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Improvement of Sub grade Strength by Partial Replacement of M-Sand

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ABSTRACT: *Pavements are conglomeration of materials. These materials, their associated properties, and their interactions determine the properties of the resultant pavement. The performance of pavements depends to a large extent on the strength and stiffness of the subgrade. Among the various methods of determining the strength of sub grade the CBR test is very important. California Bearing Ratio (CBR) is a commonly used indirect method to assess the stiffness modulus and shear strength of sub grade in pavement design work. In many situations, soils in natural state do not present adequate geotechnical properties to be used as road service layers. In order to improve their geotechnical parameters to meet the requirements of technical specifications of construction industry, soil stabilization techniques are normally emphasized. This study aims to improve sub grade CBR value by using Manufactured sand(including M-sand <150 microns which is not used for making concrete) at varying percentages respectively and to find out the optimum percentage of M-sand beyond which CBR value of soil decreases. From the experimental results optimum percentage of M-sand is found to be 45% to attain maximum CBR. After getting the CBR values for different percentage of addition, analysis is carried out and relationships are established between CBR and all the fundamental properties of soil to overcome one of the limitations of CBR method. In order to determine which properties of soil has more or less influence on CBR mathematical concepts of linear regression analysis, Power series, Exponential Series, Linear series are applied to establish the relationship between CBR and properties of the soil. Here experimental CBR is considered as dependent variable and other properties of soil are considered as independent variables. In order to test the validation of the model, the chi-squared test, F-test, t-test, evaluation fit test are carried out. By keeping factors such as Present Daily traffic, Growth Rate, Cumulative Standard Axle etc constant, thickness of pavement is evaluated by IRC 37-2001 method. From the CBR values Young's modulus of elasticity of soil sub grade is evaluated and also using stress strain curve Young's modulus of elasticity of soil sub grade are found out and the minimum value Young's modulus of elasticity of soil sub grade of soil is considered to evaluate vertical stress & vertical strain, radial stress & radial strain at the interface of each layer . Finally reduction in thickness, with % of addition of M-sand is analyzed and is presented.*

Keywords: *Un-Soaked CBR (California Bearing Ratio), Soil Properties, Regression, Power Series, Chi Square test.*

I. INTRODUCTION

Transportation contributes to the economic, industrial, social and cultural development of any country. India has seen rapid growth of industrialization in the past few decades with an increasing automobile traffic. This requires an extensive, economical road network which can be extended with increase in traffic load. In such situation, flexible pavement satisfies most of the Indian conditions.

The behavior of road surface depends on the strength of the fill material and the sub-grade below it. Road construction over soft sub-grade soil is a major issue affecting cost and scheduling of highway projects in regions where soft sub-grades are common. The strength of the sub-grade is most often expressed as California Bearing Ratio (CBR), which is the ratio of test load to standard load at a specified penetration, by a standard plunger. The values of modulus of sub-grade reaction and resilient modulus of soil have been correlated with CBR value. CBR is an indirect measure of shearing resistance of the material under controlled density and moisture conditions. In India the design of f1exible pavement is primarily on the basis of the CBR value of sub-grade CBR (IRC: 37 - 2001). The IRC: 37-2001, "Guidelines for the design of flexible pavement", recommends the use of California Bearing Ratio Method for the design of flexible pavement. Since sub-grade CBR is taken as the criterion for the design of flexible pavements, the thickness of the component layers (sub base and base course) will be reduced when the sub-grade CBR is high.

Many techniques have been evolved to strengthen the highway soil sub-grade. Soil is the basic construction material. It supports the substructure of any structure and it is the sub grade which supports the sub base and base in the pavement. A road pavement may be defined as relatively stable layer or crust constructed over the natural soil. The main function of pavement is to support and distribute the heavy wheel loads of vehicles over a wide area of the underlying sub grade soil and permitting the deformations within elastic or allowable range and to provide an adequate surface. Sub grade performance is a function of a soil's strength and its behaviour under traffic loading. The sub grade should be sufficiently stable to prevent excessive rutting and shoving during construction, provide good support for placement and compaction of pavement layers. The existing soil at a particular location may not be suitable for the construction due to poor bearing capacity and higher compressibility or even sometimes excessive swelling in case of expansive soils. So it is also necessary to determine the strength characteristics of the sub grade for the design of pavements. To achieve above all these characteristics, it is very important to have a pre- knowledge about sub grade soil properties and to suggest suitable methods to improve the sub grade soil properties if necessary. The properties of soil can be improved by stabilization with admixtures. For many years admixtures such as lime, cement and cement kiln dust are used to improve the qualities of various types of soils such as Lateritic Soil, Clayey soil. However, the cost of introducing these admixtures has also increased in recent years. This has opened the door for researchers to find alternate admixtures such as plastic, fibers, fly ash, sugarcane ash, bagasse ash, Eggshell powder etc but till now no one has made an attempt of using Manufactured sand as soil stabilizer. Therefore in this study an attempt has been made to improve sub grade CBR value by using Manufactured sand (including M-sand <150 microns which is considered as waste in the manufacture of concrete)at varying percentages respectively and to find out the optimum percentage of M-sand beyond which CBR value of soil decreases. As per IS 383, is that fraction of material passing through 75µ sieve shall not exceed 10% to 15% of the 12 sample tested in the lab (collected from different sources). The maximum fraction of the materials passing 75µ sieve is observed to be less than 8%.M-sand is defined as a purpose made crushed fine aggregate produced from suitable source materials. Manufactured sand has been produced by variety of crushing equipments including cone crushers, impact crushers, roll crushers, road rollers etc., The raw material for M sand production is the parent mass of rock. It is based on the parent rock that the chemical, mineral properties, texture, composition of sand would change.

