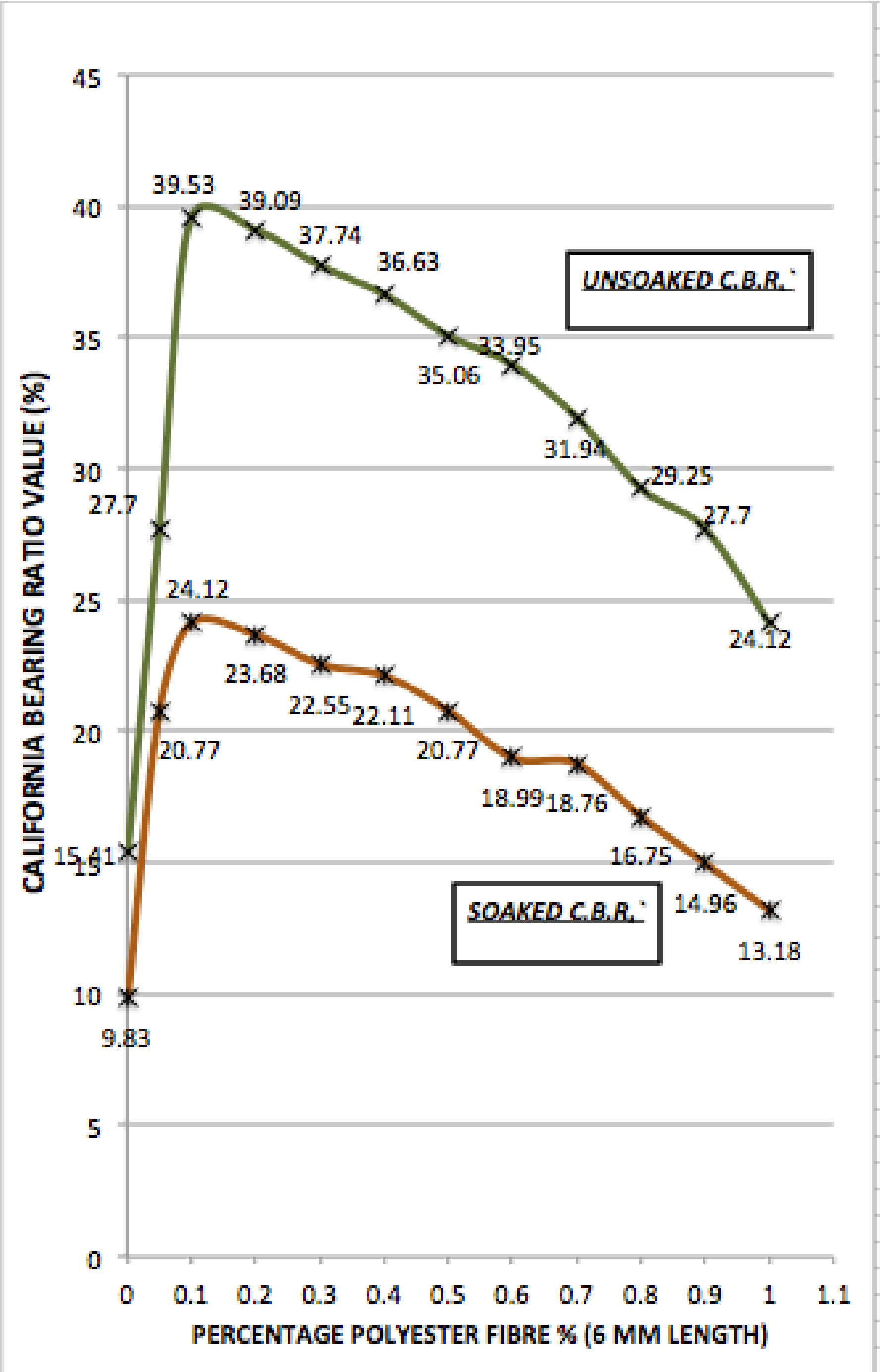


FIGURE 21: VARIATION OF CALIFORNIA BEARING RATIO OF SAND WITH 6mmPOLYESTER FIBRE SAMPLE-2

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF SAND WITH POLYESTER FIBRE (6 mm) SAMPLE 3

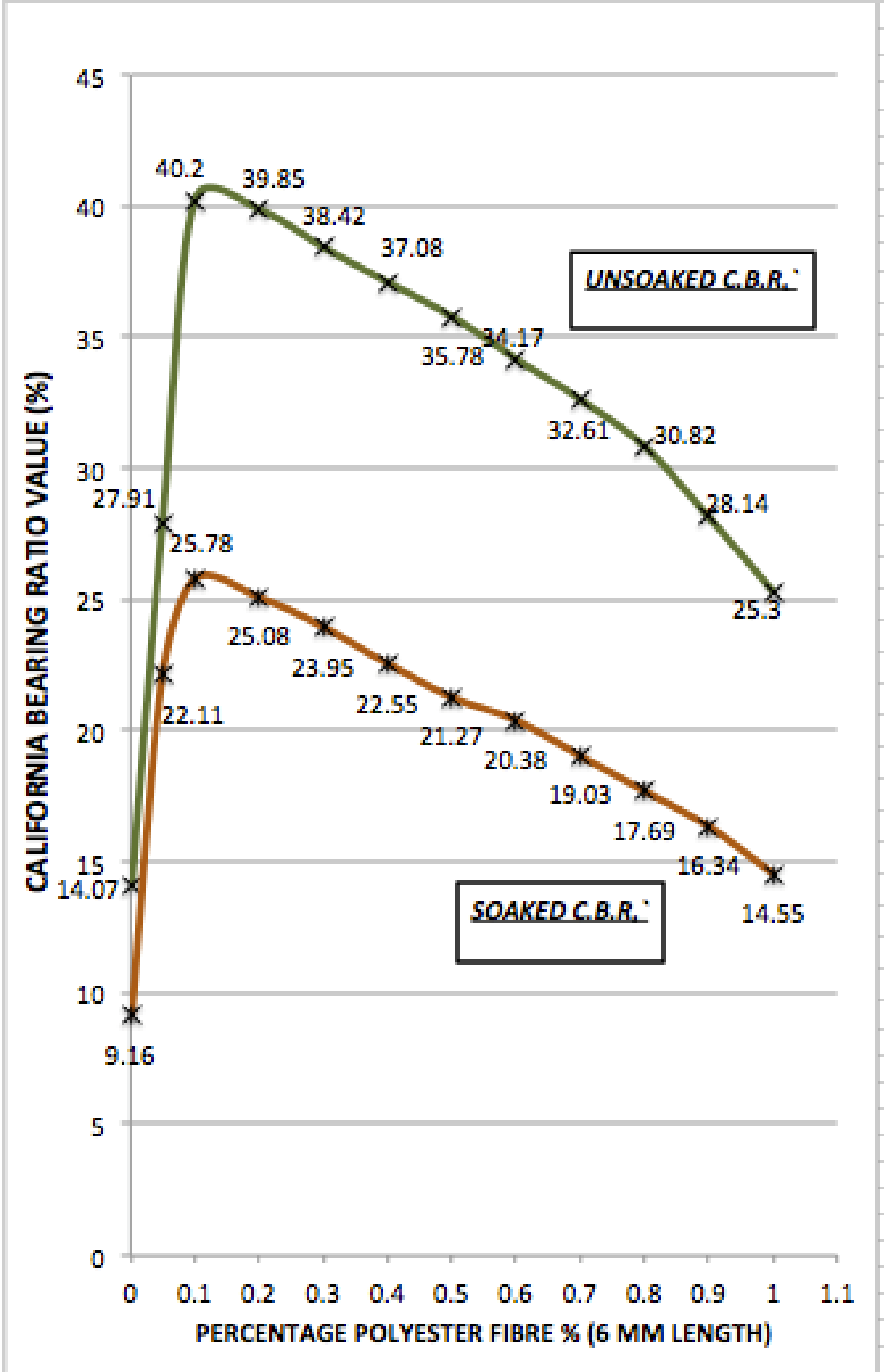


FIGURE 22: VARIATION OF CALIFORNIA BEARING RATIO OF SAND WITH 6 mm POLYESTER FIBRE SAMPLE-3

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF SAND WITH POLYESTER FIBRE (6 mm) DESIGN CURVE

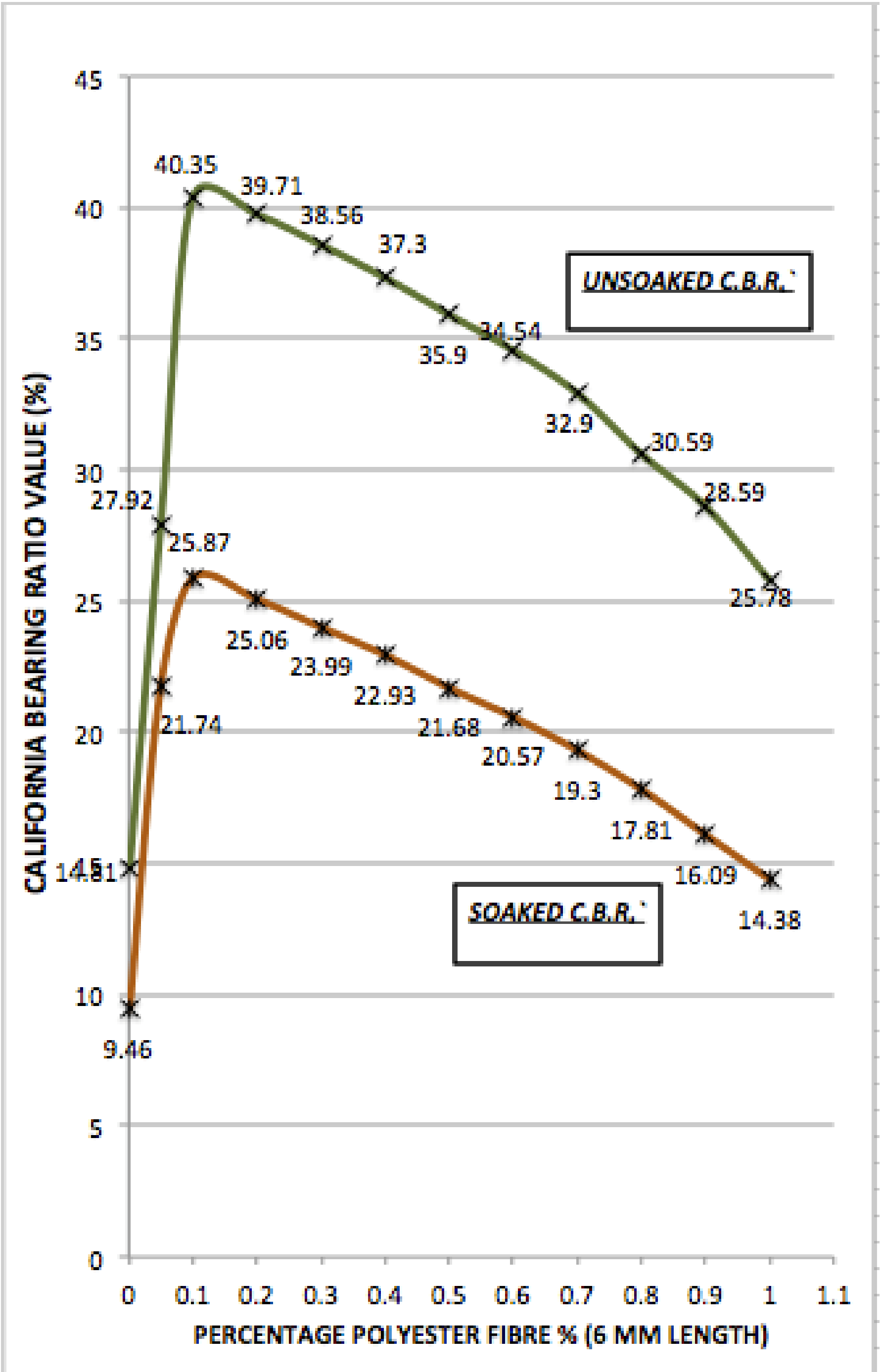


FIGURE 23: VARIATION OF CALIFORNIA BEARING RATIO OF SAND WITH 6 mmPOLYESTER FIBRE DESIGN CURVE

TABLE 19: Variation of Soaked value of California Bearing Ratio of Sandwith 12 mm Polyester Fibre

S. No.	% fibre	CBR-sample 1 %	CBR-sample 2 %	CBR-sample 3 %	Average CBR %	Maximum Permissible Variation in CBR value
1	0.0%	9.38	9.83	9.16	9.46	±2%
2	0.1%	12.28	13.18	11.83	12.43	±3%
3	0.2%	20.77	21.66	19.87	20.77	±3%
4	0.3%	32.16	31.72	33.28	32.39	±5%
5	0.4%	36.85	36.18	37.30	36.78	±5%
6	0.5%	35.96	37.07	35.07	36.03	±5%
7	0.6%	33.95	32.61	34.84	33.65	±5%
8	0.7%	31.49	30.60	32.39	31.49	±5%
9	0.8%	29.04	30.83	28.81	29.56	±3%
10	0.9%	26.13	25.46	27.70	26.43	±3%
11	1.0%	22.33	24.12	21.88	22.78	±3%

TABLE 20: Variation of Unsoaked value of California Bearing Ratio of Sand with 12 mm Polyester Fibre

S. No.	% fibre	CBR-sample 1 %	CBR-sample 2 %	CBR-sample 3 %	Average CBR %	Maximum Permissible Variation in CBR value
1	0.0%	14.96	15.41	14.07	14.81	±3%
2	0.1%	22.78	24.12	21.66	22.86	±3%
3	0.2%	35.74	36.85	34.84	35.81	±5%
4	0.3%	52.89	52.04	54.72	53.22	±5%
5	0.4%	55.84	56.73	54.05	55.54	±5%
6	0.5%	53.63	54.72	52.26	53.54	±5%
7	0.6%	51.58	52.48	50.93	51.66	±5%
8	0.7%	48.9	48.02	51.15	49.39	±5%
9	0.8%	45.56	44.67	46.68	45.64	±5%
10	0.9%	41.31	42.43	40.20	41.31	±5%
11	1.0%	35.10	33.95	36.18	35.08	±5%

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF SAND WITH POLYESTER FIBRE (12 mm) SAMPLE -1

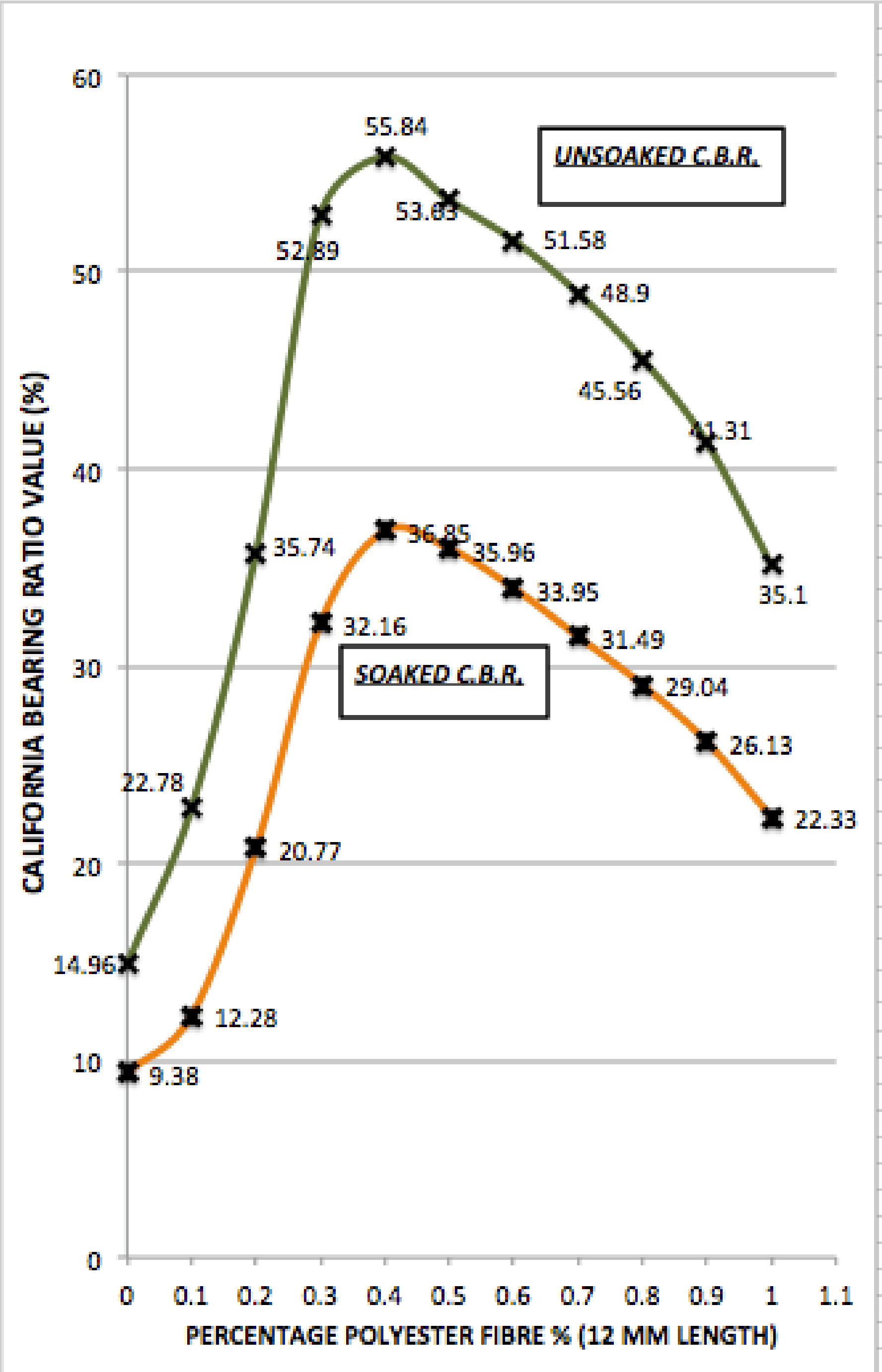


FIGURE 24: VARIATION OF CALIFORNIA BEARING RATIO OF SAND WITH 12 mm POLYESTER FIBRE SAMPLE-1

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF SAND WITH POLYESTER FIBRE (12 mm) SAMPLE -2