1.1 General Requirements of M-Sand;

1. All the sand particles should have higher crushing strength.
2. The surface texture of the particles should be smooth.
3. The edges of the particles should be grounded.
4. The ratio of fines below 600 microns in sand should not be less than 30%.
5. There should not be any organic impurities.
6. Silt in sand should not be more than 2%, for crushed sand.
7. In manufactured sand the permissible limit of fines below 75 microns shall not exceed 15%.

1.2 The Reason for Using M-Sand As Soil Stabilizer Is As Follows:

- The Manufactured sand has required gradation of fines, physical properties such as shape, smooth surface textures and consistency which make it the best sand suitable for construction.
- There is a recent trend of replacing natural river sand by M-sand in concrete works for which the strength of concrete is better than river sand.
- Higher specific gravity
- Permeability reduces with increase in proportion of manufactured sand.
- In WBM road construction crushed aggregates with stand higher stresses.
- Provides better bondage due to sharp edges.
- Higher Cohesion and Compressive Strength
- Gradation Can be controlled
- Reduction in Voids and Higher strength
- Clay and Organic impurities :Absent
- Manufactured to conform to Zone II (ideal for Concrete)
- Manufactured sand of size less than 150 micron is not used in making concrete which is considered as waste, etc.;

Soil samples are collected from form stadium and which are designated as A and. Various tests are carried out in order to determine the soil properties. In this study a number of CBR tests (Unsoaked and soaked) have been conducted on soil alone and soil mixed with incremental proportions of M-sand. The CBR values at 2.5 mm and 5 mm plunger penetration have been determined and compared with that of soil specimen. The CBR method of design is purely empirical and has several limitations. As this approach has been accepted in our country and also since most of the pavement are designed based on this method, here an attempt has been made to develop the various relationships between the both soaked CBR and for unsoaked CBR with soil parameters such has field density, dry density, optimum moisture content, coefficient of curvature, etc, using regression analysis technique.

To analyse impact of CBR on thickness, thickness is evaluated both by IRC-37:2000 technique and by three layer concept stresses and strains at each interface are evaluated by finding Young's modulus of elasticity of sub grade from CBR graphs(Load Versus Penetration) for soil and for each percentage of addition of M-sand up to optimum percentage.

Then graphs are plotted for each property and their variation with percentage addition are studied which are explained in subsequent chapters.

II. OBJECTIVE TO STUDY

In the present study, an attempt has been made to study how Manufactured sand may be effectively replaced equivalent to sand in soil to improve the CBR value and to reduce the thickness of pavement and to sustain the stress strain at interfaces of each layer. Following are the objectives of the present work:

- To determine the properties of natural soil such as specific gravity, particle size distribution, coefficient of uniformity and coefficient of curvature , liquid limit, plastic limit ,plasticity index, maximum dry density, optimum moisture content and, California bearing ratio for both soaked and unsoaked condition for two different locations.
- To determine the same properties for Manufactured-Sand.
- To replace the sand content in natural soil by M-Sand with incremental proportions and to analyze all the properties.
- To determine the optimum percentage of M-sand to attain maximum soaked CBR.
- To establish a relationship between for both soaked and unsoaked CBR considering properties of soil as independent variables and CBR as dependent variable.
- To analyze variation of both soaked and unsoaked CBR of soil before and after replacement.
- To determine Young's modulus of elasticity of sub grade soil using stress strain relationships obtained from CBR experiment.
- To evaluate the thickness of pavement as per IRC 37-2001 for natural soil and also for the replacement combination.
- To estimate the vertical stress, vertical strain, radial stress and radial strain at first interface between wearing coat and base course and second interface between base course and at sub-base by three layer concept which is a classical approach used in pavement design.
- To analyze the variation of thickness and young's modulus of elasticity of sub grade before and after replacement.

III. METHODOLOGY AND DATA COLLECTION

Soil samples were collected near stadium in Malnad college of Engineering which was designated as A samples are taken from site and experimental tests are carried out in the Geo-technical laboratory. M-sand is collected from Kunigal Manufacturing Company, Tumkur district, Karnataka, India.

The samples were randomly chosen near stadium ground to study the behavior of the natural soil with partial replacement of sand with m-sand in increasing trend.

Table 3.1 Properties of A sample with % increase of M-sand

A	C_u	C_c	G	γ_d (g/cc)	OMC (%)	LL (%)	PL (%)	PI	UNSOAKED CBR (%)	Soaked CBR (%)
Soil	6.47	0.288	2.295	1.99	14.73	37	23.5	13.5	3.12	2.22
5%	7.6	0.33	2.312	2.1	13.5	36.48	23.93	12.55	3.57	2.87
10%	7.794	0.412	2.359	2.15	12.63	36.13	24.28	11.85	4.23	2.91
15%	8.75	0.432	2.392	2.19	12.19	35.75	24.59	11.16	4.767	3.13
20%	10	0.454	2.426	2.23	12	35.29	24.93	10.36	5.46	3.49
25%	10.62	0.522	2.44	2.29	11.6	34.93	25.2	9.03	7.93	4.16
30%	11.43	0.654	2.474	2.34	10.45	34.68	25.78	8.9	8.4	5.09
35%	13.32	0.69	2.54	2.36	9.6	34.19	26.02	8.17	8.9	6.27
40%	14.17	0.727	2.546	2.4	8.75	33.83	26.54	7.29	11.62	7.57
45%	14.24	0.961	2.579	2.42	7.69	32.8	26.83	5.97	14.63	8.73
50%	-	-	-	2.37	7.72	-	-	-	13.19	7.78

The soil samples have been found to contain liquid limit greater than 35% and since more than half of the material is smaller than 4.75mm and greater than 75 microns .Both The soil samples were classified as Sandy clay or Poorly graded sand clay mixtures (SC) as per IS 1498-1970.

3.1 Assumptions made in the analysis.

- The important assumptions made in the analysis are
- The present daily traffic along the length of the road under consideration remains same 800CVPD.
- The type of terrain for 1km length is plain having same vehicle damaging factor equal to 3.5 as per IRC-37:2001 guideline.
- The road under consideration two-lane duel carriage way having a lane distribution factor of 0 .75.
- The life of the pavement is assumed to be 15 years.
- The quantity of soil required preparing CBR mould and water content to be added depends on maximum density and optimum moisture content.

IV. METHODOLOGY

The soil that is being stabilized must be tested before validating for widespread usage on the field. For all official purposes, the initial tests are mandatory and they must fulfil the basic requirements of IS 2720 prescribed in our country. The shear strength and the CBR values are determined and the pavement is designed as per the specifications of IRC 37:2001 re affirmed in 2012. The laboratory investigations were carried by blending of soil sample with M-sand in different percentages i.e. 0%, 10%, 20%, 30% and 40% by weight of soil. Then soils are tested for various parameters to quality and performance, i.e. the grain size distribution analysis, Atterberg limits, CBR test for soaked and unsoaked condition are conducted as per the codal provision suggested by IS 2720. These values help the engineer to judge the quality of methods employed to stabilize the soil in the field during the implementation of the work.

V. RESULTS AND DISCUSSION

Table 5.1 Tabled values of Chi square test F-test and t-test for the experiment.

	X^2_{tabled}	F_{tabled}	t_{tabled}
Tabled value	1.723	2.44	3.25
Confidence level	99.5%	99.9%	99.5%

5.1 Soaked Condition

Table 5.1.1 Relationship between Soaked CBR (%) and Cu

C_U	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	$t_{(CALC)}$	Standard error calculated	Fit Evaluation value
6.47	2.22	2.22	0.2436	0.842151583	0.701895	0.658441	0.18861
7.6	2.87	2.66					
7.794	2.91	2.75					
8.75	3.13	3.20					
10	3.49	3.91					
10.625	4.16	4.32					
11.43	5.09	4.91					
13.32	6.27	6.65					
14.17	7.57	7.62					
14.24	8.73	7.70					

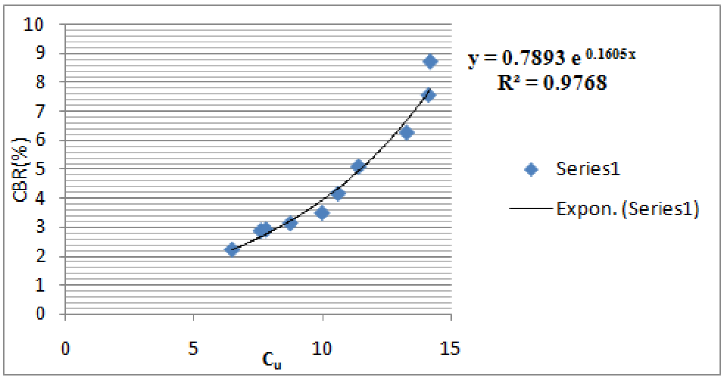

Fig5.1.1 Relationship between soaked CBR (%) and C_u

The above relation between CBR and Cu satisfies exponential series and the relation is having a correlation coefficient of 0.976 which is very close to 1.0

CBR(%)= $0.789e^{0.160C_u}$……………………5.1

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval. F- test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable. Further as Co–efficient of uniformity increases CBR also increases.