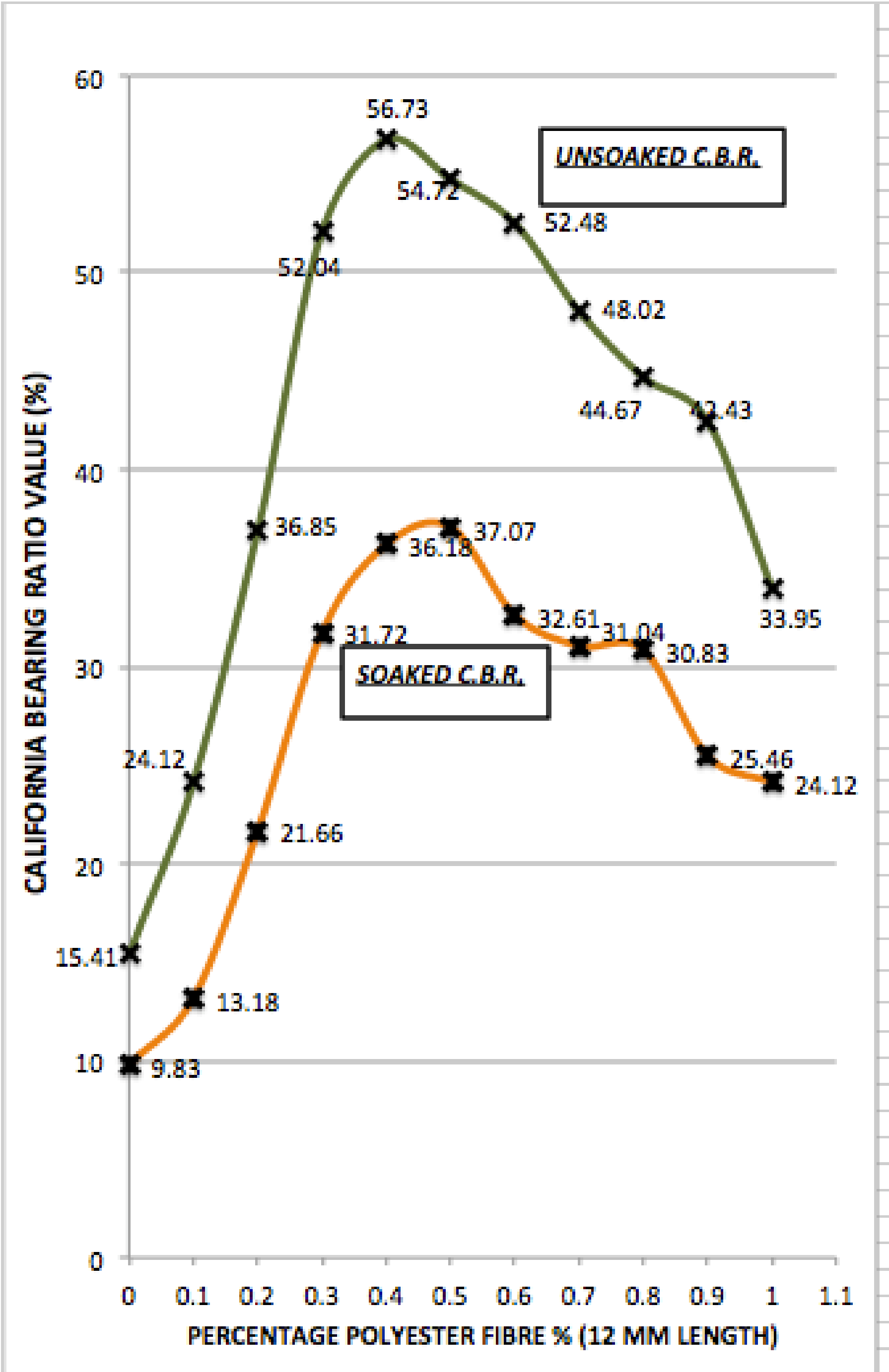


FIGURE 25: VARIATION OF CALIFORNIA BEARING RATIO OF SAND WITH 12 mm POLYESTER FIBRE SAMPLE-2

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF SAND WITH POLYESTER FIBRE (12 mm) SAMPLE -3

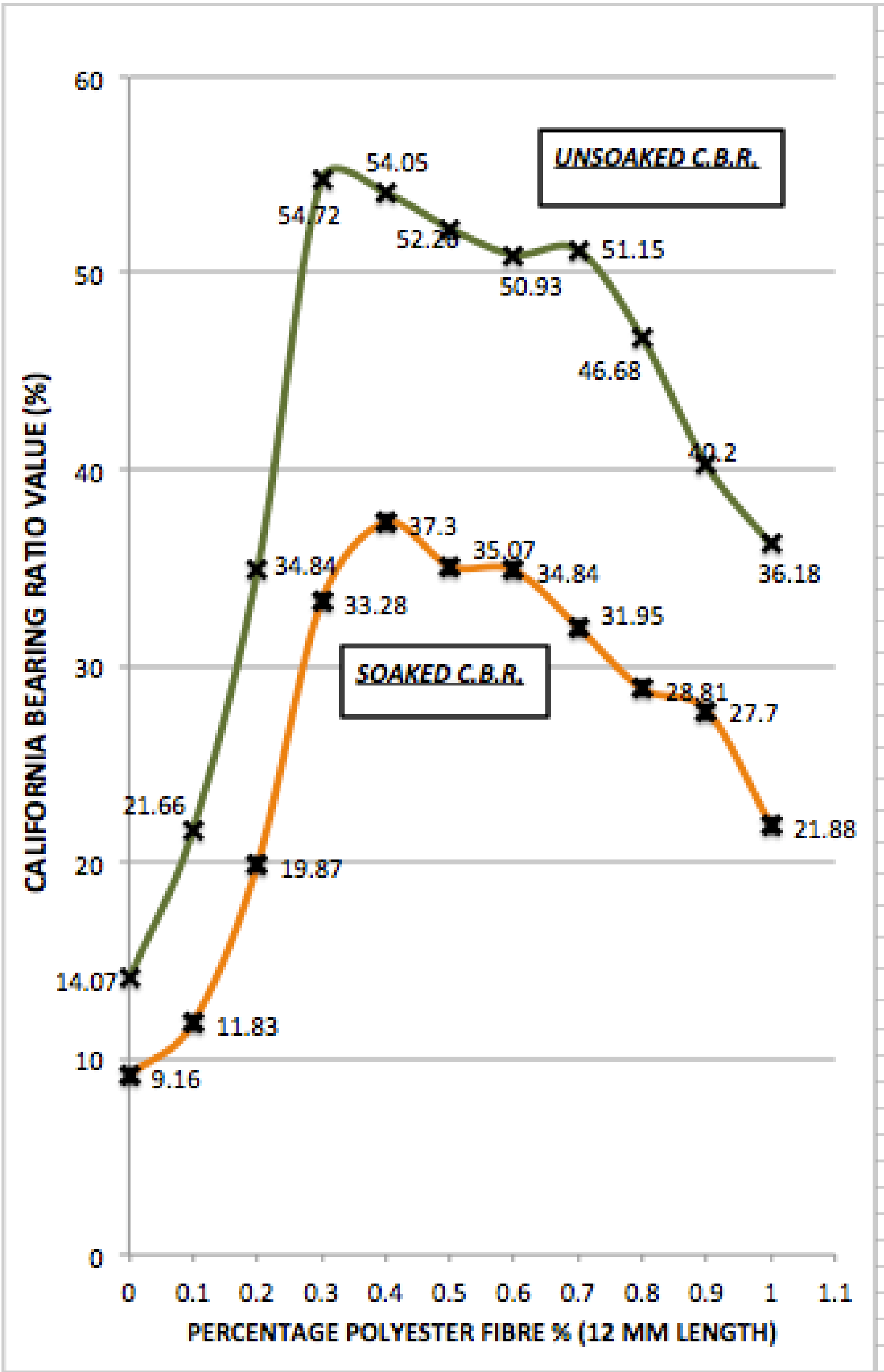


FIGURE 26: VARIATION OF CALIFORNIA BEARING RATIO OF SAND WITH 12 mm POLYESTER FIBRE SAMPLE-3

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF SAND WITH POLYESTER FIBRE (12 mm) DESIGN CURVE

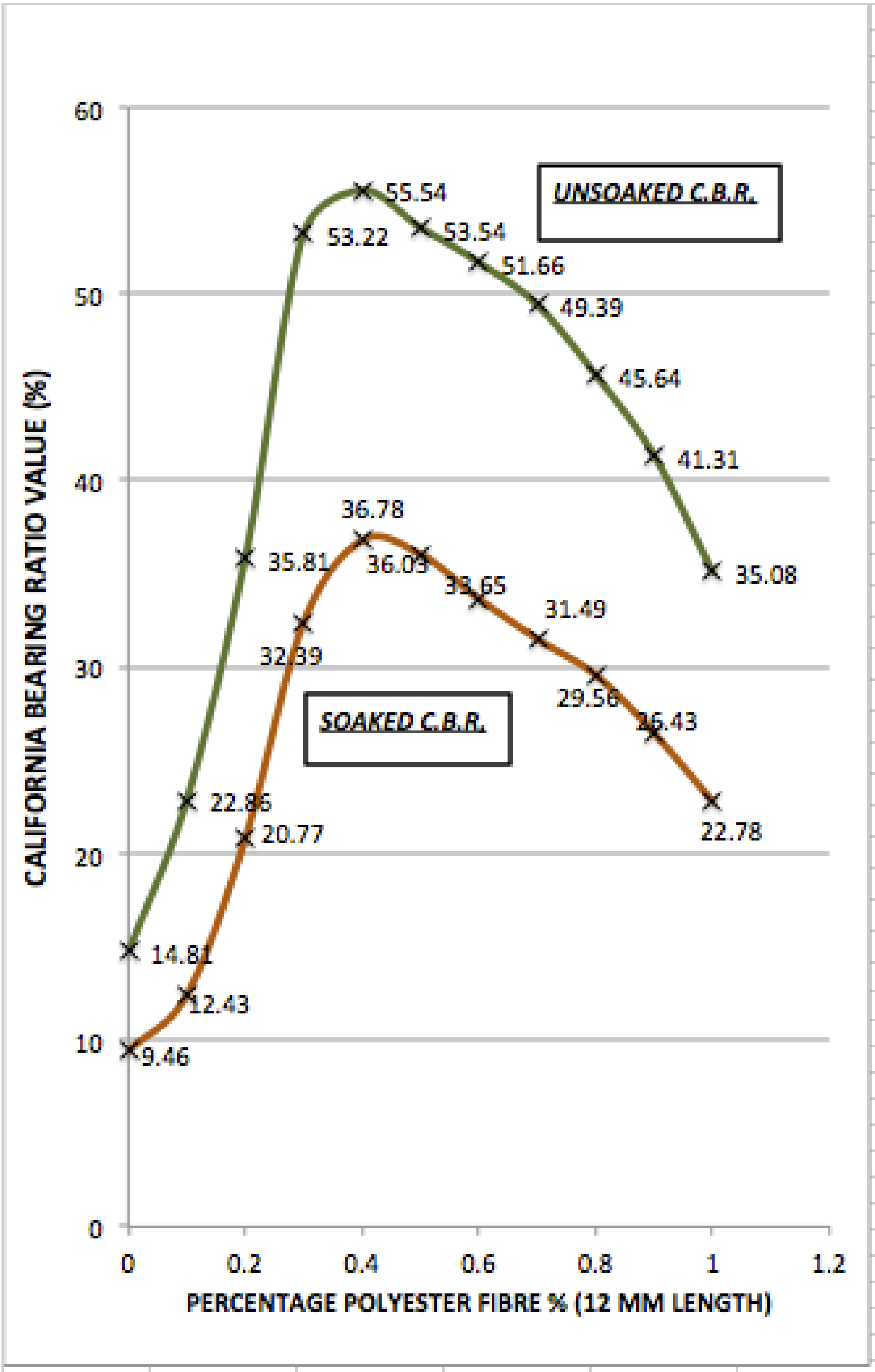


FIGURE 27: VARIATION OF CALIFORNIA BEARING RATIO OF SAND WITH 12 mm POLYESTER FIBRE DESIGN CURVE

5.2.2 Effect of fibre length on California Bearing Ratio of Clay

- **<u>6 mm fibre</u>**

  California Bearing Ratio of clay increased steeply from 0% polyester fibre to 0.1% fibre. Highest average value of **soaked CBR, 4.62 %** was obtained at 0.1% fibre content. Highest average value of **unsoaked CBR, 17.50 %** was obtained at 0.1% fibre. On further increase in fibre content there was a gradual fall in the CBR value, giving the lowest value at 1.0% fibre content. Lowest average value of **soaked CBR, 2.38 %** was obtained at 1.0% fibre. Lowest average value of **unsoaked CBR, 14.54 %** was obtained at 1.0% fibre. Additional test was carried out at 0.05% fibre to confirm the proportion of highest CBR value.

- **<u>12 mm fibre</u>**

  California Bearing Ratio of clay increased gradually from 0% polyester fibre to 0.5% fibre content. Highest average value of **soaked CBR, 4.84 %** was obtained at 0.5% fibre. Highest average value of **unsoaked CBR, 17.50 %** was obtained at 0.5% fibre. On further increase in fibre content there was a gradual fall in the CBR value, giving the lowest value at 1.0% fibre content. Lowest average value of **soaked CBR, 2.61 %** was obtained at 1.0% fibre. Lowest average value of **unsoaked CBR, 12.28%** was obtained at 1.0% fibre.

TABLE 21: Variation of Soaked value of California Bearing Ratio of Claywith 6 mm Polyester Fibre

S. No.	% fibre	CBR-sample 1 %	CBR-sample 2 %	CBR-sample 3 %	Average CBR %	Maximum Permissible Variation in CBR value
1	0.0%	2.90	3.13	2.68	2.90	±1%
2	0.05%	4.02	4.24	3.35	3.87	±1%
3	0.1%	4.69	5.14	4.02	4.62	±1%
4	0.2%	4.24	4.91	3.80	4.32	±1%
5	0.3%	4.02	4.69	3.35	4.02	±1%
6	0.4%	3.80	4.24	3.13	3.73	±1%
7	0.5%	3.57	4.02	2.90	3.50	±1%
8	0.6%	3.35	3.80	2.68	3.28	±1%
9	0.7%	3.13	3.57	2.46	3.05	±1%
10	0.8%	2.90	3.35	2.23	2.83	±1%
11	0.9%	2.68	3.13	2.01	2.61	±1%
12	1.0%	2.46	2.90	1.78	2.38	±1%

TABLE 22: Variation of Unsoaked value of California Bearing Ratio of Claywith 6 mm Polyester Fibre

S. No.	% fibre	CBR-sample 1 %	CBR-sample 2 %	CBR-sample 3 %	Average CBR %	Maximum Permissible Variation in CBR value
1	0.0%	15.41	16.08	15.64	15.71	±3%
2	0.05%	16.75	17.20	16.31	16.75	±3%
3	0.1%	17.42	18.32	16.98	17.50	±3%
4	0.2%	17.20	18.12	16.75	17.36	±3%
5	0.3%	16.75	17.88	16.53	17.05	±3%
6	0.4%	16.53	17.65	16.31	16.83	±3%
7	0.5%	16.31	17.42	15.86	16.53	±3%
8	0.6%	16.08	17.17	15.64	16.30	±3%
9	0.7%	15.86	16.93	15.41	16.07	±3%
10	0.8%	15.64	16.21	14.96	15.60	±3%
11	0.9%	14.96	15.49	14.52	14.99	±3%
12	1.0%	14.52	15.02	14.07	14.54	±3%

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF CLAY WITH POLYESTER FIBRE (6 mm) SAMPLE -1

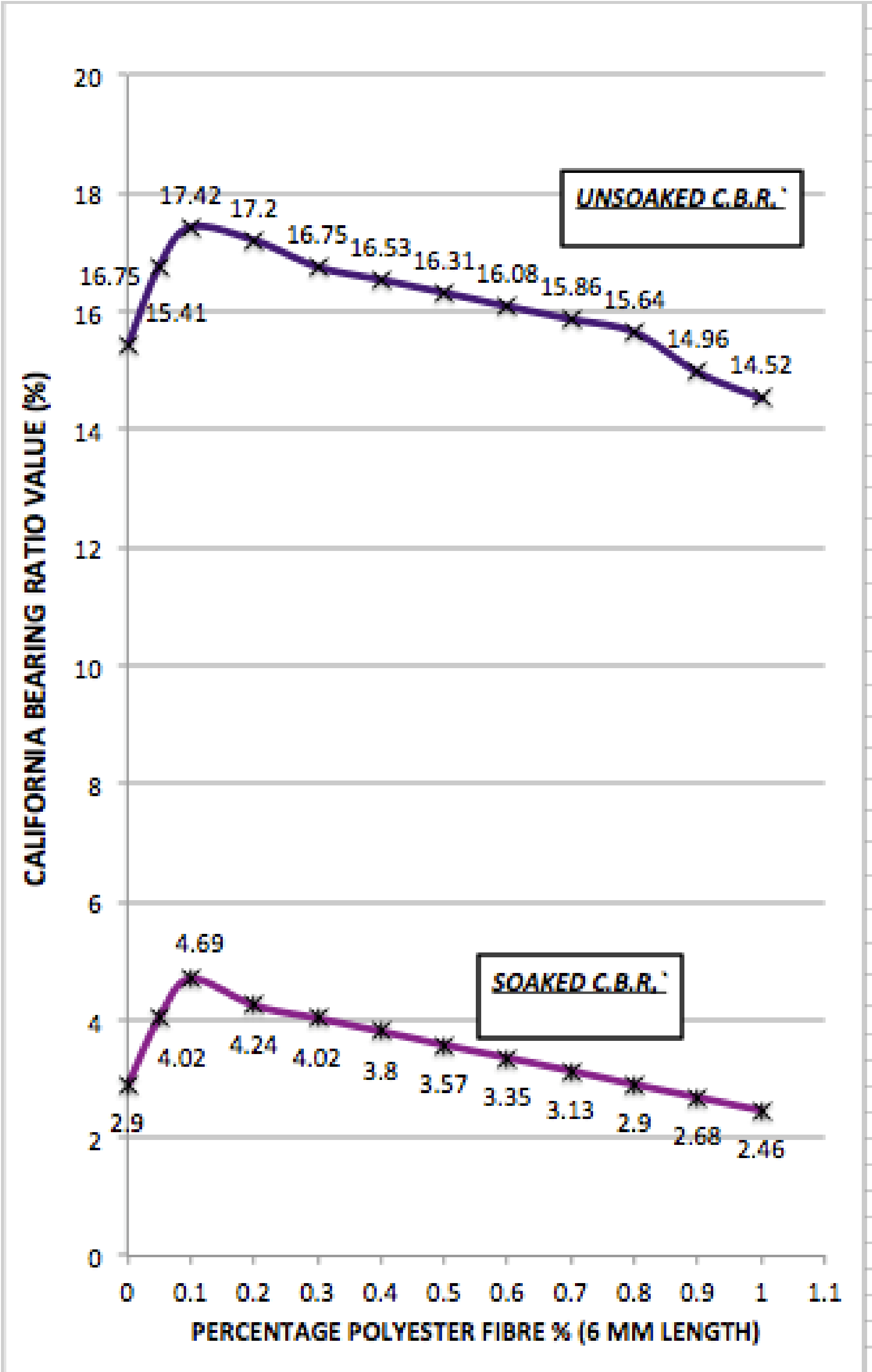


FIGURE 28: VARIATION OF CALIFORNIA BEARING RATIO OF CLAY WITH 6 mmPOLYESTER FIBRE SAMPLE-1

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF CLAY WITH POLYESTER FIBRE (6 mm) SAMPLE -2