Table 5.1.2 Relationship between Soaked CBR (%) and Cc

C_C	CBR (%)	Expected CBR (%)	X^2_{calc}	$F_{(CALC)}$	$t_{(CALC)}$	Standard error calculated	Fit Evaluation value
0.288	2.22	2.12	0.412	0.866122	0.85372	0.661648	0.2728
0.3342	2.87	2.53					
0.412	2.91	3.24					
0.432	3.13	3.43					
0.454	3.49	3.64					
0.522	4.16	4.30					
0.6541	5.09	5.62					
0.69	6.27	5.99					
0.727	7.57	6.38					
0.961	8.73	8.89					

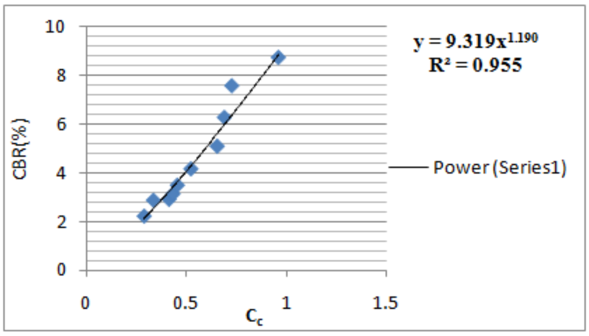

Fig5.1.2 Relationship between soaked CBR (%) and C_C

The above relation between CBR and Cc satisfies power series and the relation is having a correlation coefficient of 0.955 which is very close to 1.0

CBR(%)= $9.319\ Cc^{1.190}$……………………5.2

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. , which suggests that the above hypothesis is acceptable. . Further as Co–efficient of curvature increases CBR also increases.

Table 5.1.3 Relationship between Soaked CBR (%) and G

G	CBR (%)	Expected CBR (%)	X^2_{calc}	$F_{(CALC)}$	$t_{(CALC)}$	Standard error calculated	Fit Evaluation value
2.295	2.22	2.27	0.3473	0.844612	0.667812	0.658792	0.208549
2.312	2.87	2.45					
2.359	2.91	3.03					
2.392	3.13	3.52					
2.426	3.49	4.11					
2.44	4.16	4.38					
2.474	5.09	5.11					
2.54	6.27	6.88					
2.546	7.57	7.07					
2.579	8.73	8.21					

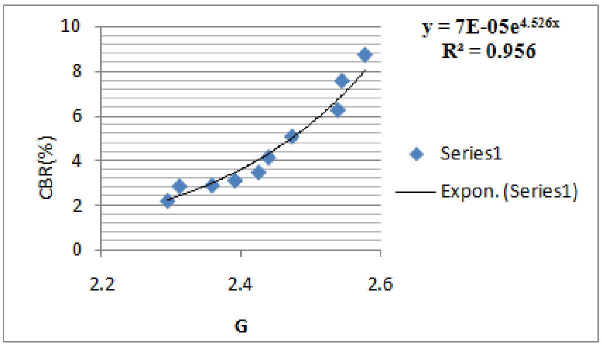

Fig 5.1.3 Relationship between soaked CBR (%) and Specific Gravity

The above relation between CBR and G satisfies exponential series and the relation is having a correlation coefficient of 0.956 which is very close to 1.0

CBR(%)= $7E\text{-}05e^{4.526G}$……………………5.3

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable. Further as specific gravity increases CBR also increases.

Table 5.1.4 Relationship between Soaked CBR (%) and ϒd

$ϒ_D$ (g/cc)	CBR (%)	Expected CBR (%)	X^2_{calc}	$F_{(CALC)}$	$t_{(CALC)}$	Standard error calculated	Fit Evaluation value
1.99	2.22	1.81	0.9836	0.479434	0.43519	0.612195	0.700709
2.1	2.87	2.61					
2.15	2.91	3.07					
2.19	3.13	3.49					
2.23	3.49	3.95					
2.29	4.16	4.74					
2.34	5.09	5.50					
2.36	6.27	5.83					
2.4	7.57	6.54					
2.42	8.73	6.93					

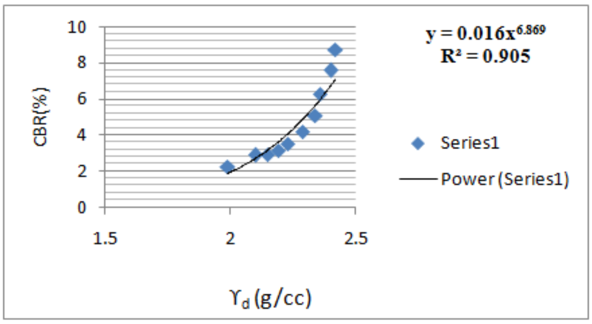

Fig 5.1.4 Relationship between soaked CBR (%) and MDD

The above relation between CBR and $\square_d$ satisfies power series and the relation is having a correlation coefficient of 0.905 which is very close to 1.0

CBR (%)= $0.016\square_d^{6.869}$……………………5.4

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. Which suggests that the above hypothesis is acceptable? Further as dry density increases CBR also increases.

Table 5.1.5 Relationship between Soaked CBR (%) and OMC

OMC (%)	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	$t_{(CALC)}$	Standard error calculated	Fit Evaluation value
14.73	2.22	2.29	0.23756	0.872516	0.510627	0.700112	0.200129
13.5	2.87	2.79					
12.63	2.91	3.23					
12.19	3.13	3.50					
12	3.49	3.62					
11.6	4.16	3.91					
10.45	5.09	4.93					
9.6	6.27	5.96					
8.75	7.57	7.33					
7.69	8.73	9.77					

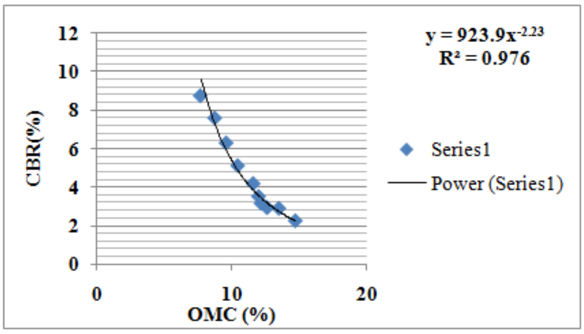

Fig 5.1.5 Relationship between soaked CBR (%) and OMC

The above relation between CBR and OMC satisfies power series and the relation is having a correlation coefficient of 0.976 which is very close to 1.0

$CBR(\%) = 923.9OMC^{-2.23}$……………………5.5

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%, which suggests that the above hypothesis is acceptable. Further as OMC decreases CBR increases.

Table 5.1.6 Relationship between Soaked CBR (%) and Liquid Limit

LL (%)	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	$t_{(CALC)}$	Standard error calculated	Fit Evaluation value
37	2.22	3.18	6.19	0.302493	0.000359	0.898595	6.338819
36.48	2.87	3.77					
36.13	2.91	4.24					
35.75	3.13	4.81					
35.29	3.49	5.63					
34.93	4.16	6.37					
34.68	5.09	6.95					
34.19	6.27	8.26					
33.83	7.57	9.39					
32.8	8.73	13.65					

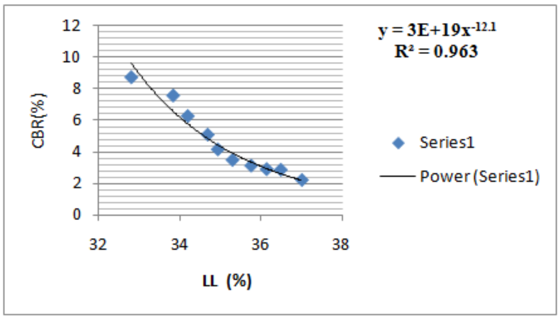

Fig 5.1.6 Relationship between soaked CBR (%) and LL

The above relation between CBR and LL satisfies power series and the relation is having a correlation coefficient of 0.963 which is very close to 1.0

CBR(%) = 3E+19LL$^{-12.1}$……………………5.6

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is greater than chi-square tabled value at 99.5% confidence interval. The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. Which suggests that the above hypothesis is acceptable. Further as liquid limit decreases CBR increases.

Table 5.1.7 Relationship between Soaked CBR (%) and Plastic Limit

PL (%)	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	t(CALC)	Standard error calculated	Fit Evaluation value
23.5	2.22	1.81	1.4688	0.503349	0.002115	0.624941	0.922725
23.93	2.87	2.18					
24.28	2.91	2.53					
24.59	3.13	2.88					
24.93	3.49	3.31					
25.2	4.16	3.69					
25.78	5.09	4.65					
26.02	6.27	5.12					
26.54	7.57	6.26					
26.83	8.73	6.99					

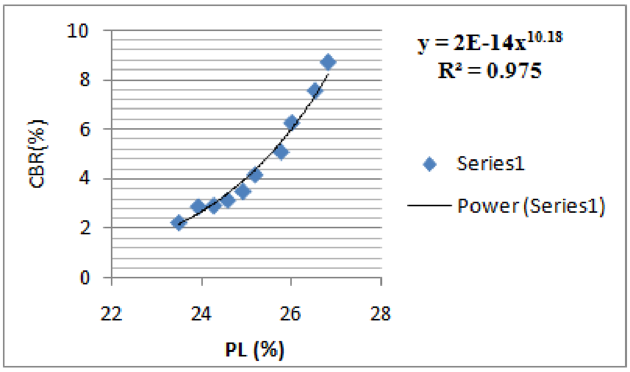

Fig 5.1.7 Relationship between soaked CBR (%) and PL

The above relation between CBR and PL satisfies power series and the relation is having a correlation coefficient of 0.975 which is very close to 1.0

CBR (%)= 2E-14PL$^{10.18}$……………………5.7

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. Which suggests that the above hypothesis is acceptable. Further as plastic limit increases CBR also increases?