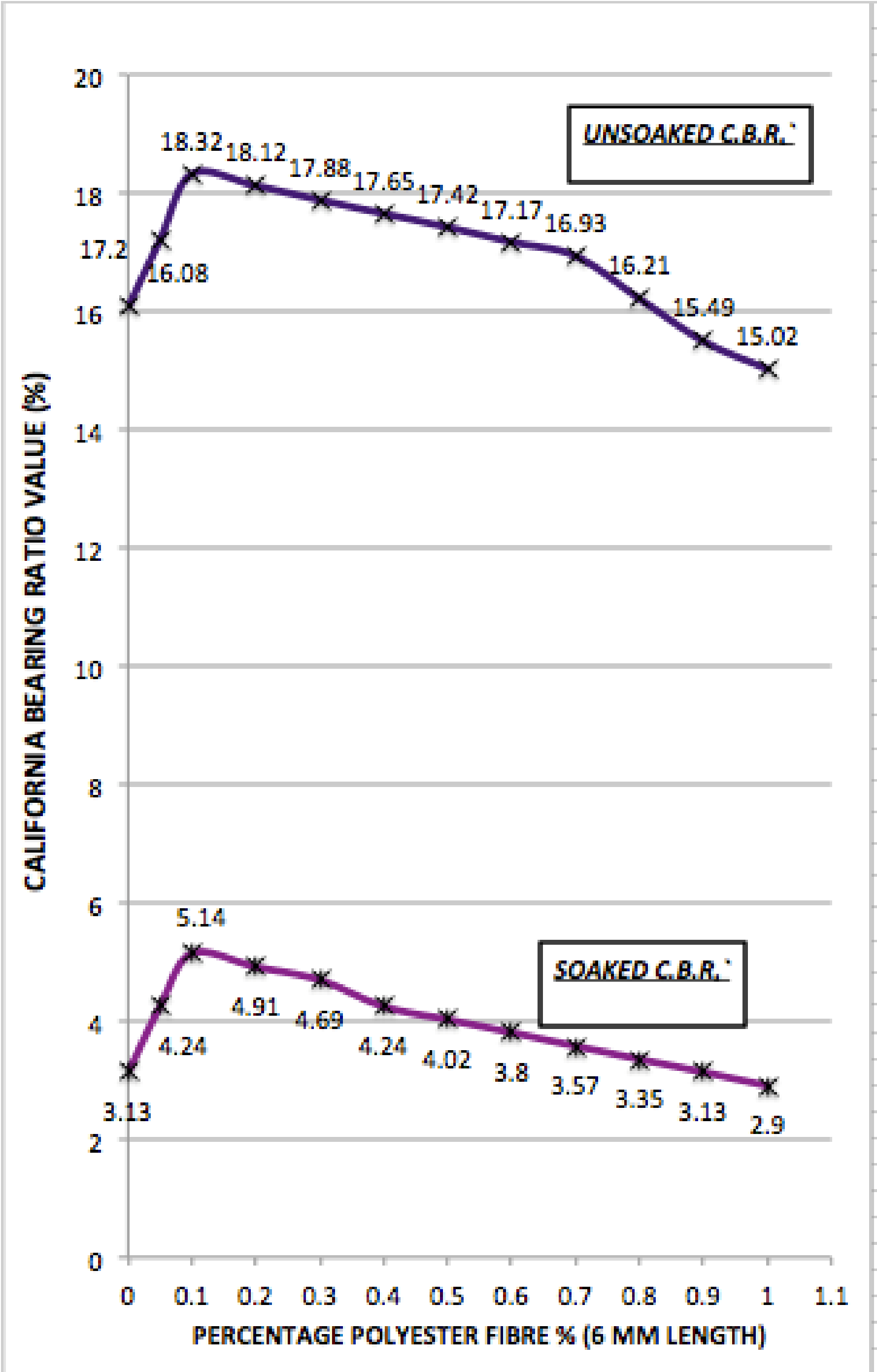


FIGURE 29: VARIATION OF CALIFORNIA BEARING RATIO OF CLAY WITH 6 mmPOLYESTER FIBRE SAMPLE-2

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF CLAY WITH POLYESTER FIBRE (6 mm) DESIGN CURVE

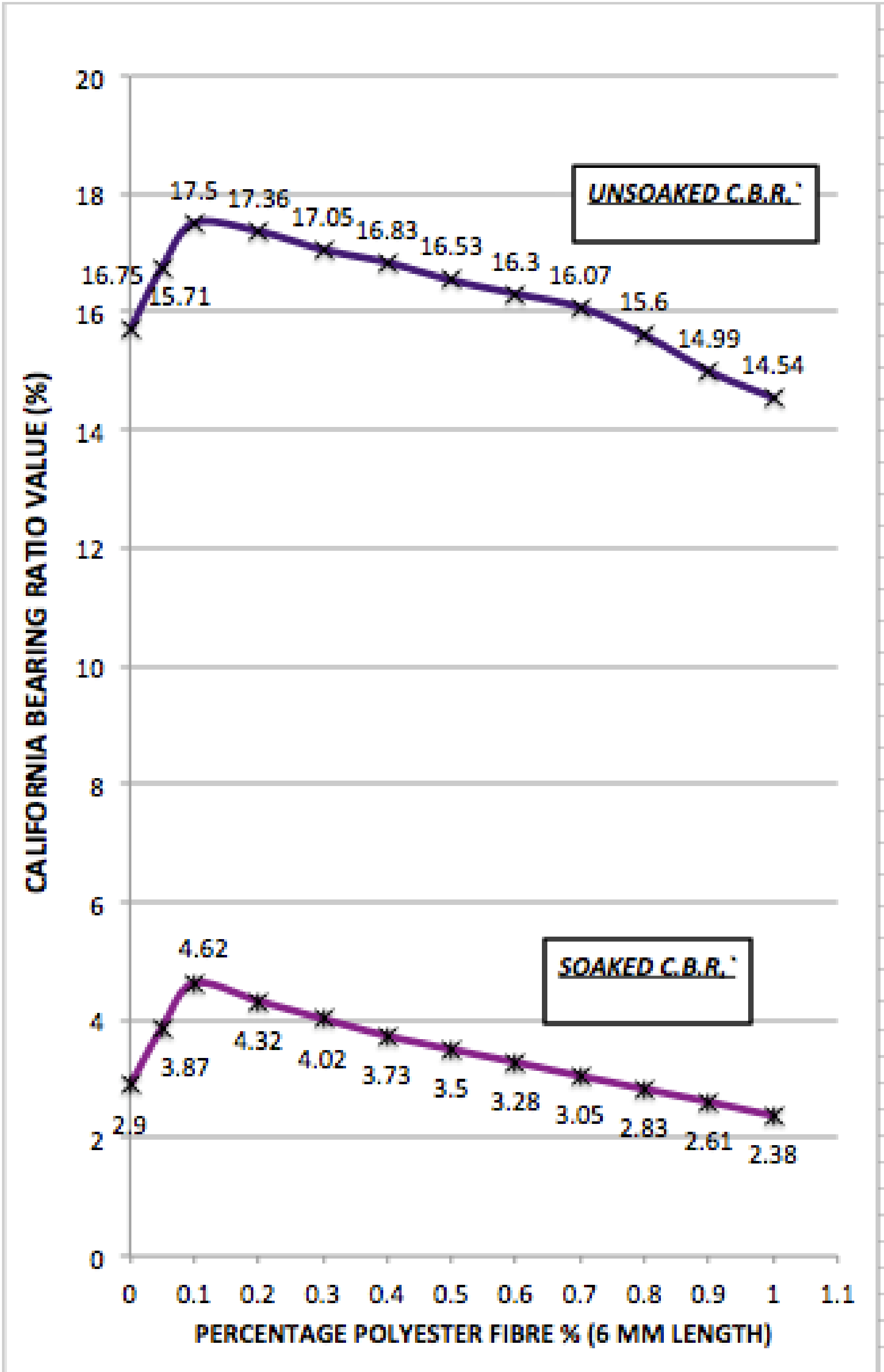


FIGURE 31: VARIATION OF CALIFORNIA BEARING RATIO OF CLAY WITH 6 mmPOLYESTER FIBRE DESIGN CURVE

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF CLAY WITH POLYESTER FIBRE (6 mm) SAMPLE -3

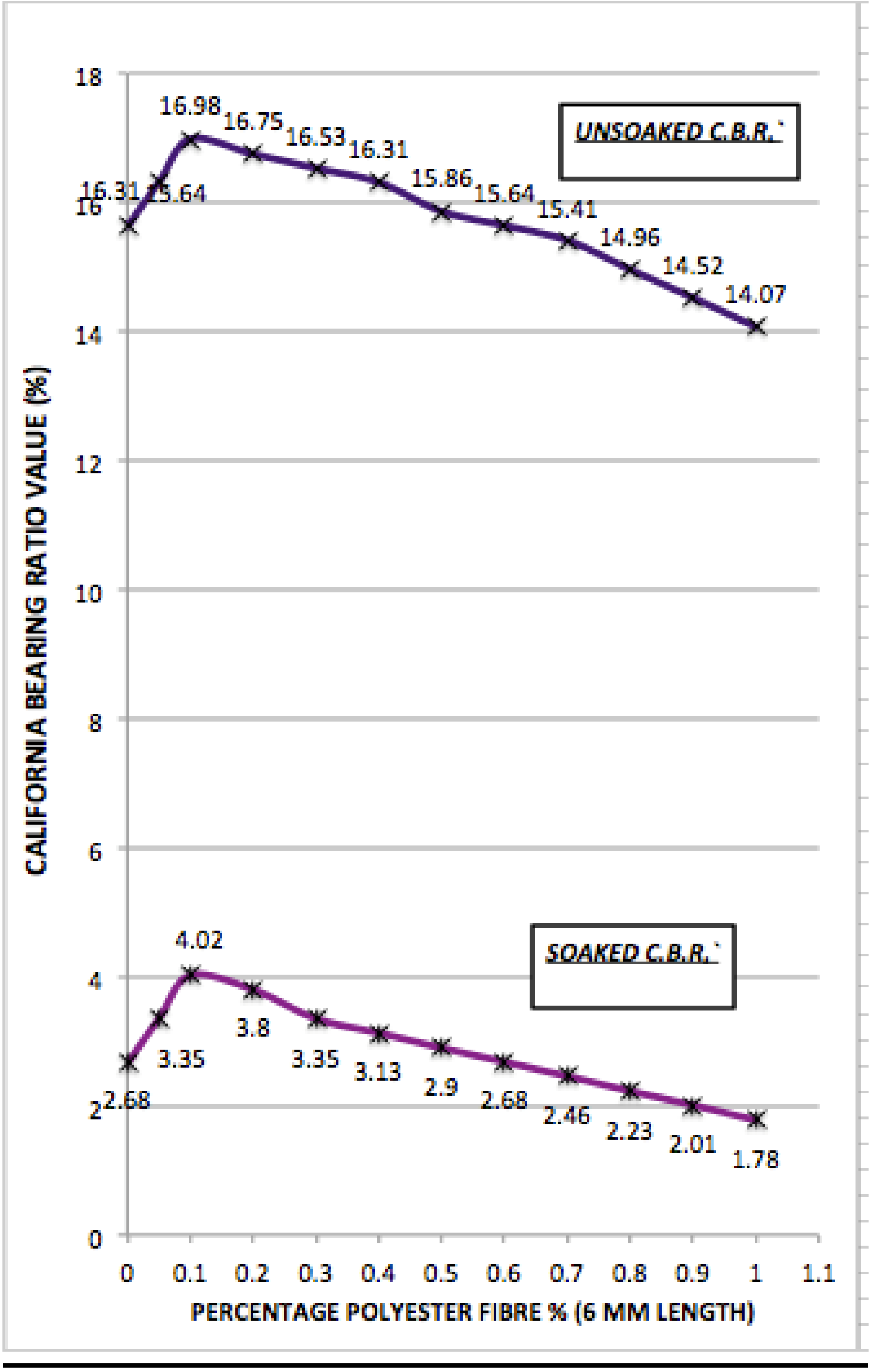


FIGURE 30: VARIATION OF CALIFORNIA BEARING RATIO OF CLAY WITH 6 mmPOLYESTER FIBRE SAMPLE-3

TABLE 23: Variation of Unsoaked value of California Bearing Ratio of Claywith 12 mm polyester fibre

S. No.	% fibre	CBR-sample 1 %	CBR-sample 2 %	CBR-sample 3 %	Average CBR %	Maximum Permissible Variation in CBR value
1	0.0%	2.90	3.13	2.68	2.90	±1%
2	0.1%	3.13	3.57	2.68	3.13	±1%
3	0.2%	3.35	4.02	2.90	3.42	±1%
4	0.3%	3.57	4.47	3.13	3.72	±1%
5	0.4%	4.24	4.69	3.57	4.17	±1%
6	0.5%	4.91	5.14	4.47	4.84	±1%
7	0.6%	4.24	4.91	4.02	4.39	±1%
8	0.7%	3.80	4.24	3.57	3.87	±1%
9	0.8%	3.35	4.02	3.13	3.50	±1%
10	0.9%	2.90	3.35	2.68	2.98	±1%
11	1.0%	2.46	3.13	2.23	2.61	±1%

TABLE 24: Variation of Unsoaked value of California Bearing Ratio of Claywith 12 mm polyester fibre

S. No.	% fibre	CBR-sample 1 %	CBR-sample 2 %	CBR-sample 3 %	Average CBR %	Maximum Permissible Variation in CBR value
1	0.0%	15.41	16.08	15.64	15.71	±3%
2	0.1%	16.08	16.75	15.86	16.23	±3%
3	0.2%	16.31	16.98	16.08	16.46	±3%
4	0.3%	16.53	17.20	16.31	16.68	±3%
5	0.4%	16.98	17.42	16.53	16.98	±3%
6	0.5%	17.42	18.09	16.98	17.50	±3%
7	0.6%	17.20	17.87	16.75	17.27	±3%
8	0.7%	16.75	17.42	16.08	16.75	±3%
9	0.8%	15.19	16.31	14.74	15.41	±3%
10	0.9%	13.85	14.96	13.18	14.52	±3%
11	1.0%	12.51	13.85	12.28	12.28	±3%

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF CLAY WITH POLYESTER FIBRE (12 MM) SAMPLE 1

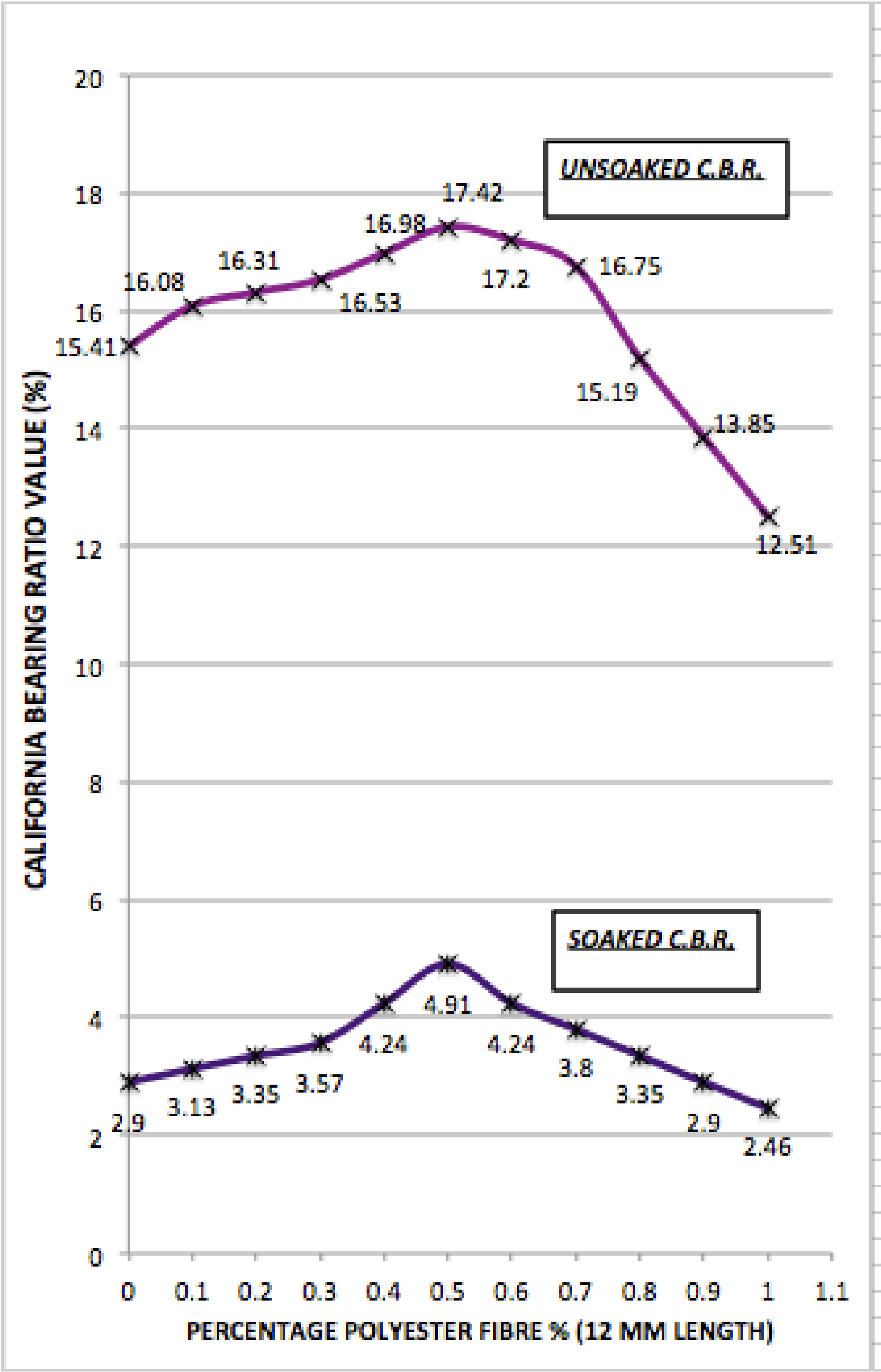


FIGURE 32: VARIATION OF CALIFORNIA BEARING RATIO OF CLAY WITH 6 mmPOLYESTER FIBRE SAMPLE-1

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF CLAY WITH POLYESTER FIBRE (12 MM) SAMPLE-2

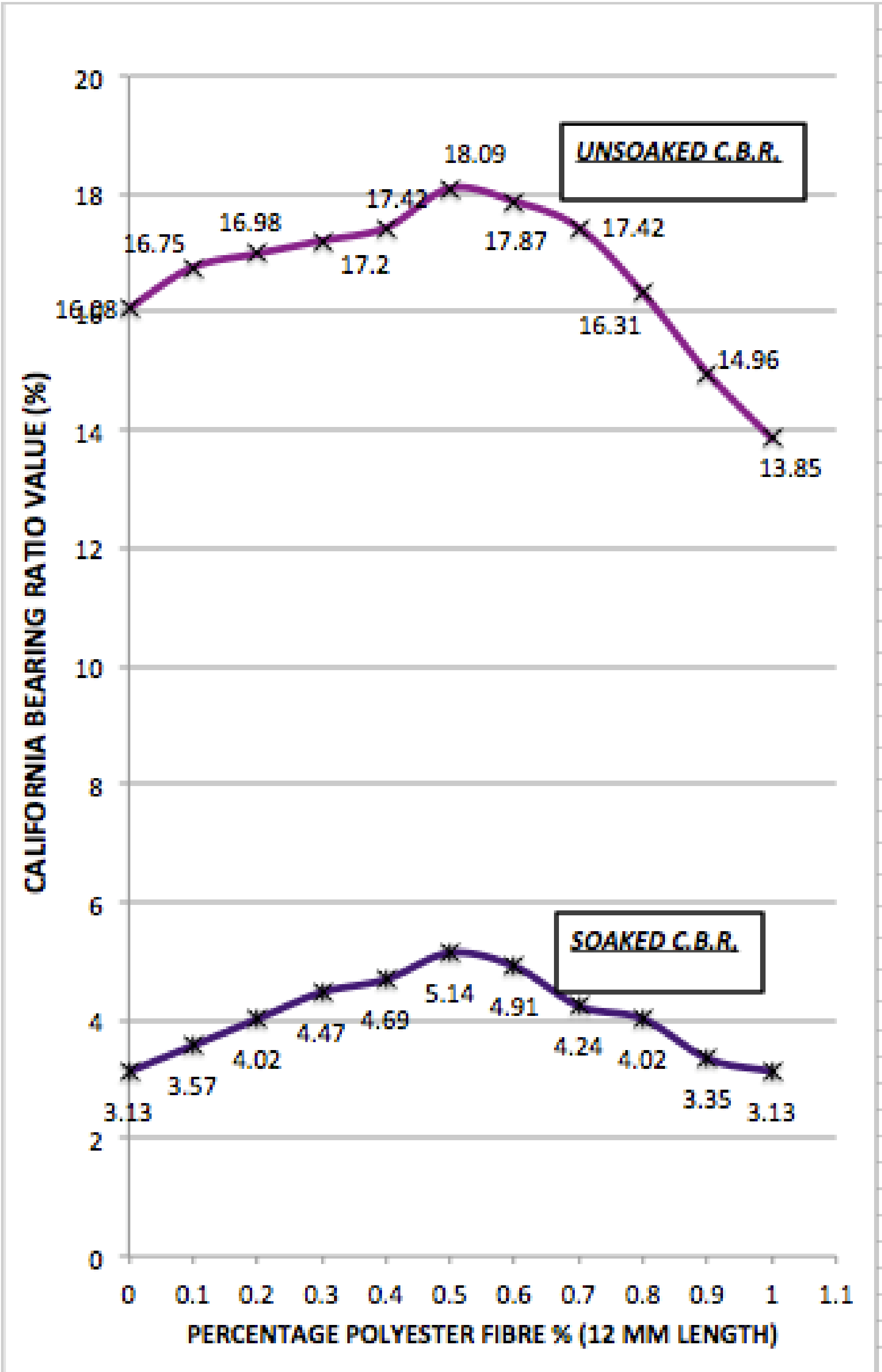


FIGURE 33: VARIATION OF CALIFORNIA BEARING RATIO OF CLAY WITH 12 mmPOLYESTER FIBRE SAMPLE-2

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF CLAY WITH POLYESTER FIBRE (12 MM) SAMPLE-3