Table 5.1.8 Relationship between Soaked CBR (%) and Plasticity Index

PI	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	t(CALC)	Standard error calculated	Fit Evaluation value
13.5	2.22	2.36	0.371	0.928385	0.777974	0.691228	0.303672
12.55	2.87	2.68					
11.85	2.91	2.96					
11.16	3.13	3.28					
10.36	3.49	3.74					
9.03	4.16	4.75					
8.9	5.09	4.87					
8.17	6.27	5.65					
7.29	7.57	6.89					
5.97	8.73	9.75					

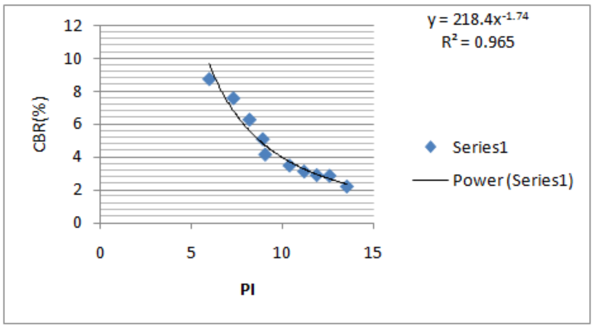

Fig 5.1.8 Relationship between soaked CBR (%) and PI

The above relation between CBR and PI satisfies power series and the relation is having a correlation coefficient of 0.965 which is very close to 1.0

CBR (%) = $218.4PI^{-1.74}$……………………5.8

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. Which suggests that the above hypothesis is acceptable. Further as plasticity index decreases CBR increases.

5.2 Un-Soaked Condition of soil.

Table 5.2.1 Relationship between Unsoaked CBR (%) and Cu

C_U	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	$t_{(CALC)}$	Standard error calculated	Fit Evaluation value
6.47	3.12	2.86	1.172	0.757996	0.758414	1.100601	1.487632
7.6	3.57	3.83					
7.794	4.23	4.01					
8.75	4.767	4.95					
10	5.46	6.31					
10.625	7.93	7.04					
11.43	8.4	8.04					
13.32	8.9	10.60					
14.17	11.62	11.86					
14.24	14.63	11.97					

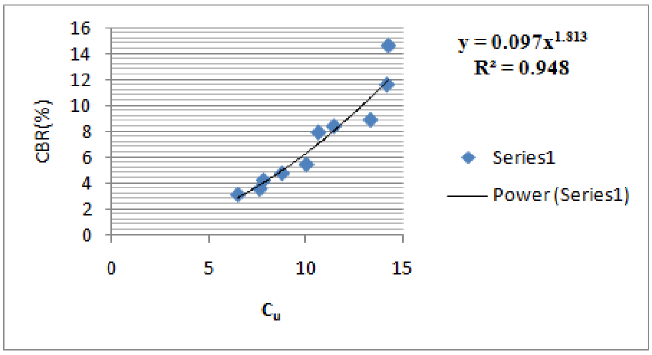

Fig5.4 (d) Relationship between Unsoaked CBR (%) and C_u

The above relation between CBR and Cu satisfies power series and the relation is having a correlation coefficient of 0.948 which is very close to 1.0

CBR(%) = $0.097Cu^{1.813}$……………………5.9

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable.further as CU increases CBR also increases.

Table 5.2.2 Relationship between Unsoaked CBR (%) and Cc

C_c	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	$t_{(CALC)}$	Standard error calculated	Fit Evaluation value
0.288	3.12	2.95	0.6319	0.974775	0.906311	1.150822	0.614969
0.3342	3.57	3.60					
0.412	4.23	4.78					
0.432	4.767	5.10					
0.454	5.46	5.45					
0.522	7.93	6.59					
0.6541	8.4	8.93					
0.69	8.9	9.60					
0.727	11.62	10.31					
0.961	14.63	15.03					

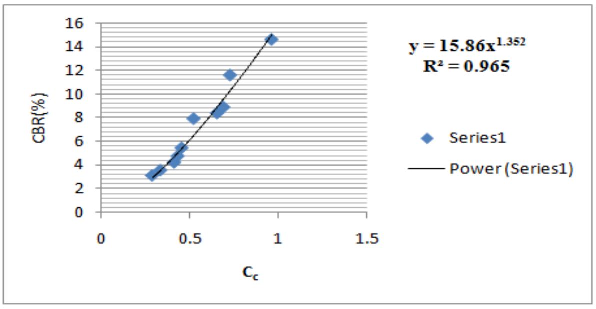

Fig 5.2.2 Relationship between Unsoaked CBR (%) and C_C

The above relation between CBR and Cc satisfies power series and the relation is having a correlation coefficient of 0.965 which is very close to 1.0

$CBR(\%) = 15.86Cc^{1.352}$……………………5.10

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable. Further as Co–efficient of curvature increases CBR also increases.

Table 5.2.3 Relationship between Unsoaked CBR (%) and G

G	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	$t_{(CALC)}$	Standard error calculated	Fit Evaluation value
2.295	3.12	3.67	2.4448	0.767636	0.008718	1.235007	3.126189
2.312	3.57	4.00					
2.359	4.23	5.08					
2.392	4.767	6.02					
2.426	5.46	7.16					
2.44	7.93	7.69					
2.474	8.4	9.14					
2.54	8.9	12.81					
2.546	11.62	13.20					
2.579	14.63	15.63					

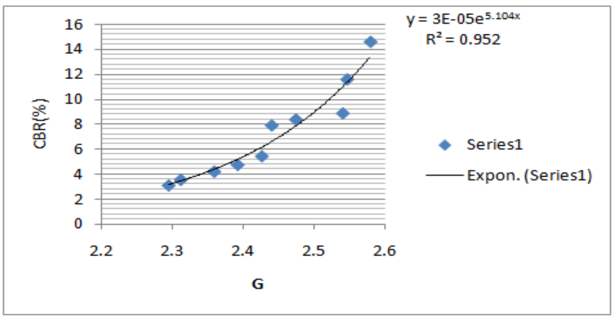

Fig 5.2.3 Relationship between Unsoaked CBR (%) and Specific Gravity

The above relation between CBR and G satisfies exponential series and the relation is having a correlation coefficient of 0.952 which is very close to 1.0

CBR(%) = 3E-05$e^{5.104G}$……………………5.11

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is greater than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable. Further as specific gravity increases CBR also increases.

Table 5.2.4 Relationship between Unsoaked CBR (%) and ϒd

Y_d(g/cc)	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	t(CALC)	Standard error calculated	Fit Evaluation value
1.99	3.12	2.51	1.191575	0.606107	0.763605	1.067299	1.384978628
2.1	3.57	3.84					
2.15	4.23	4.62					
2.19	4.767	5.35					
2.23	5.46	6.17					
2.29	7.93	7.61					
2.34	8.4	9.02					
2.36	8.9	9.65					
2.4	11.62	11.02					
2.42	14.63	11.76					

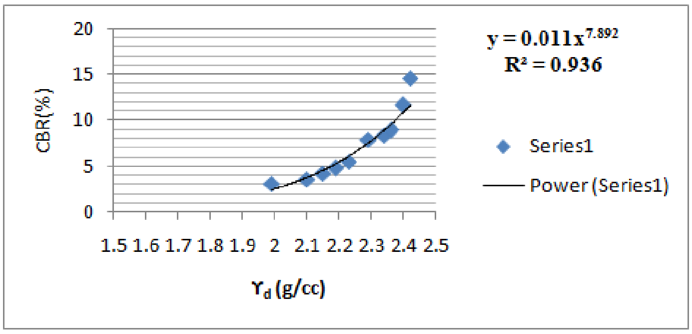

Fig 5.2.4 Relationship between Unsoaked CBR (%) and MDD

The above relation between CBR and $\square_d$satisfies power series and the relation is having a correlation coefficient of 0.936 which is very close to 1.0

CBR(%) = 0.011$\square_d^{7.892}$……………………5.12

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable further as dry density increases CBR also increases.

Table 5.2.5 Relationship between Unsoaked CBR (%) and OMC

OMC (%)	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	t(CALC)	Standard error calculated	Fit Evaluation value
14.73	3.12	3.271385346	1.144	0.818219	0.697563	1.205458	1.068322
13.5	3.57	4.057589242					
12.63	4.23	4.783284501					
12.19	4.767	5.221115922					
12	5.46	5.427687197					
11.6	7.93	5.901756068					
10.45	8.4	7.637922567					
9.6	8.9	9.418517368					
8.75	11.62	11.84220562					
7.69	14.63	16.29125079					

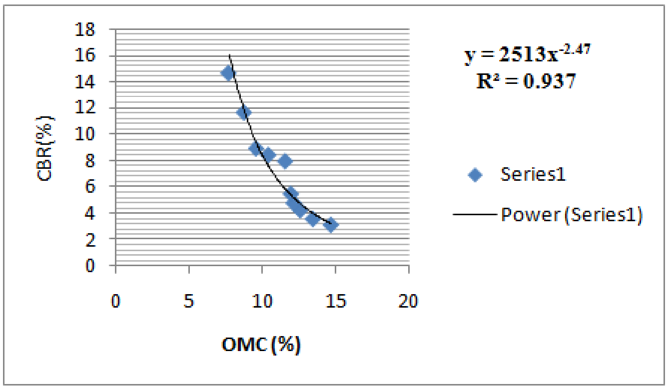

Fig 5.2.5 Relationship between unsoaked CBR (%) and OMC

The above relation between CBR and OMC satisfies power series and the relation is having a correlation coefficient of 0.937 which is very close to 1.0

CBR(%) = $2513MC^{-2.47}$……………………5.13

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of

99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable. Further as OMC decreases CBR increases.