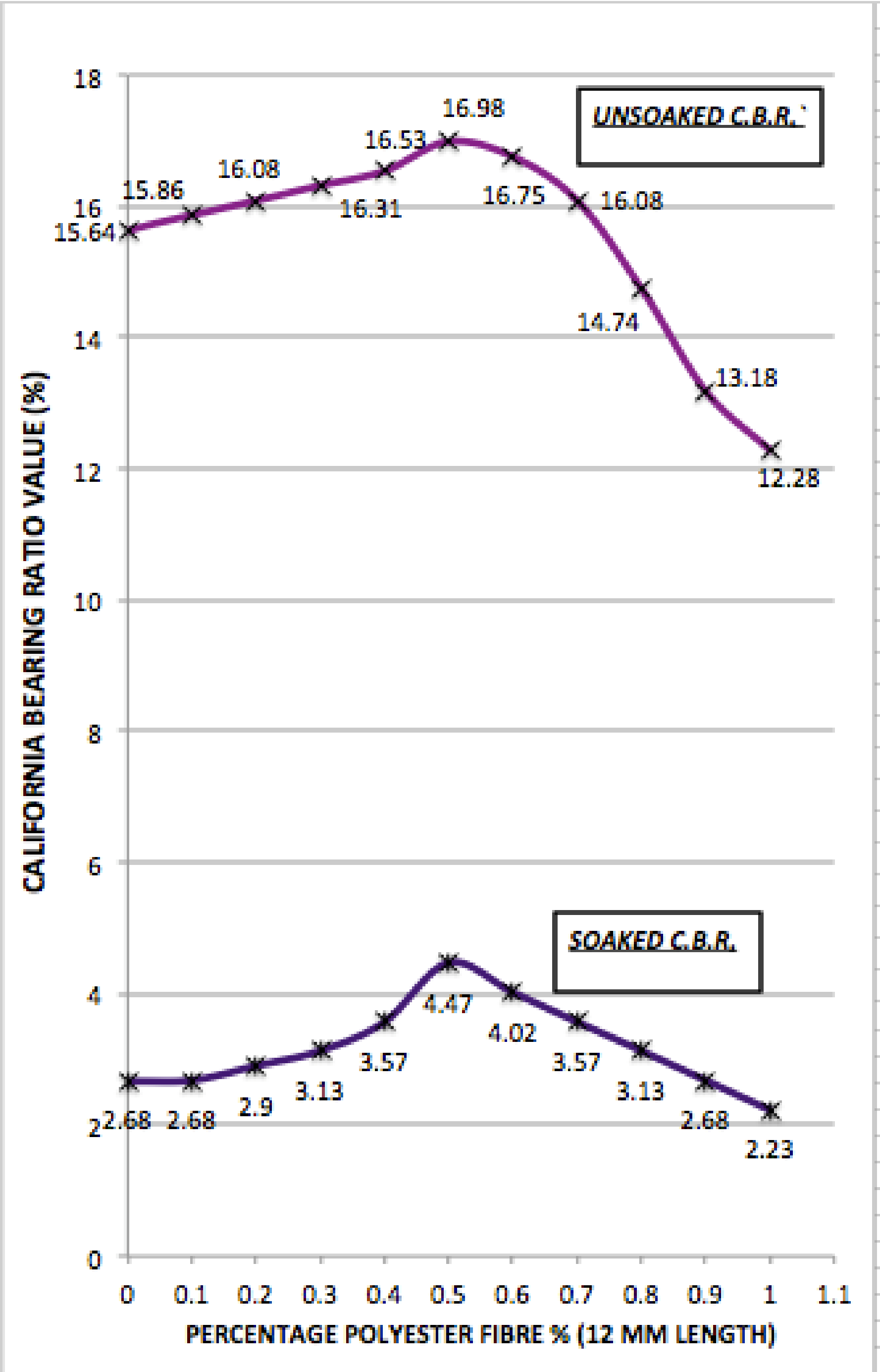


FIGURE 34: VARIATION OF CALIFORNIA BEARING RATIO OF CLAY WITH 12 mmPOLYESTER FIBRE SAMPLE-3

VARIATION OF CALIFORNIA BEARING RATIO VALUE OF CLAY WITH POLYESTER FIBRE (12 MM) DESIGN CURVE

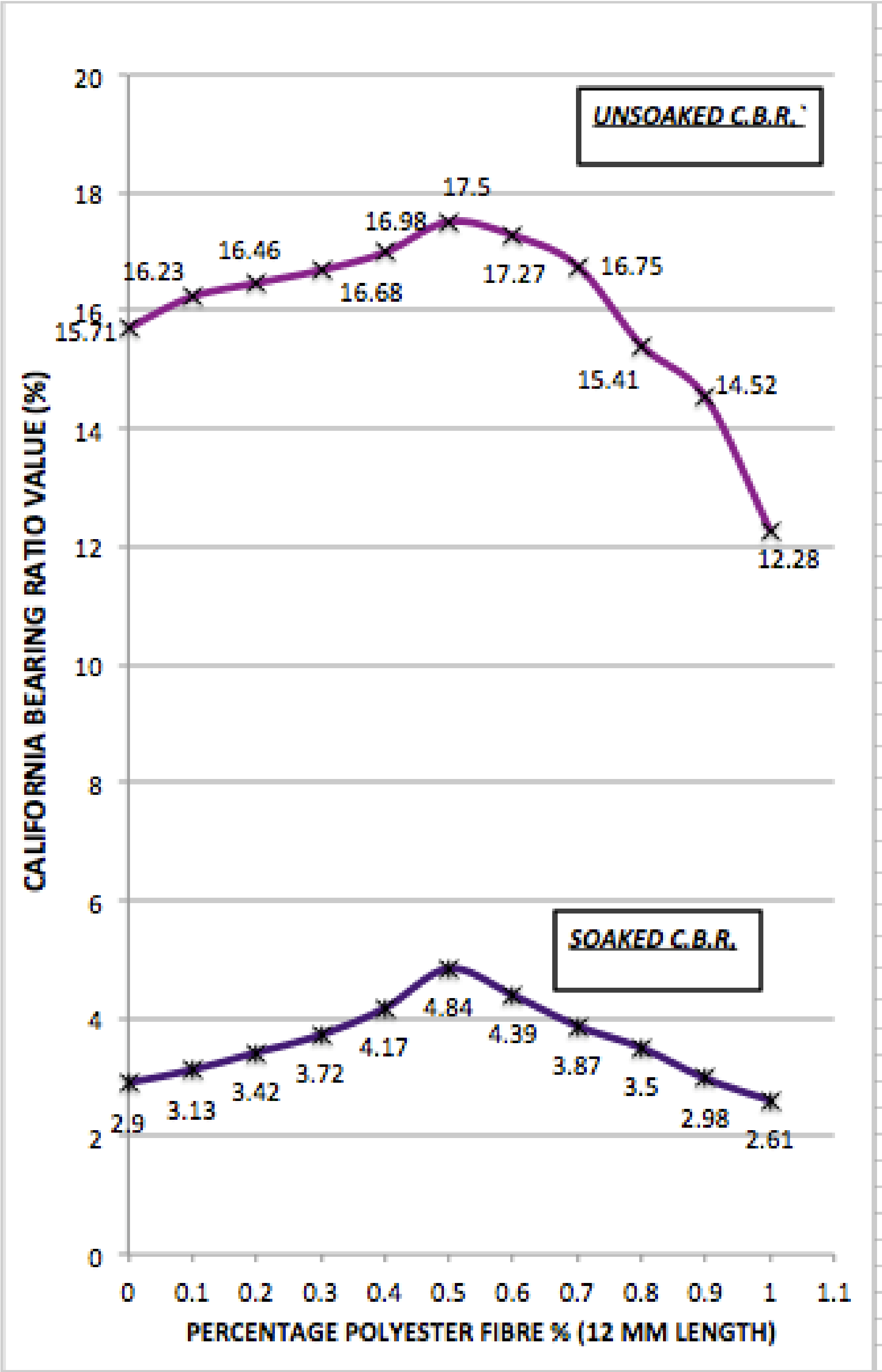


FIGURE 35: VARIATION OF CALIFORNIA BEARING RATIO OF CLAY WITH 12 mmPOLYESTER FIBRE DESIGN CURVE

5.3 Graphs Showing The Effect Of Fibre Length On Various Tests That Have Been Carried Out

In this chapter following graphs have been shown:

- Figure 36: Effect of Fibre Length on Maximum Dry Density of Sand
- Figure 37: Effect of Fibre Length on Optimum Moisture Content of Sand
- Figure 38: Effect of Fibre Length on Maximum Dry Density of Clay
- Figure 39: Effect of Fibre Length on Optimum Moisture Content of Clay
- Figure 40: Effect of Fibre Length on California Bearing Ratio (unsoaked) value of Sand
- Figure 41: Effect of Fibre Length on California Bearing Ratio (soaked) value of Sand
- Figure 42: Effect of Fibre Length on California Bearing Ratio (unsoaked) value of Clay
- Figure 43: Effect of Fibre Length on California Bearing Ratio (soaked) value of Clay

EFFECT OF FIBRE LENGTH ON MAXIMUM DRY DENSITY OF SAND

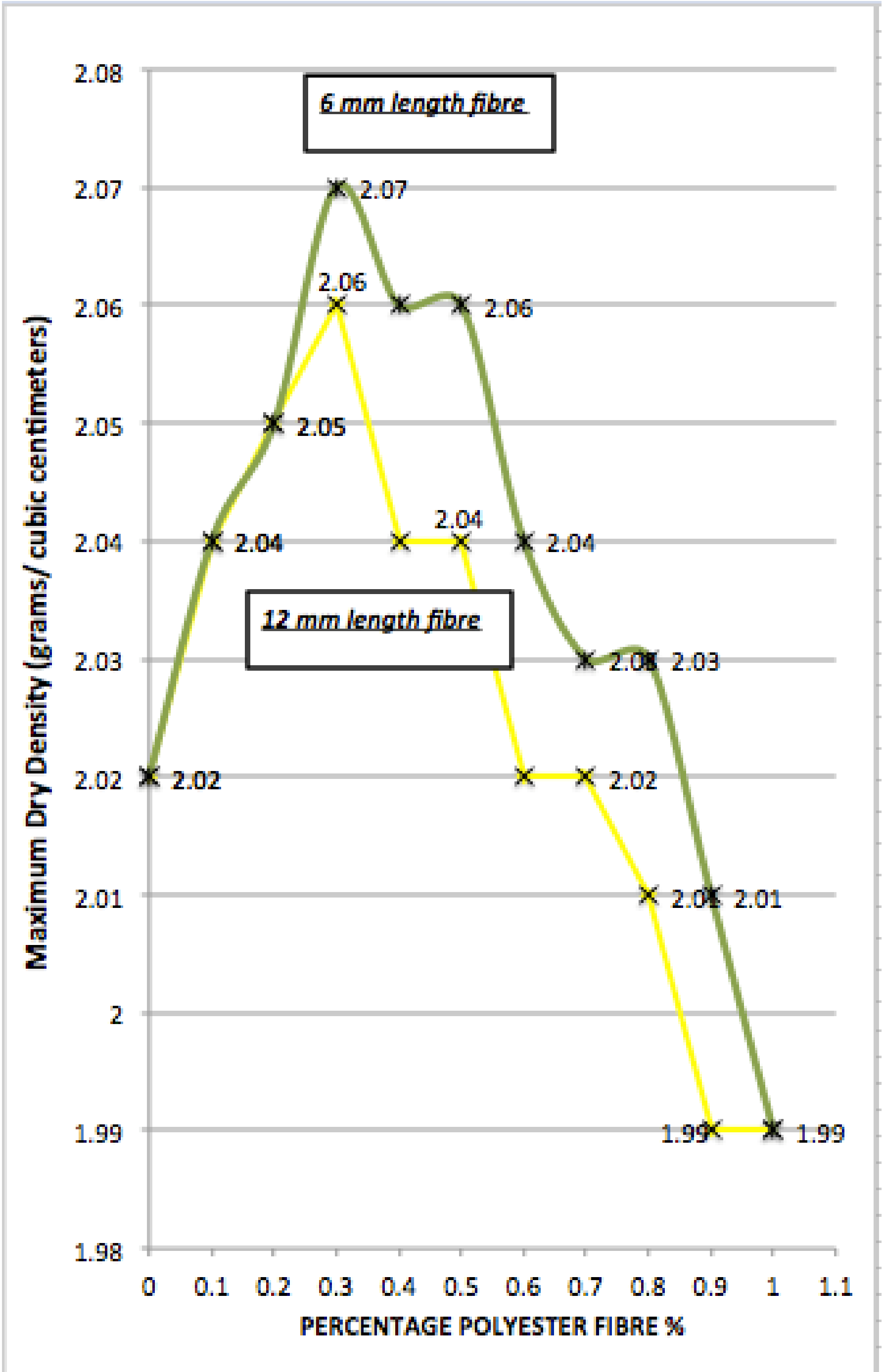


FIGURE 36: EFFECT OF FIBRE LENGTH ON MAXIMUMDRY DENSITY OF SAND

EFFECT OF FIBRE LENGTH ON OPTIMUM MOISTURE CONTENT OF SAND

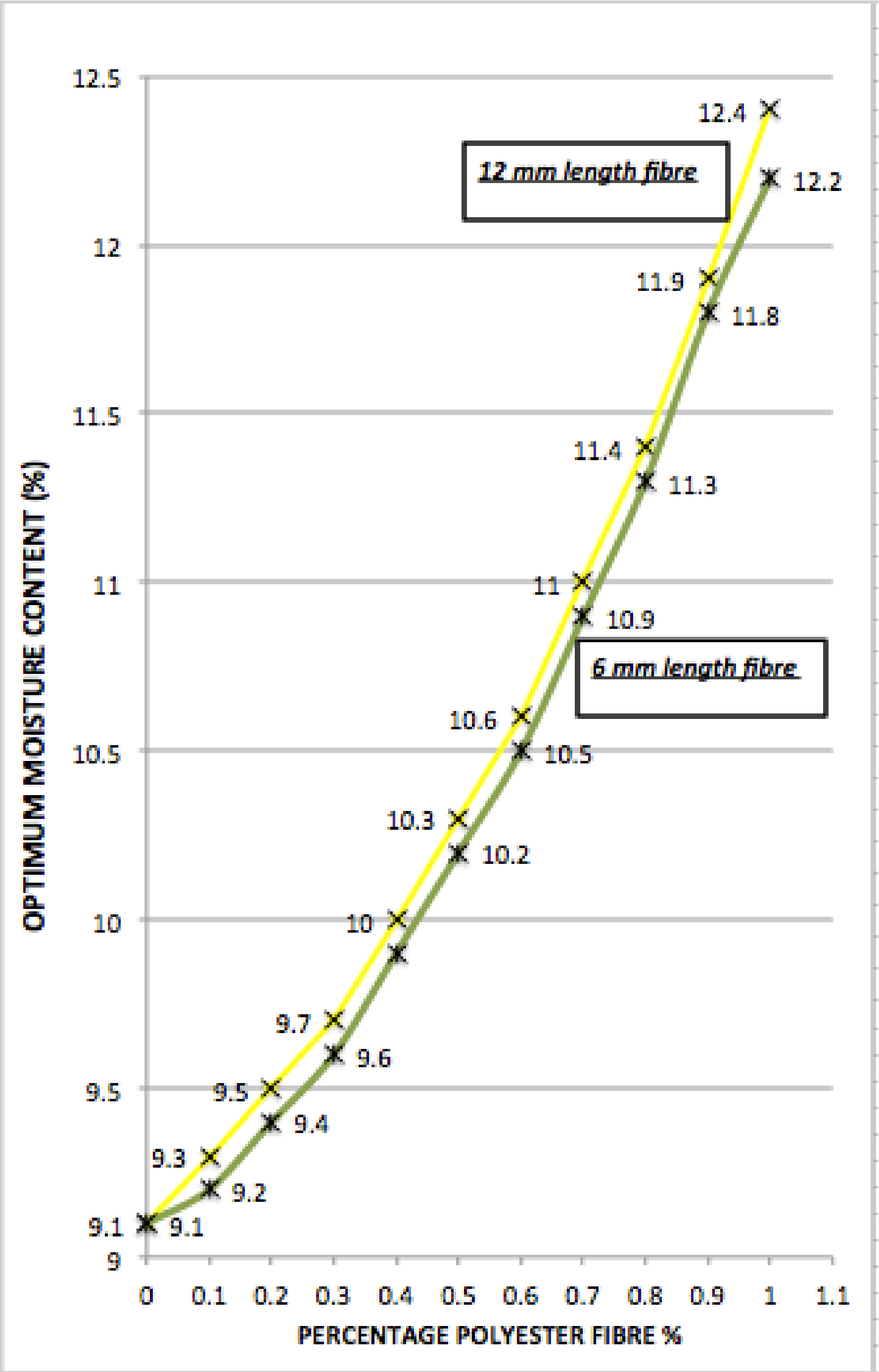


FIGURE 37: EFFECT OF FIBRE LENGTH ON OPTIMUM MOISTURE CONTENT OF SAND

EFFECT OF FIBRE LENGTH ON MAXIMUM DRY DENSITY OF CLAY

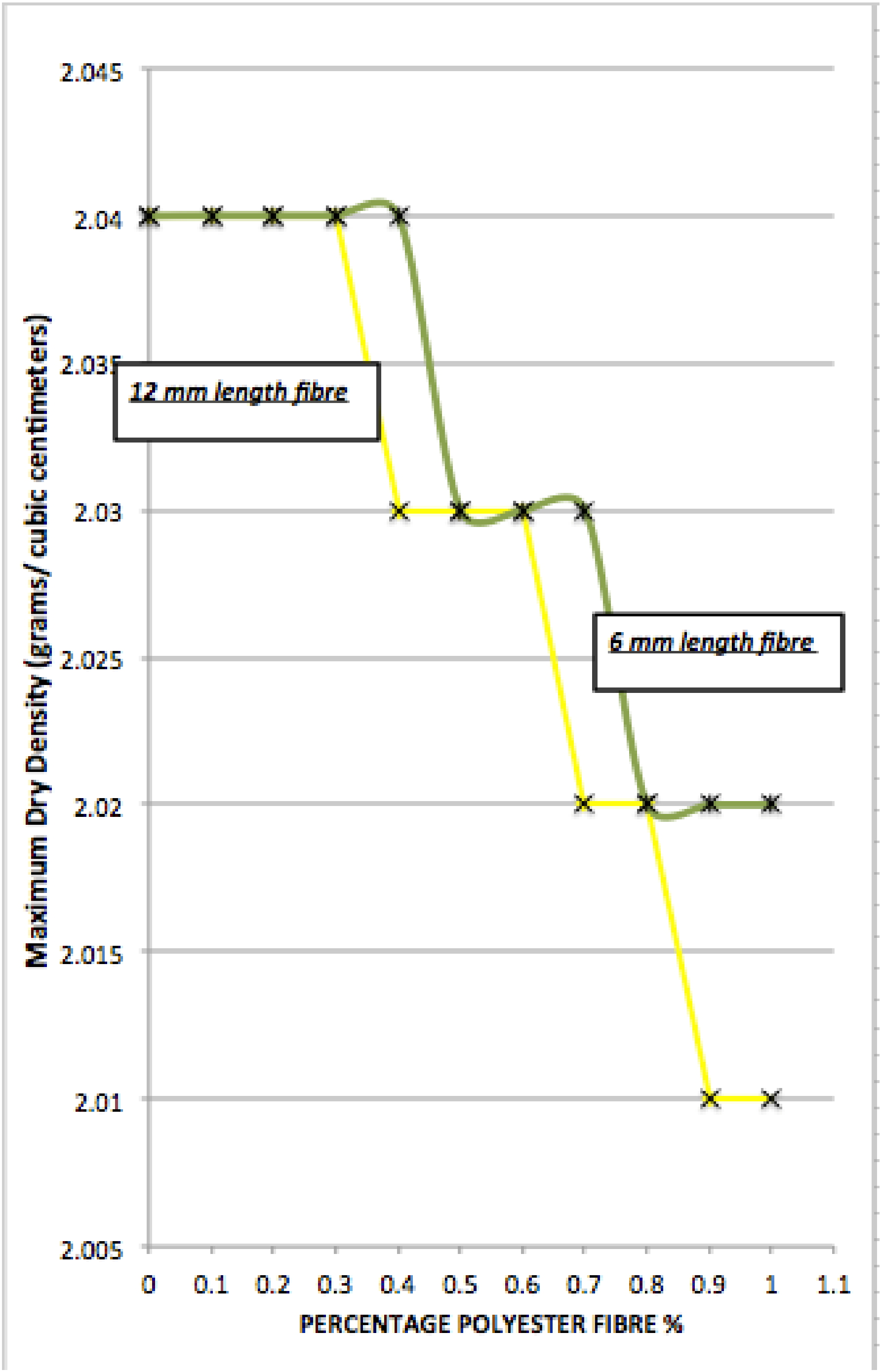


FIGURE 38: EFFECT OF FIBRE LENGTH ON MAXIMUM DRY DENSITY OF CLAY

EFFECT OF FIBRE LENGTH ON OPTIMUM MOISTURE CONTENT OF CLAY

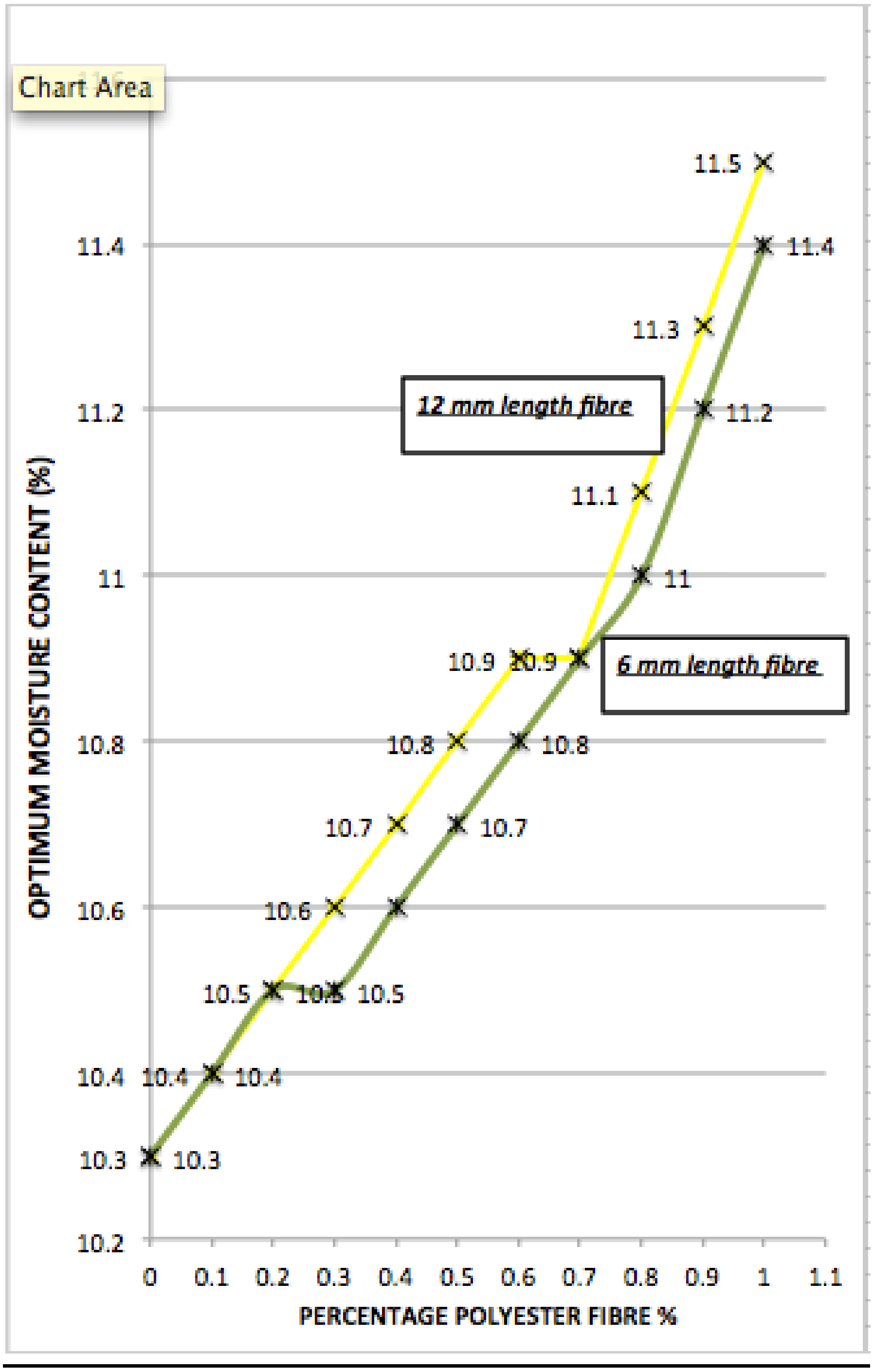


FIGURE 39: EFFECT OF FIBRE LENGTH ON OPTIMUM MOISTURE CONTENT OF CLAY

EFFECT OF FIBRE LENGTH ON CALIFORNIA BEARING RATIO (UNSOAKED) OF SAND

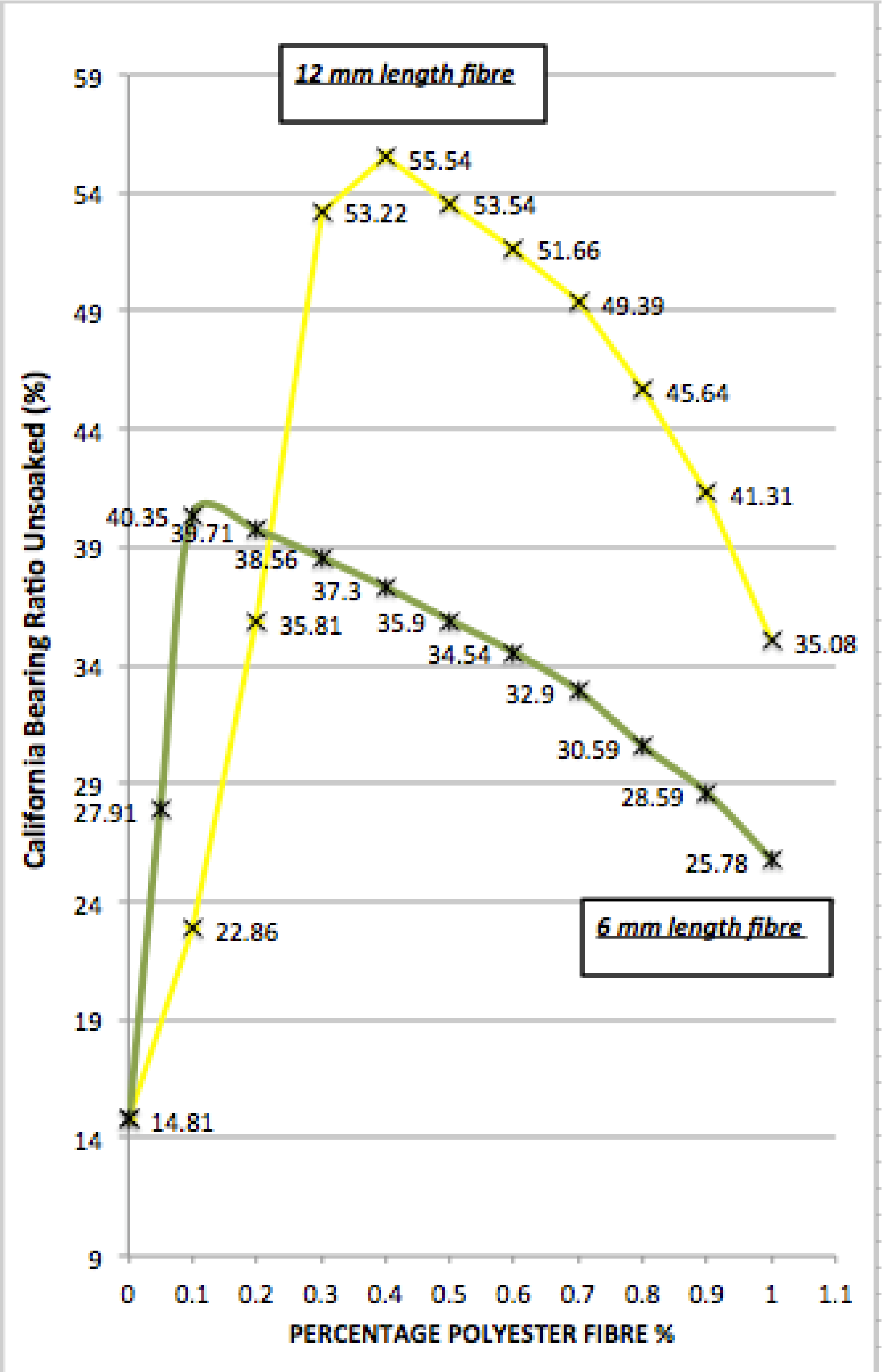


FIGURE 40: EFFECT OF FIBRE LENGTH ON CALIFORNIA BEARING RATIO (UNSOAKED) VALUE OF SAND

EFFECT OF FIBRE LENGTH ON CALIFORNIA BEARING RATIO (SOAKED) OF SAND

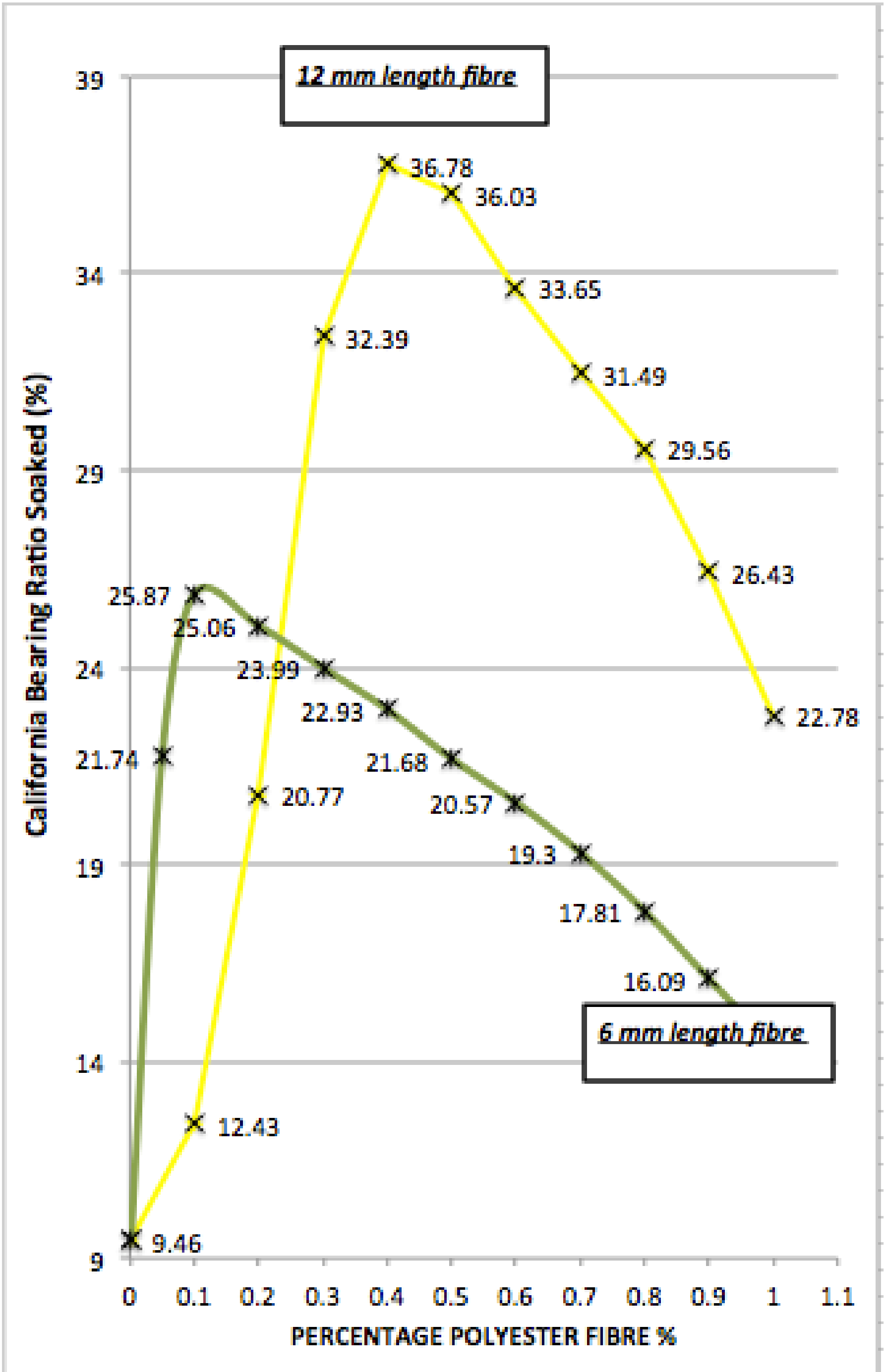


FIGURE 41: EFFECT OF FIBRE LENGTH ON CALIFORNIA BEARING RATIO (SOAKED) VALUE OF SAND

EFFECT OF FIBRE LENGTH ON CALIFORNIA BEARING RATIO (UNSOAKED) OF CLAY

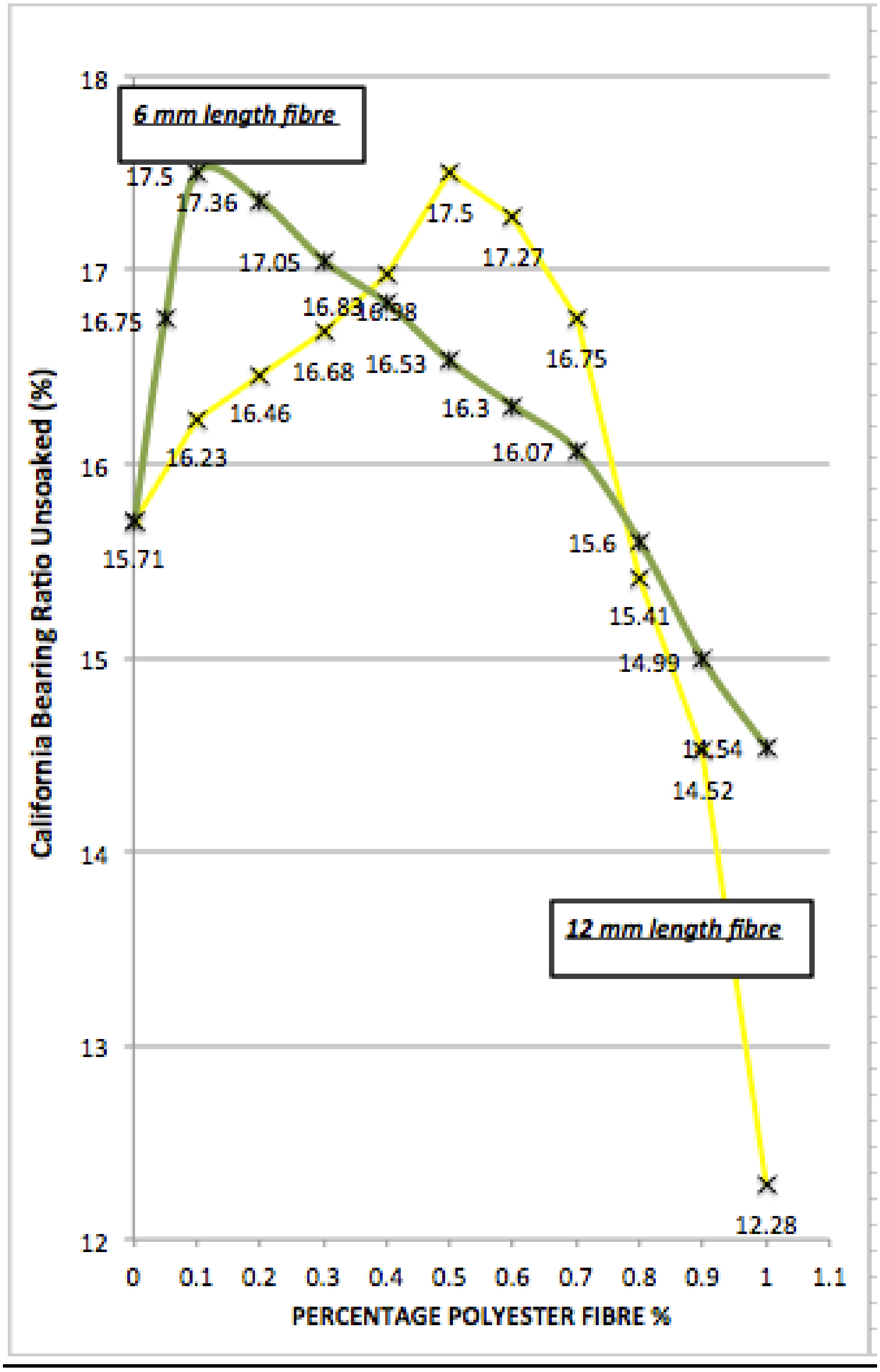


FIGURE 42: EFFECT OF FIBRE LENGTH ON CALIFORNIA BEARING RATIO (UNSOAKED) VALUE OF CLAY

EFFECT OF FIBRE LENGTH ON CALIFORNIA BEARING RATIO (SOAKED) OF CLAY

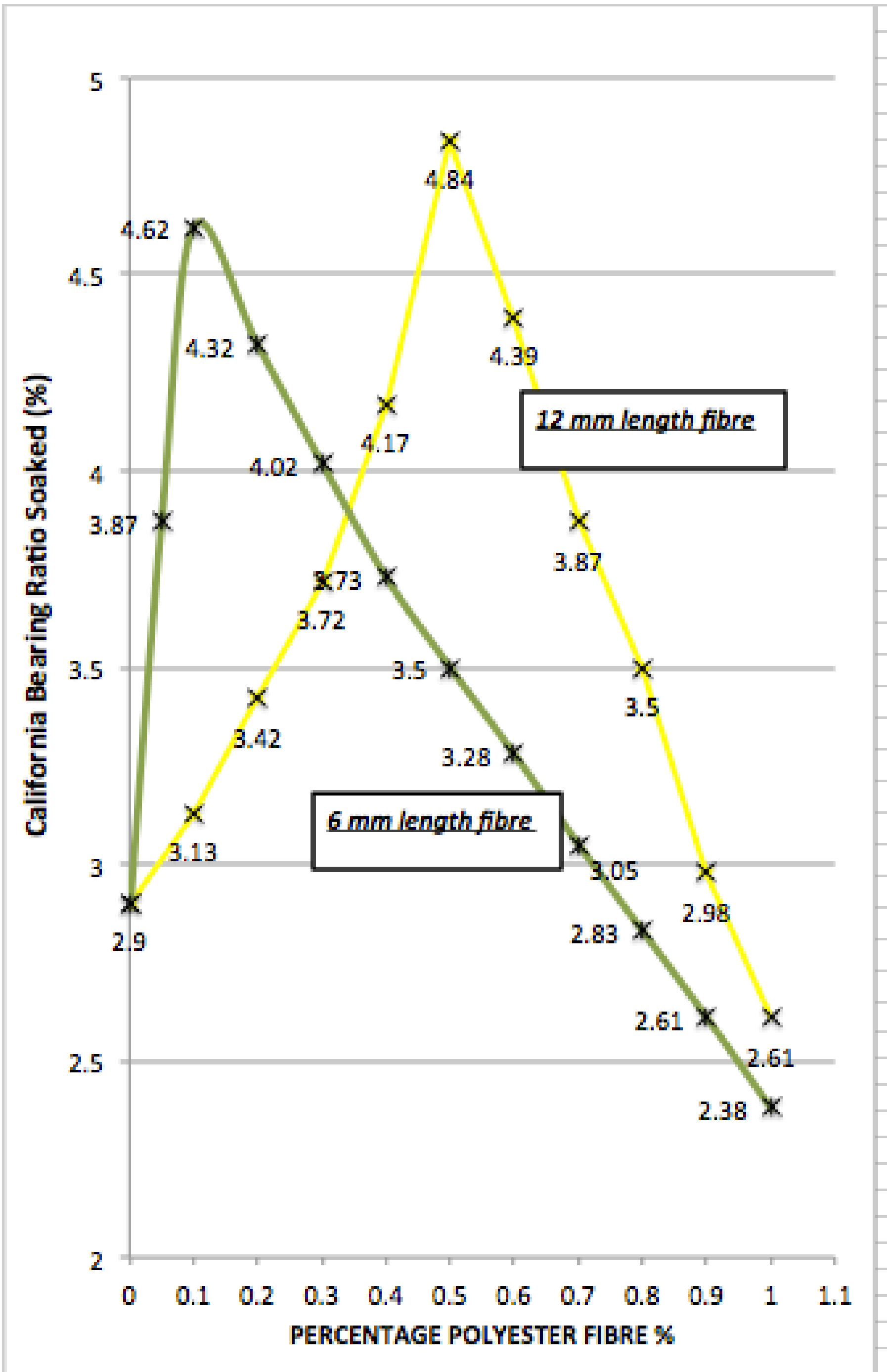


FIGURE 43: EFFECT OF FIBRE LENGTH ON CALIFORNIA BEARING RATIO (SOAKED) VALUE OF CLAY

5.4Graphs showing mathematical relation between percentage gain of California bearing ratio and amount of polyester fibre (in percentage) required to attain that gain in strength of CBR value.

In this chapter following graphs have been shown

5.4.1 Derivation of Mathematical Relations

- Mathematical relations between percentage gain in CBR value and percentage of polyester fibre to beadded, are derived.
- Linear mathematical functions have been derived.
- Separate functions have been derived for soaked and unsoaked conditions.
- By using these relations a user knowing the amount of percentage gain in CBR value required can find out the percentage of polyester fibre required to be added.

5.4.2Mathematical Relations Using Curve Fitting Method

Following are the mathematical results derived.

TABLE 25: Mathematical Relations Using Curve Fitting Method

S. No.	Type of Soil	Length of Fibre	Type of CBR value	Mathematical Relation
1	SM	6 mm	Unsoaked	**Y=0.0006X – 0.0584**
2	SM	6 mm	Soaked	**Y=0.0005X – 0.0571**
3	SM	12 mm	Unsoaked	**Y=0.0013X – 0.114**
4	SM	12 mm	Soaked	**Y=0.0012X – 0.0896**
5	CI	6 mm	Unsoaked	**Y=0.0117X – 1.1668**
6	CI	6 mm	Soaked	**Y=0.002X – 0.2**
7	CI	12 mm	Unsoaked	**Y=0.0468X - 4.6978**
8	CI	12 mm	Soaked	**Y=0.0078X – 0.795**

Where, Y= % Polyester Fibre
X= % Increase In California Bearing Ratio Value

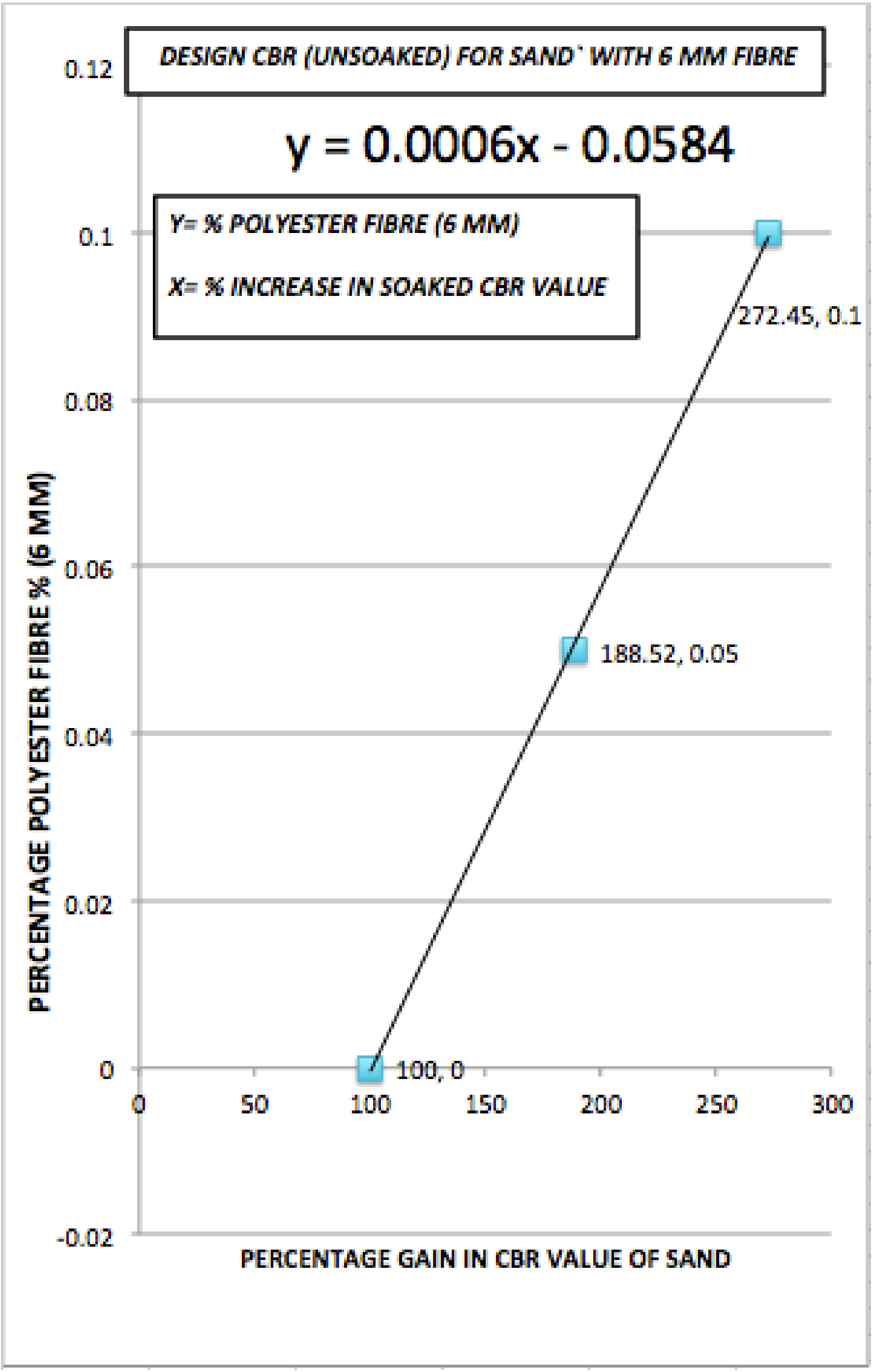


FIGURE 44: MATHEMATICAL RELATION BETWEEN PERCENTAGE GAIN IN CBR VALUE OF SAND AND PERCENTAGE POLYESTER FIBRE REQUIRED TO BE ADDED

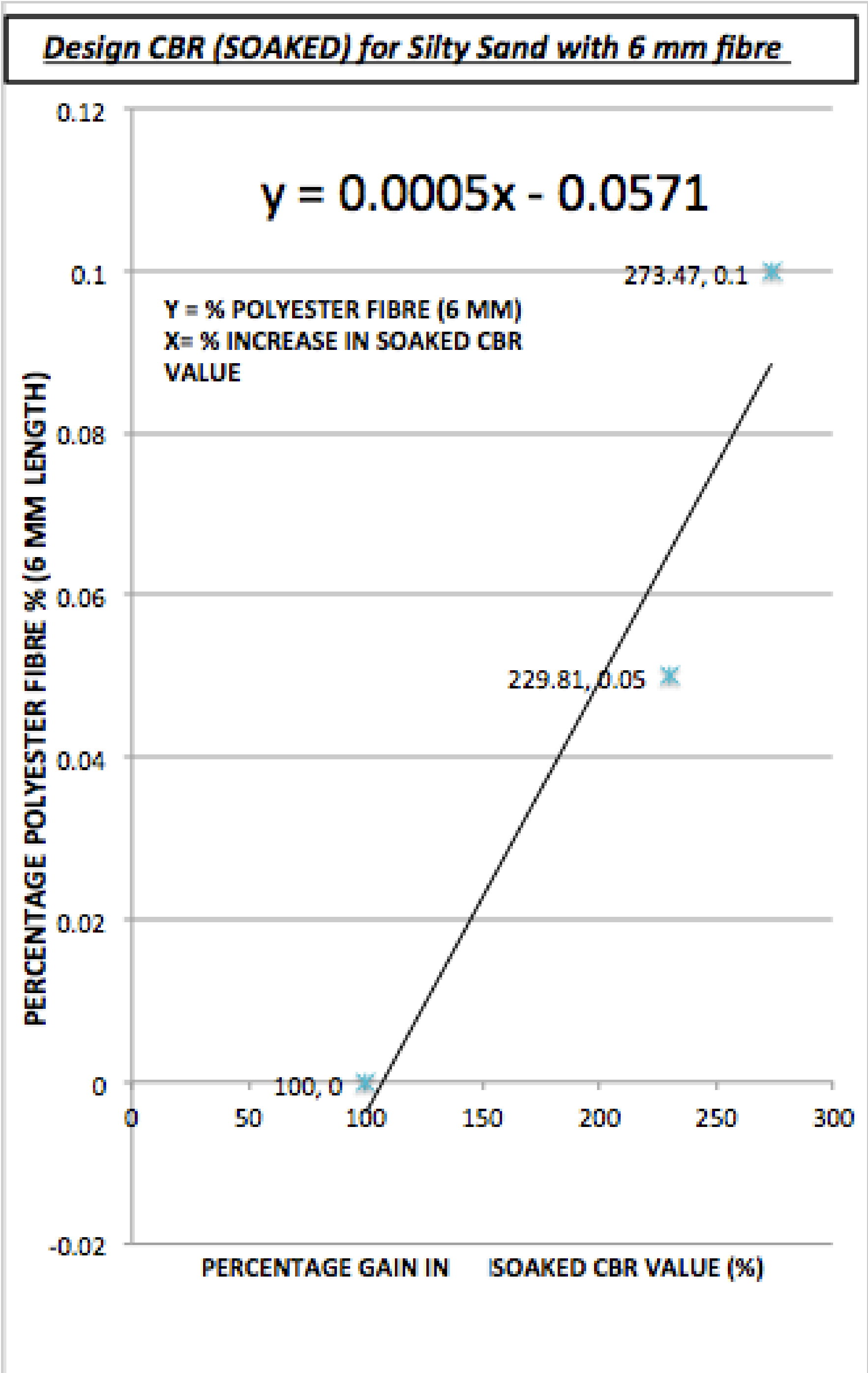


FIGURE 45: MATHEMATICAL RELATION BETWEEN PERCENTAGE GAIN IN CBR VALUE OF SAND AND PERCENTAGE POLYESTER FIBRE REQUIRED TO BE ADDED

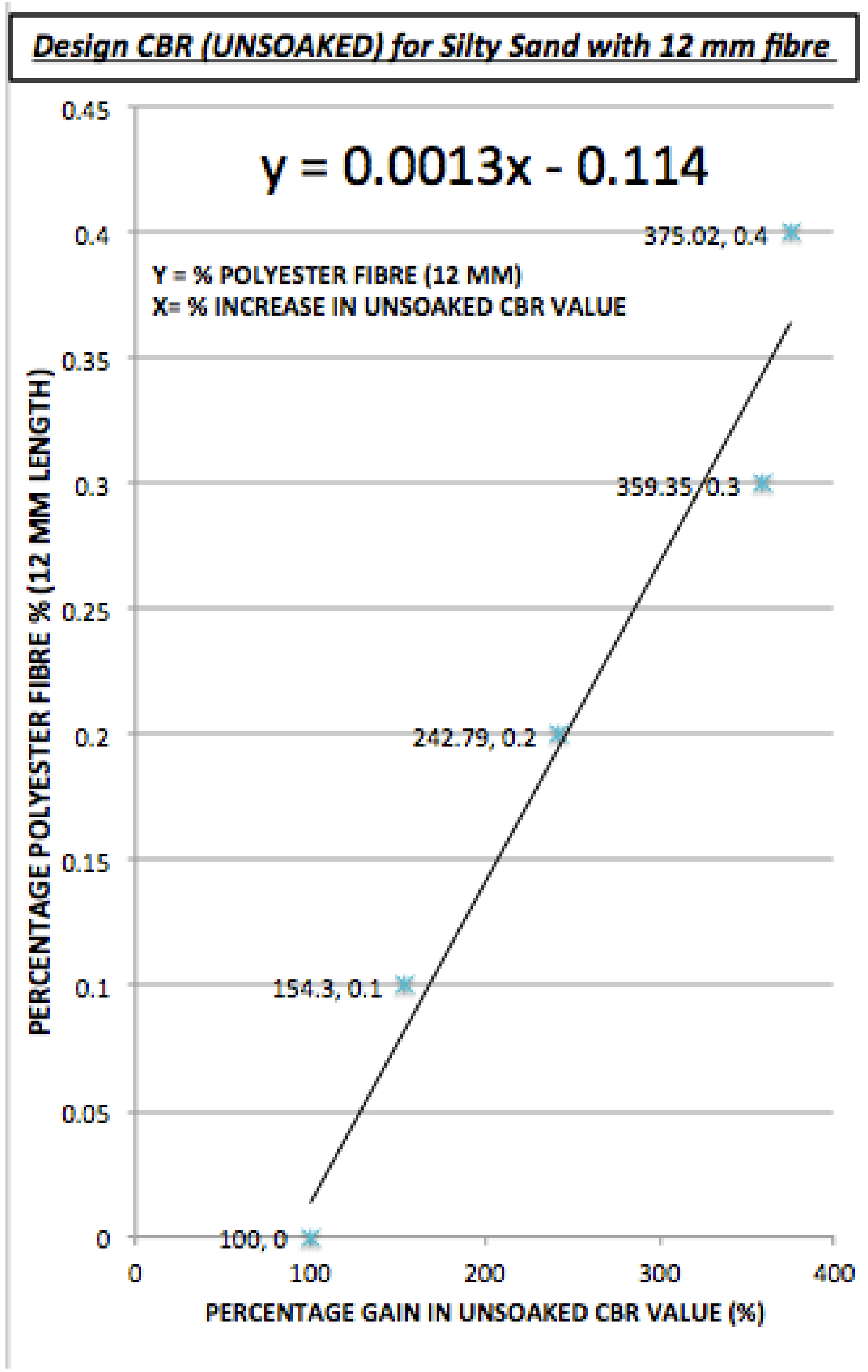


FIGURE 46: MATHEMATICAL RELATION BETWEEN PERCENTAGE GAIN IN CBR VALUE OF SAND AND PERCENTAGE POLYESTER FIBRE REQUIRED TO BE ADDED

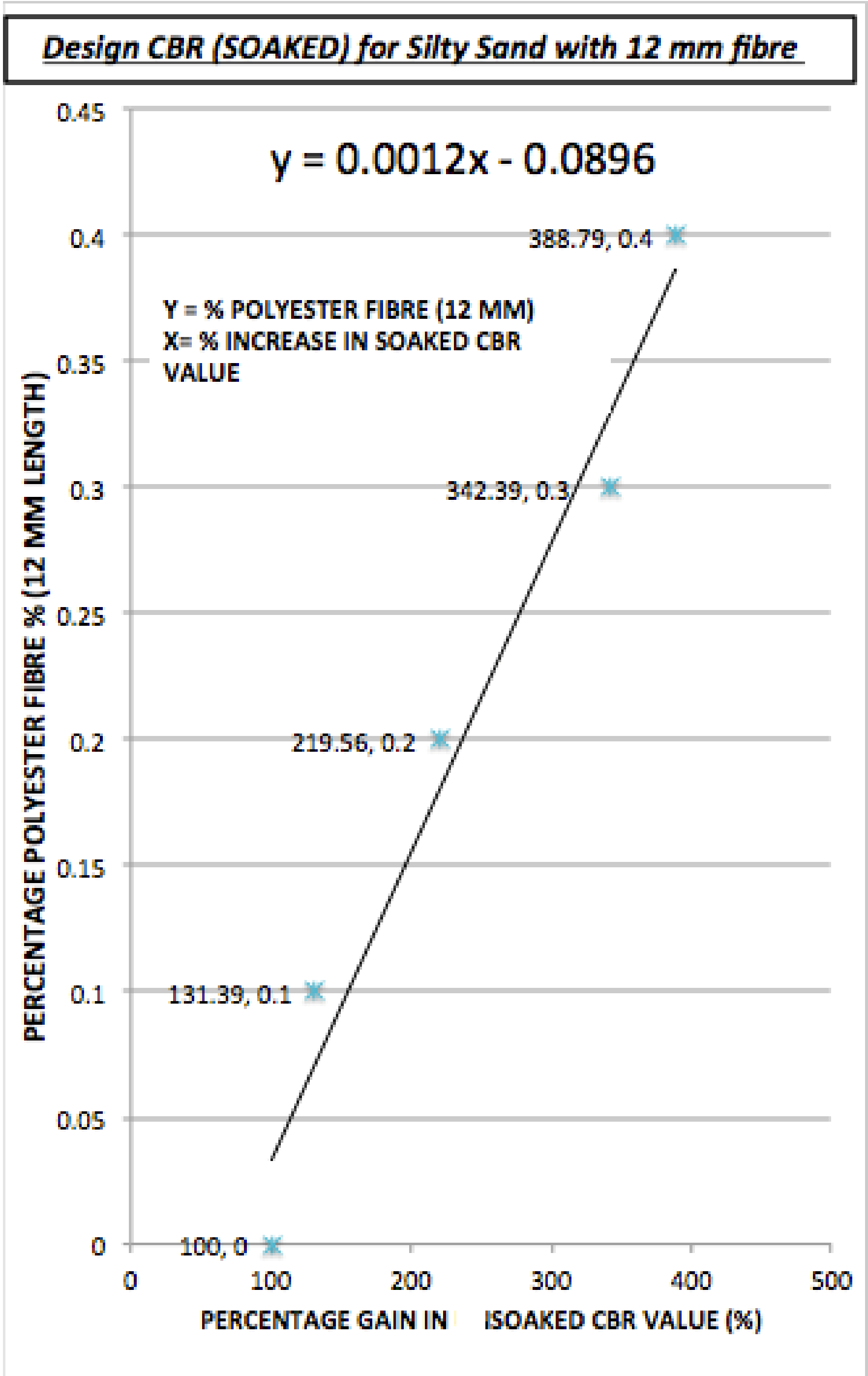


FIGURE 47: MATHEMATICAL RELATION BETWEEN PERCENTAGE GAIN IN CBR VALUE OF SAND AND PERCENTAGE POLYESTER FIBRE REQUIRED TO BE ADDED

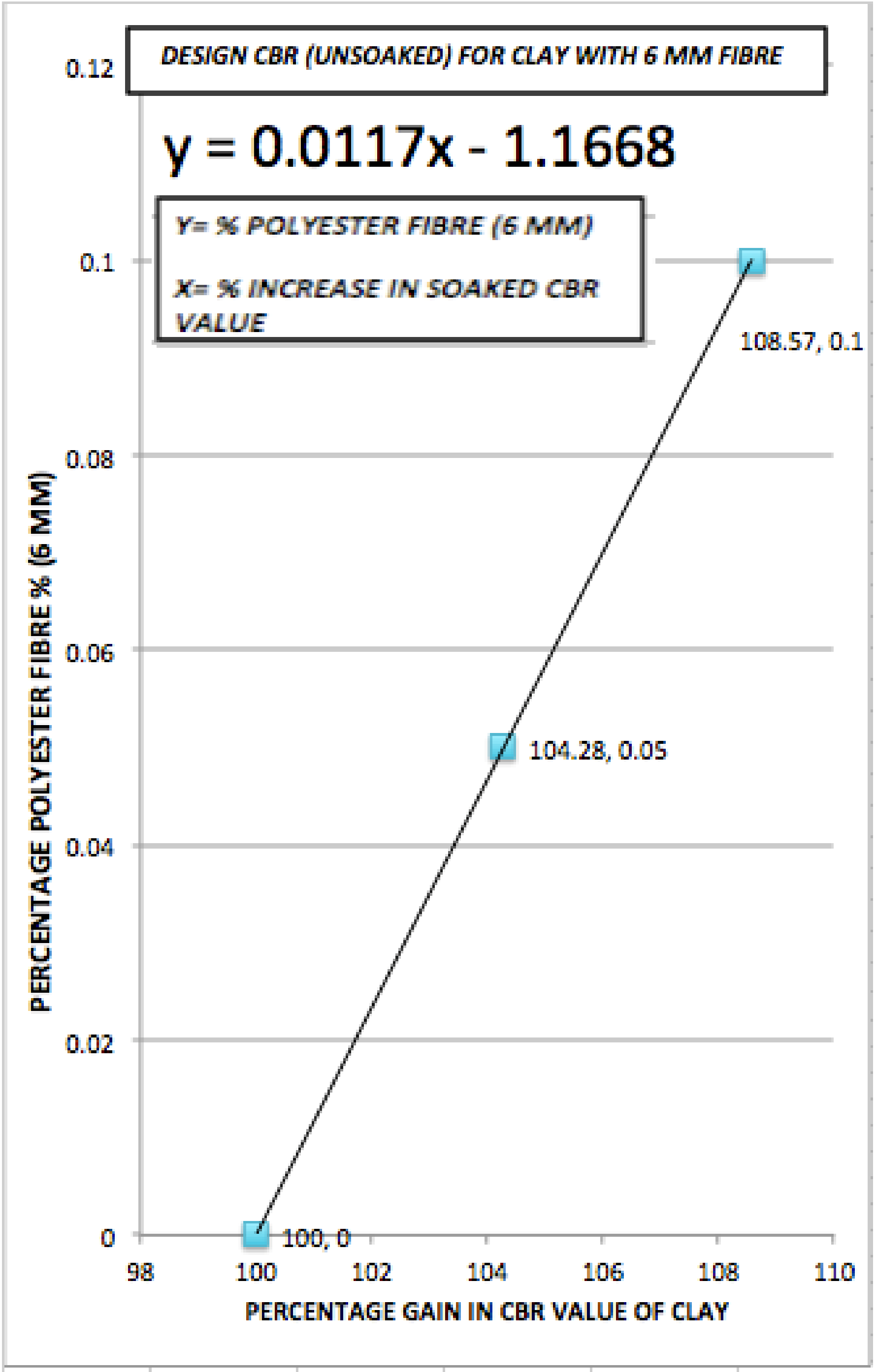


FIGURE 48: MATHEMATICAL RELATION BETWEEN PERCENTAGE GAIN IN CBR VALUE OF CLAY AND PERCENTAGE POLYESTER FIBRE REQUIRED TO BE ADDED

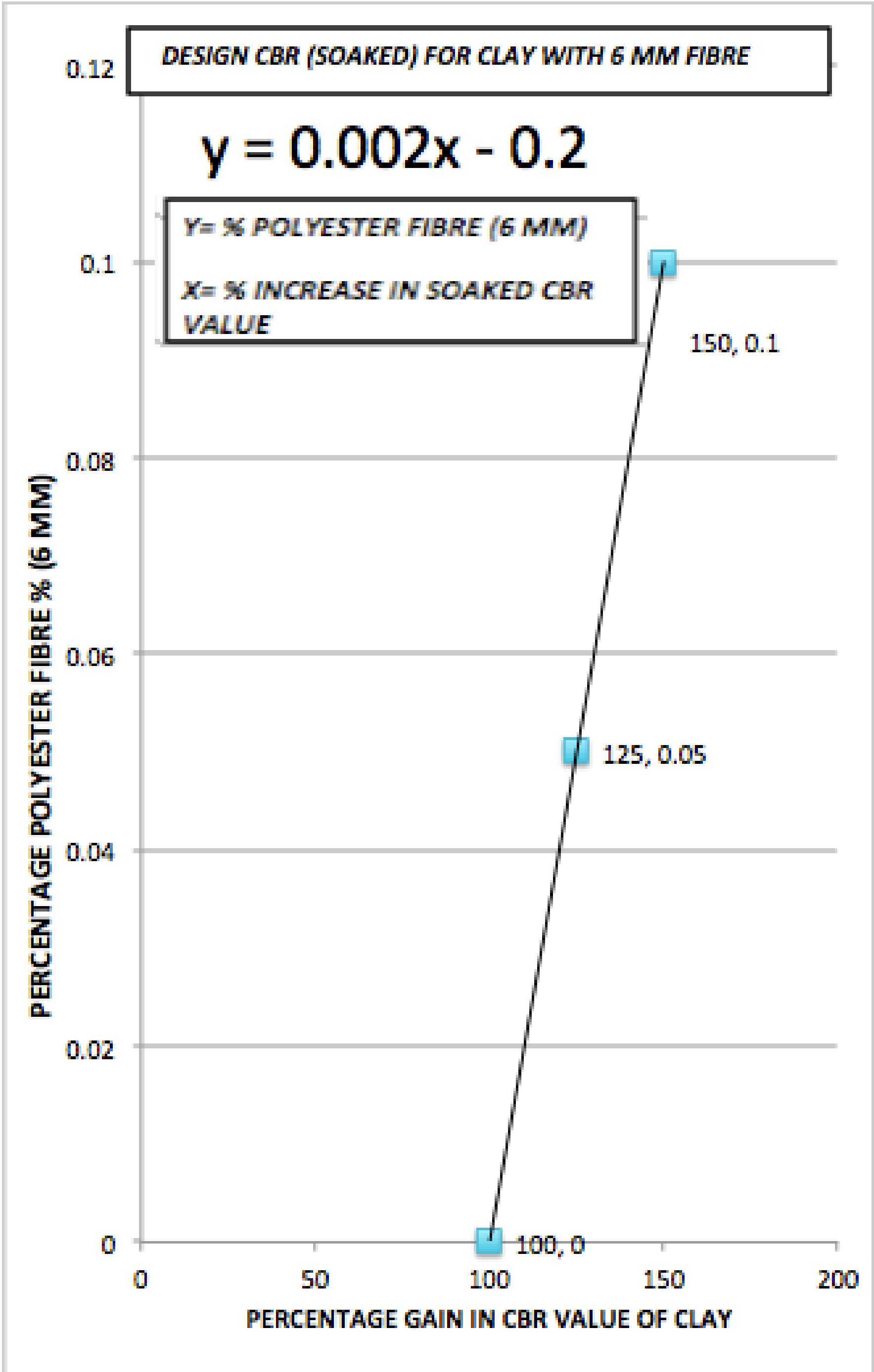


FIGURE 49: MATHEMATICAL RELATION BETWEEN PERCENTAGE GAIN IN CBR VALUE OF CLAY AND PERCENTAGE POLYESTER FIBRE REQUIRED TO BE ADDED

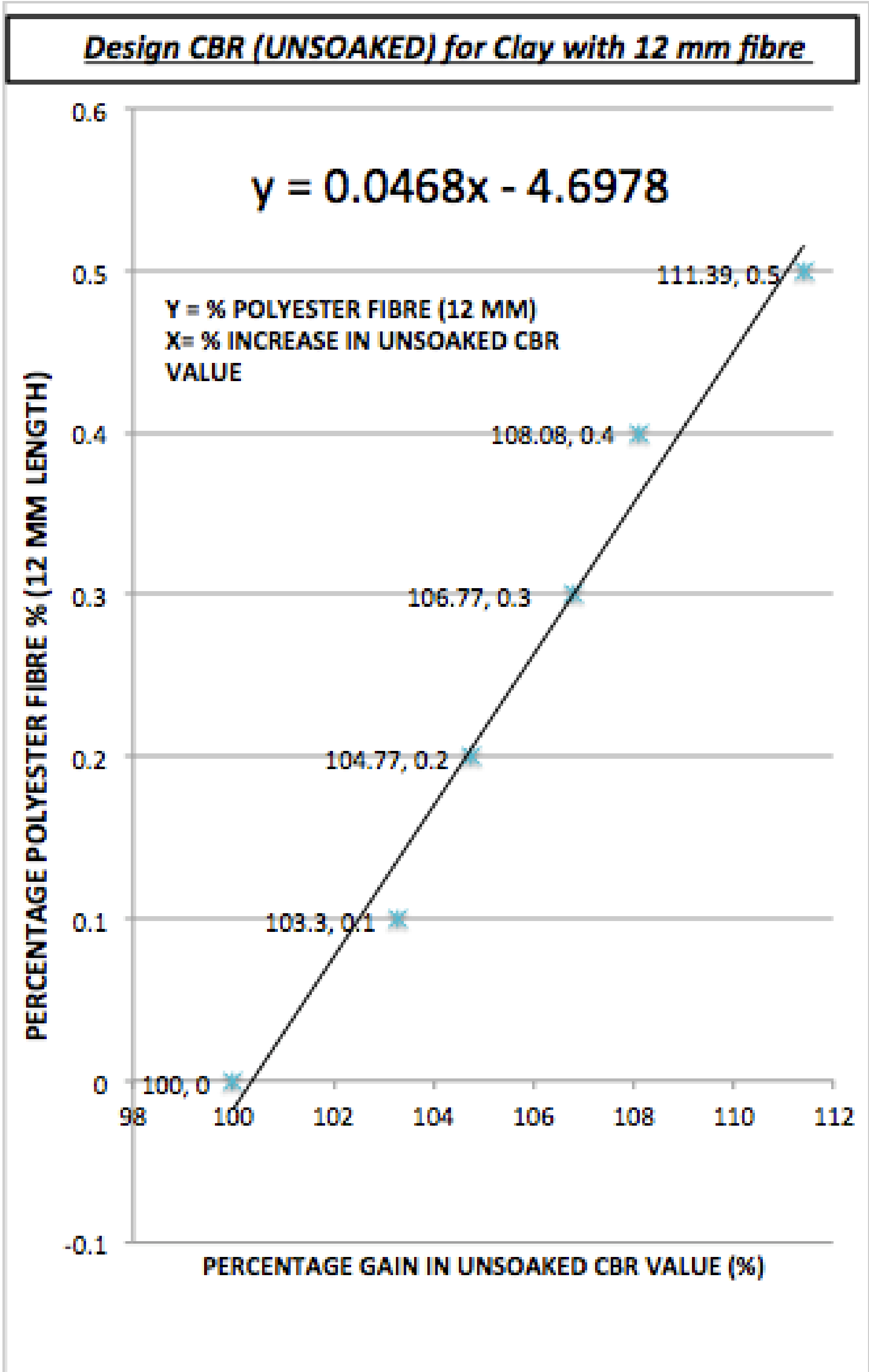


FIGURE 50: MATHEMATICAL RELATION BETWEEN PERCENTAGE GAIN IN CBR VALUE OF CLAY AND PERCENTAGE POLYESTER FIBRE REQUIRED TO BE ADDED

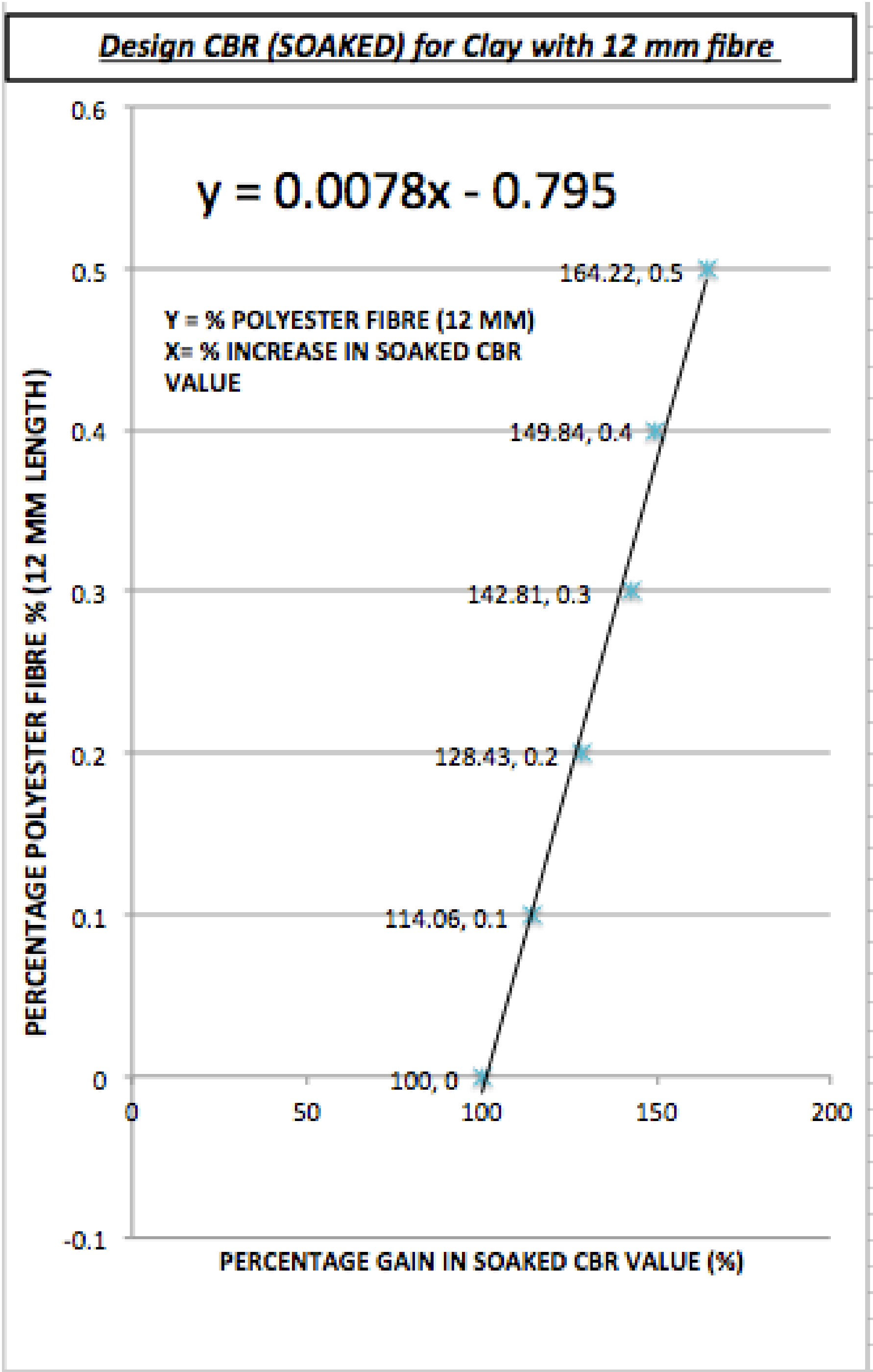


FIGURE 51: MATHEMATICAL RELATION BETWEEN PERCENTAGE GAIN IN CBR VALUE OF CLAY AND PERCENTAGE POLYESTER FIBRE REQUIRED TO BE ADDED

CHAPTER 6

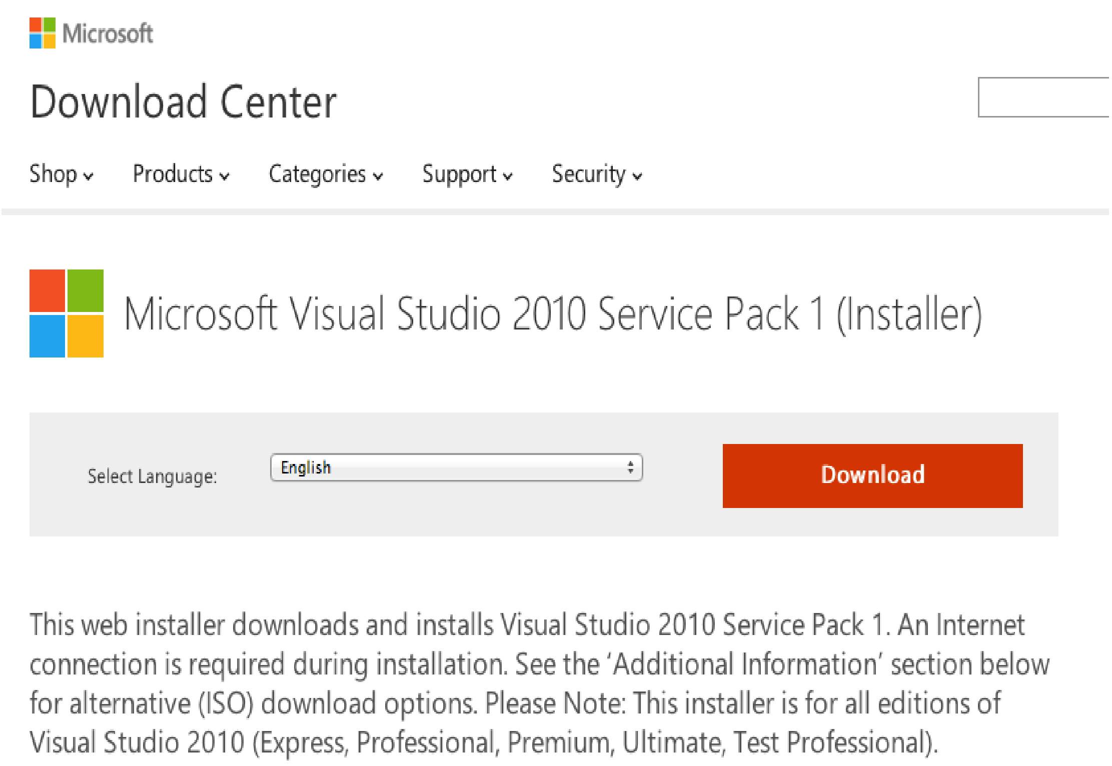
SOFTWARE DEVELOPMENT

6.1 Microsoft Visual Studio 2010

Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft. It is used to develop computer programs for Microsoft Windows superfamily of operating systems, as well as web sites, web applications and web services. Visual Studio uses Microsoft software development platforms such as Windows API, Windows Forms, Windows Presentation Foundation, Windows Store and Microsoft Silverlight. It can produce both native code and managed code.

Visual Studio supports different programming languages and allows the code editor and debugger to support (to varying degrees) nearly any programming language, provided a language-specific service exists. Built-in languages include C,[5] C++ and C++/CLI (via Visual C++), VB.NET (via Visual Basic .NET), C# (via Visual C#), and F# (as of Visual Studio 2010[6]). Support for other languages such as M, Python, and Ruby among others is available via language services installed separately. It also supports XML/XSLT, HTML/XHTML, JavaScript and CSS.

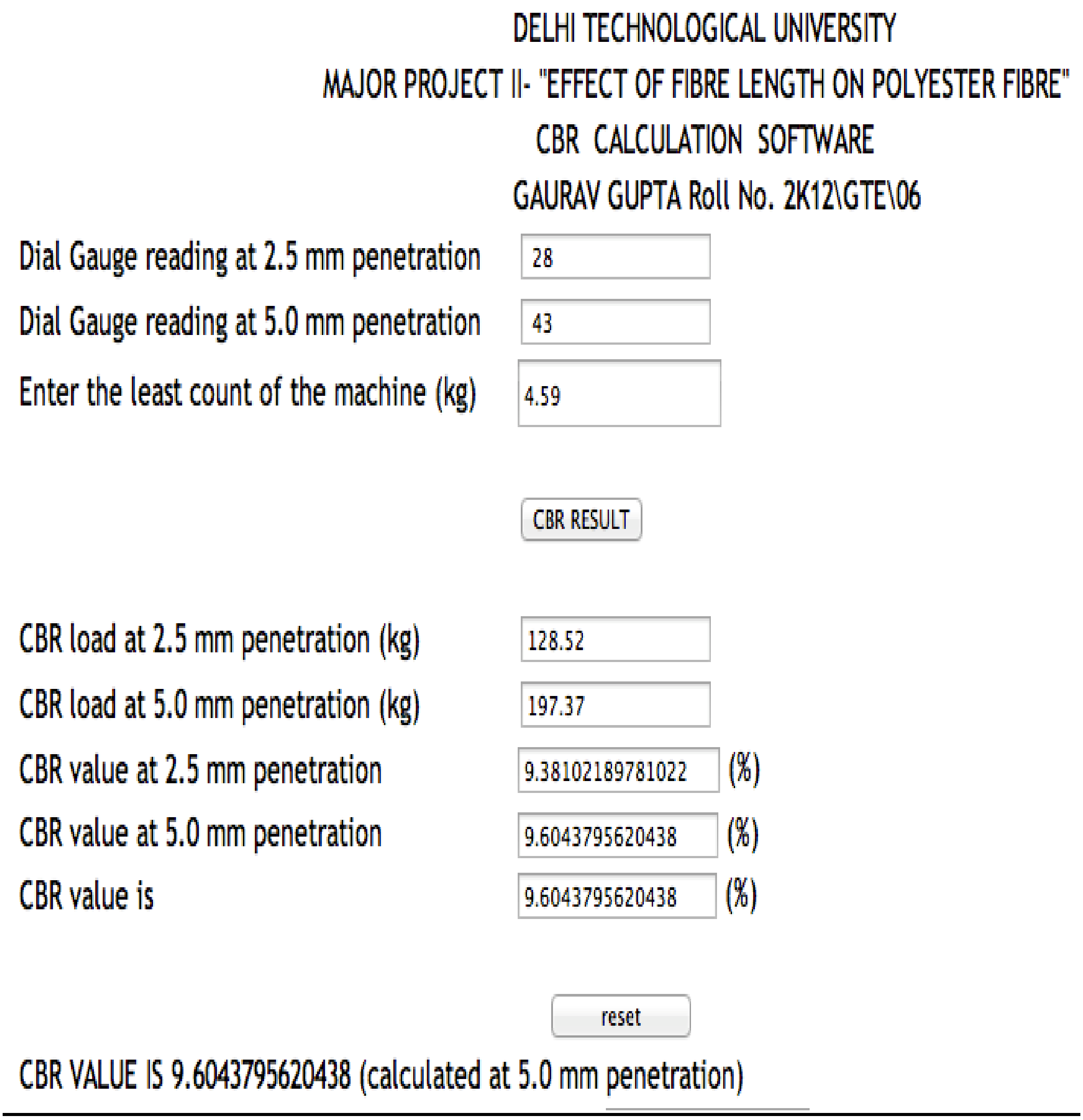
Microsoft provides free download of Microsoft Visual Studio 2010 on there website, URL: http://www.microsoft.com/en-in/download/details.aspx?id=23691



6.2 Working Example Of The Program:

Taking an example in various steps has showed the working of the program. In the following program, a case of sandy soil with 12 mm fibre for soaked case has been taken. Following pictures show the steps involved in working of the program.

Step 1: Enter The Dial Gauge Readings Observed and Press "CBR RESULT" button to Obtain CBR Values



Step 2: Enter Type Of Soil, Length Of Fibre And Type Of Sample

CBR VALUE IS 9.6043795620438 (calculated at 5.0 mm penetration)

Enter the type of soil (1 for clay or 2 for sand)	2
Enter the length of the fibre (6 mm or 12 mm)	12
Enter type of sample: 1 for Unsoaked 2 for Soaked	2

RESULT

Maximum gain in CBR value possible is	388.79

We get the maximum gain in CBR value possible for our case

Step 3: Enter the Required Percentage Gain in CBR value Required

Maximum gain in CBR value possible is	388.79
Enter the required gain in CBR value	300

Result

CBR value to be attained is	28.8131386861314

Result

Press Result Button to get the CBR value (%) to be attained

Step 4: Press Result Button to obtain the proposed percentage fibre to be added in soil to obtain the design CBR value

CBR value to be attained is 28.813138686131 4

Result

proposed percentage of polyester fibre to be added 2.3432

Mathematical Equation used for the above calculation Y = 0.0117x-0.0896

where Y= perentage polyester fibre added and X= percentage gain in CBR value

The mathematical relation used to find the percentage fibre added is displayed in the end

NOTE: The program coding has been given in Annexure-1

CHAPTER 7

CONCLUSIONS

AND

FUTURE SCOPE

CONCLUSIONS

1. For 6 mm length fibre in Sand, highest value of maximum dry density obtained was 2.07-grams/ cu. centimeters at 0.3% polyester fibre. The lowest value of maximum dry density obtained was 2.00-grams/ cu. centimeters at 1.0% polyester fibre.

2. For 12 mm length fibre in Sand, highest value of maximum dry density obtained was 2.06-grams/ cu. centimeters at 0.3% polyester fibre. The lowest value of maximum dry density obtained was 1.99-grams/ cu. centimeters at 1.0% polyester fibre.

3. For 6 mm length fibre in Sand, the maximum value of 12.2% optimum moisture content was observed at 1.0% polyester fibre.

4. For 12 mm length fibre in Sand, the maximum value of 12.4% optimum moisture content was observed at 1.0% polyester fibre.

5. For 6 mm length fibre in Clay, highest value of maximum dry density obtained was 2.04-grams/ cu. centimeters at 0.0%, 0.1%, 0.2%, 0.3%, 0.4% polyester fibre. The maximum dry density fell to 2.03-grams/ cu. centimeters for 0.5%, 0.6%, and 0.7% of polyester fibre. The maximum dry density fell further to 2.02-grams/ cu. centimeters for 0.8%, 0.9%, and 1.0% of polyester fibre.

6. For 12 mm length fibre in Clay, highest value of maximum dry density obtained was 2.04-grams/ cu. centimeters at 0.0%, 0.1%, 0.2%, and 0.3%, polyester fibre. The maximum dry density fell to 2.03-grams/ cu. centimeters for 0.4%, 0.5%, and 0.6% of polyester fibre. The maximum dry density fell to 2.02-grams/ cu. centimeters for 0.7% and 0.8% of polyester fibre. The maximum dry density fell to 2.01-grams/ cu. centimeters for 0.9% and 1.0% of polyester fibre.

7. For 6 mm length fibre in Clay, the maximum value of 11.4% optimum moisture content was observed at 1.0% polyester fibre.

8. For 12 mm length fibre in Clay, the maximum value of 11.5% optimum moisture content was observed at 1.0% polyester fibre.

9. For 6 mm fibre in sand, California Bearing Ratio of sand increased steeply from 0% polyester fibre to 0.1% fibre. Highest average value of **soaked CBR, 25.87 %** was obtained at 0.1% fibre content. Highest average value of **unsoaked CBR, 40.35 %** was obtained at 0.1% fibre. On further increase in fibre content there was a gradual fall in the CBR value, giving the lowest value at 1.0% fibre content. Lowest average value of **soaked CBR, 14.38 %** was obtained at 1.0% fibre. Lowest average value of **unsoaked CBR, 25.78 %** was obtained at 1.0% fibre.

10. For 12 mm fibre in sand, California Bearing Ratio of sand increased gradually from 0% polyester fibre to 0.4% fibre content. Highest average value of **soaked CBR, 25.87 %** was obtained at 0.4% fibre. Highest average value of **unsoaked CBR, 40.35 %** was obtained at 0.4% fibre. On further increase in fibre content there was a gradual fall in the CBR value, giving the lowest value at 1.0% fibre content. Lowest average value of **soaked CBR, 22.78 %** was obtained at 1.0% fibre. Lowest average value of **unsoaked CBR, 35.08%** was obtained at 1.0% fibre.

11. For 6 mm fibre in Clay, California Bearing Ratio of clay increased steeply from 0% polyester fibre to 0.1% fibre. Highest average value of **soaked CBR, 4.62 %** was obtained at 0.1% fibre content. Highest average value of **unsoaked CBR, 17.50 %** was obtained at 0.1% fibre. On further increase in fibre content there was a gradual fall in the CBR value, giving the lowest value at 1.0% fibre content. Lowest average value of **soaked CBR, 2.38 %** was obtained at 1.0% fibre. Lowest average value of **unsoaked CBR, 14.54 %** was obtained at 1.0% fibre.

12. For 12 mm fibre in Clay, California Bearing Ratio of clay increased gradually from 0% polyester fibre to 0.4% fibre content. Highest average value of **soaked CBR, 4.84 %** was obtained at 0.5% fibre. Highest average value of **unsoaked CBR, 17.50 %** was obtained at 0.5% fibre. On further increase in fibre content there was a gradual fall in the CBR value, giving the lowest value at 1.0% fibre content. Lowest average value of **soaked CBR, 2.61 %** was obtained at 1.0% fibre. Lowest average value of **unsoaked CBR, 12.28%** was obtained at 1.0% fibre.

IMPORTANT RECOMMENDATIONS

1. For 6 mm fibre in sand, add 0.1% polyester fibre to obtain highest average value of soaked CBR, 25.87 % and highest value of unsoaked CBR, 40.35 %.

2. For 12 mm fibre in sand, add 0.4% polyester fibre to obtain highest average value of soaked CBR, 36.78% and highest value of unsoaked CBR, 55.54 %.

3. For 6 mm fibre in clay, add 0.1% polyester fibre to obtain highest average value of soaked CBR, 4.62 % and highest value of unsoaked CBR, 17.50 %.

4. For 12 mm fibre in clay, add 0.5% polyester fibre to obtain highest average value of soaked CBR, 4.84 % and highest value of unsoaked CBR, 17.50 %.

FUTURE SCOPE

1. Similar study can be carried out on different types of natural and synthetic fibres.
2. Shear tests like direct shear test, tri-axial test can be carried out to study the effect of inclusion of polyester fibre in soil.
3. Similar study can be carried out on other type of soils like, expansive clays, organic clay, fine sand etc.

Annexure – 1

The program coding has been given in this annexure

```
using System;
usingSystem.Collections.Generic;
usingSystem.Linq;
usingSystem.Web;
usingSystem.Web.UI;
usingSystem.Web.UI.WebControls;

public partial class Default3 : System.Web.UI.Page
{
    protected void Page_Load(object sender, EventArgs e)
    {

    }
    protected void Button1_Click(object sender, EventArgs e)
    {
        if (txtFirstNumber.Text != null &&txtSecondNumber.Text != null)
        {

            if ((Convert.ToDouble(txtFirstNumber.Text) / 13.7>=
Convert.ToDouble(txtSecondNumber.Text)/20.55))
            {
                txtResult.Text =
Convert.ToString((Convert.ToDouble(txtFirstNumber.Text) *
Convert.ToDouble(TextBox1.Text)) / 13.7);

                lblMessage.Text = "FINAL CBR VALUE IS" + txtResult.Text +
"(calculated at 2.5 mm penetration)";
            }
            else
            {
                txtResult.Text =
Convert.ToString(Convert.ToDouble(txtSecondNumber.Text) *
Convert.ToDouble(TextBox1.Text) / 20.55);
                // Response.Write("fail");
                lblMessage.Text = "CBR VALUE IS " + txtResult.Text + " (calculated at
5.0 mm penetration)";
            }

            txtSecondNumber0.Text =
Convert.ToString(Convert.ToDouble(txtFirstNumber.Text) *
Convert.ToDouble(TextBox1.Text));
            txtSecondNumber1.Text =
Convert.ToString(Convert.ToDouble(txtSecondNumber.Text) *
Convert.ToDouble(TextBox1.Text));
```

```
            txtThirdNumber.Text =
Convert.ToString(Convert.ToDouble(txtFirstNumber.Text) *
Convert.ToDouble(TextBox1.Text) / 13.7);
            txtFourthNumber.Text =
Convert.ToString(Convert.ToDouble(txtSecondNumber.Text) *
Convert.ToDouble(TextBox1.Text) / 20.55);

        }



        else
        {
            Response.Write("insert values");
        }
    }
    protected void txtFirstNumber_TextChanged(object sender, EventArgs e)
    {

    }
    protected void txtSecondNumber1_TextChanged(object sender, EventArgs e)
    {

    }
    protected void Button2_Click(object sender, EventArgs e)
    {



        txtResult.Text = " " ;
        txtSecondNumber0.Text = " ";
        txtSecondNumber.Text = " ";
        txtSecondNumber1.Text = " ";
        txtThirdNumber.Text = " ";
        txtFourthNumber.Text = " ";
        txtFirstNumber.Text = " ";

    }
    protected void Button3_Click(object sender, EventArgs e)
    {
        //start
        {
            if (TextBox2.Text != null && TextBox3.Text != null && TextBox4.Text !=
null )
            {

                if ((Convert.ToDouble(TextBox2.Text) == 1) &&
(Convert.ToDouble(TextBox3.Text) == 6) && (Convert.ToDouble(TextBox4.Text)
== 1))
                {
                    TextBox5.Text = Convert.ToString(108.57);
```

```
            // clay 6mm unsoaked

        }

        if ((Convert.ToDouble(TextBox2.Text) == 1) &&
(Convert.ToDouble(TextBox3.Text) == 12) && (Convert.ToDouble(TextBox4.Text)
== 1))
        {
            TextBox5.Text = Convert.ToString(111.39);
            //clay 12 mm unsoaked

        } if ((Convert.ToDouble(TextBox2.Text) == 1) &&
(Convert.ToDouble(TextBox3.Text) == 6) && (Convert.ToDouble(TextBox4.Text)
== 2))
        {
            TextBox5.Text = Convert.ToString(150);
            //clay 6 mm soaked

        }
         if ((Convert.ToDouble(TextBox2.Text) == 1) &&
(Convert.ToDouble(TextBox3.Text) == 12) && (Convert.ToDouble(TextBox4.Text)
== 2))
        {
            TextBox5.Text = Convert.ToString(164.22);
             //clay 12 soaked

        }
        if ((Convert.ToDouble(TextBox2.Text) == 2) &&
(Convert.ToDouble(TextBox3.Text) == 6) && (Convert.ToDouble(TextBox4.Text)
== 1))

        {
            TextBox5.Text = Convert.ToString(272.45);
            //sand 6 unsoak


        }

        if ((Convert.ToDouble(TextBox2.Text) ==2) &&
(Convert.ToDouble(TextBox3.Text) == 12) && (Convert.ToDouble(TextBox4.Text)
== 1))
        {
            TextBox5.Text = Convert.ToString(375.02);
            //sand 12 unso

        }

        if ((Convert.ToDouble(TextBox2.Text) == 2) &&
(Convert.ToDouble(TextBox3.Text) == 6) && (Convert.ToDouble(TextBox4.Text)
```

```
== 2))
            {
               TextBox5.Text = Convert.ToString(273.47);
               //SAND 6 SOAKED

            }

            if ((Convert.ToDouble(TextBox2.Text) == 2) &&
(Convert.ToDouble(TextBox3.Text) == 12) && (Convert.ToDouble(TextBox4.Text)
== 2))
            {
               TextBox5.Text = Convert.ToString(388.79);

               //SAND 12 SOAK
            }


            else
            {
               }



         }



         else
         {
            Response.Write("insert values");
         }
      }
      //end
   }
   protected void Button4_Click(object sender, EventArgs e)
   {



      TextBox7.Text = Convert.ToString(Convert.ToDouble(TextBox6.Text) *
Convert.ToDouble(txtResult.Text) / 100);

   }
   protected void Button5_Click(object sender, EventArgs e)
   {
      //fstart

      {
         if (TextBox2.Text != null && TextBox3.Text != null && TextBox4.Text !=
null)
         {
```

```
            if ((Convert.ToDouble(TextBox2.Text) == 1) &&
(Convert.ToDouble(TextBox3.Text) == 6) && (Convert.ToDouble(TextBox4.Text)
== 1))
            {
                TextBox8.Text = Convert.ToString((Convert.ToDouble(TextBox6.Text)
* 0.0117) - 1.1668);
                TextBox9.Text = Convert.ToString("Y = 0.0117x-1.1668");

                // clay 6mm unsoaked

            }

            if ((Convert.ToDouble(TextBox2.Text) == 1) &&
(Convert.ToDouble(TextBox3.Text) == 12) && (Convert.ToDouble(TextBox4.Text)
== 1))
            {
                TextBox8.Text = Convert.ToString((Convert.ToDouble(TextBox6.Text)
* Convert.ToDouble(TextBox6.Text) * 0.2261) - (Convert.ToDouble(TextBox6.Text)
* Convert.ToDouble(TextBox6.Text) * Convert.ToDouble(TextBox6.Text) * 0.0007)
- (Convert.ToDouble(TextBox6.Text) * 23.798) + 832.81);
                TextBox9.Text = Convert.ToString("Y = 0.0468x-4.6978SS");
                //clay 12 mm unsoaked

            } if ((Convert.ToDouble(TextBox2.Text) == 1) &&
(Convert.ToDouble(TextBox3.Text) == 6) && (Convert.ToDouble(TextBox4.Text)
== 2))
            {
                TextBox8.Text = Convert.ToString((Convert.ToDouble(TextBox6.Text)
* 0.002) - 0.2);
                TextBox9.Text = Convert.ToString("Y = 0.002x-0.2    ");
                //clay 6 mm soaked

            }
            if ((Convert.ToDouble(TextBox2.Text) == 1) &&
(Convert.ToDouble(TextBox3.Text) == 12) && (Convert.ToDouble(TextBox4.Text)
== 2))
            {
                TextBox8.Text = Convert.ToString((Convert.ToDouble(TextBox6.Text)
* 0.0117) - 1.1668);
                TextBox9.Text = Convert.ToString("Y = 0.0078x-0.795");
                //clay 12 soaked

            }
            if ((Convert.ToDouble(TextBox2.Text) == 2) &&
(Convert.ToDouble(TextBox3.Text) == 6) && (Convert.ToDouble(TextBox4.Text)
== 1))
            {
                TextBox8.Text = Convert.ToString((Convert.ToDouble(TextBox6.Text)
* 0.0006) - 0.0584);
```

```
                    TextBox9.Text = Convert.ToString("Y = 0.0006x-0.0584");
                    //sand 6 unsoak


                }

                if ((Convert.ToDouble(TextBox2.Text) == 2) &&
(Convert.ToDouble(TextBox3.Text) == 12) && (Convert.ToDouble(TextBox4.Text)
== 1))
                {
                    TextBox8.Text = Convert.ToString((Convert.ToDouble(TextBox6.Text)
* 0.0117) - 1.1668);
                    TextBox9.Text = Convert.ToString("Y = 0.0013x-0.114");
                    //sand 12 unso

                }

                if ((Convert.ToDouble(TextBox2.Text) == 2) &&
(Convert.ToDouble(TextBox3.Text) == 6) && (Convert.ToDouble(TextBox4.Text)
== 2))
                {
                    TextBox8.Text = Convert.ToString((Convert.ToDouble(TextBox6.Text)
* 0.0117) - 1.1668);
                    TextBox9.Text = Convert.ToString("Y = 0.0005x-1.0571");
                    //SAND 6 SOAKED

                }

                if ((Convert.ToDouble(TextBox2.Text) == 2) &&
(Convert.ToDouble(TextBox3.Text) == 12) && (Convert.ToDouble(TextBox4.Text)
== 2))
                {
                    TextBox8.Text = Convert.ToString((Convert.ToDouble(TextBox6.Text)
* 0.0117) - 1.1668);
                    TextBox9.Text = Convert.ToString("Y = 0.0117x-0.0896");
                    //SAND 12 SOAK
                }


                else
                {
                }



            }


            else
            {
```

```
                Response.Write("insert values");
            }
        }
        //end
    }
    protected void Button6_Click(object sender, EventArgs e)
    {

    }
}
```

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