Table 5.2.6 Relationship between Unsoaked CBR (%) and Liquid Limit

LL (%)	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	t(CALC)	Standard error calculated	Fit Evaluation value
37	3.12	3.79	3.417	0.499995	0.002691	1.34323	5.131635
36.48	3.57	4.64					
36.13	4.23	5.32					
35.75	4.767	6.17					
35.29	5.46	7.38					
34.93	7.93	8.49					
34.68	8.4	9.36					
34.19	8.9	11.33					
33.83	11.62	13.04					
32.8	14.63	19.48					

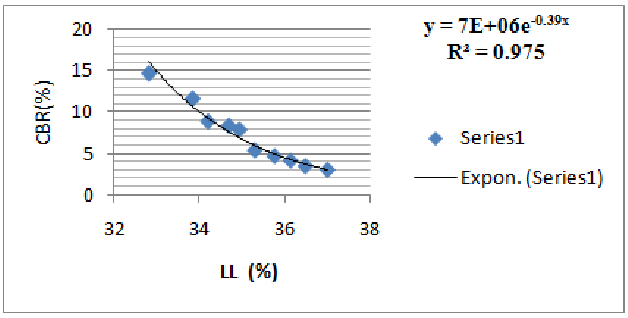

Fig 5.2.6 Relationship between unsoaked CBR (%) and LL

The above relation between CBR and LL satisfies exponential series and the relation is having a correlation coefficient of 0.975 which is very close to 1.0

CBR (%) = $7E+06e^{-0.39LL}$……………………5.14

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is greater than chi-square tabled value at 99.5% confidence interval. The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable. Further as liquid limit decreases CBR increases.

Table 5.2.7 Relationship between Unsoaked CBR (%) and Plastic Limit

PL (%)	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	t(CALC)	Standard error calculated	Fit Evaluation value
23.5	3.12	3.02	0.4483	0.956319	0.642079	1.146327	0.454245
23.93	3.57	3.72					
24.28	4.23	4.40					
24.59	4.767	5.09					
24.93	5.46	5.96					
25.2	7.93	6.75					
25.78	8.4	8.77					
26.02	8.9	9.75					
26.54	11.62	12.25					
26.83	14.63	13.88					

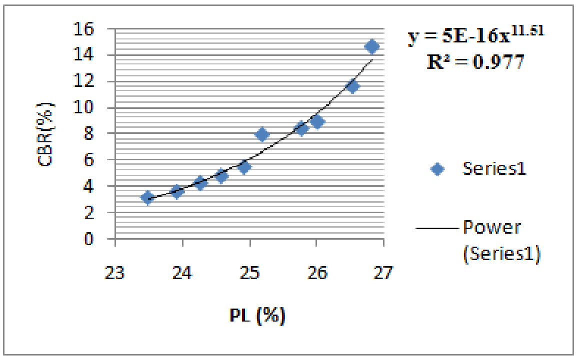

Fig 5.2.7 Relationship between unsoaked CBR (%) and PL

The above relation between CBR and PL satisfies power series and the relation is having a correlation coefficient of 0.977 which is very close to 1.0

CBR(%) = 5E-16PL$^{11.51}$……………………5.15

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable. Further as plastic limit increases CBR also increases.

Table 5.2.8 Relationship between unsoaked CBR (%) and Plasticity Index

PI	CBR (%)	Expected CBR (%)	X^2_{calc}	F (CALC)	t(CALC)	Standard error calculated	Fit Evaluation value
13.5	3.12	3.35	0.4587	0.773402	0.516283	1.218762	0.749047
12.55	3.57	3.87					
11.85	4.23	4.33					
11.16	4.767	4.88					
10.36	5.46	5.65					
9.03	7.93	7.42					
8.9	8.4	7.63					
8.17	8.9	9.04					
7.29	11.62	11.33					
5.97	14.63	16.83					

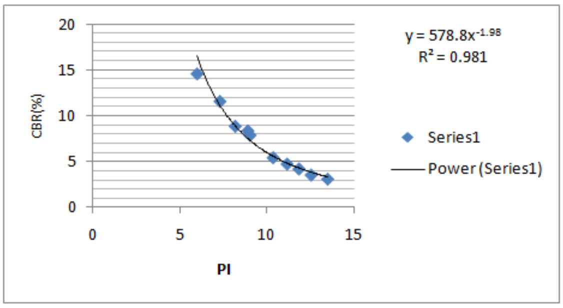

Fig 5.2.8 Relationship between unsoaked CBR (%) and PI

The above relation between CBR and PI satisfies power series and the relation is having a correlation coefficient of 0.981 which is very close to 1.0

$CBR(\%) = 578.8PI^{-1.98}$……………………5.16

After obtaining the required values of CBR the remaining relationships are computed. The chi-square calculated value is less than chi-square tabled value at 99.5% confidence interval.

The F test calculated value is less than the F test tabled value for a confidence level of 99.9%. The t-test calculated value is lesser than the t-test tabled value for confidence level of 99.5%. The standard residual error is less than ±2%. This suggests that the above hypothesis is acceptable. Further as plasticity index decreases CBR increases.

Table 5.3 Variation of Thickness of Pavement with Percentage of Addition of M-Sand for Location A

% OF M-SAND	THICKNESS$_{UNSOAKED}$ (mm)	THICKNESS$_{SOAKED}$ (mm)
0	792.54	869.74
5	765.54	811.44
10	730.54	807.84
15	708.94	792.54
20	675.62	770.34
25	584.92	733.34
30	580.305	695.02
35	577.805	639.86
40	500	598.4
45	470	578.655

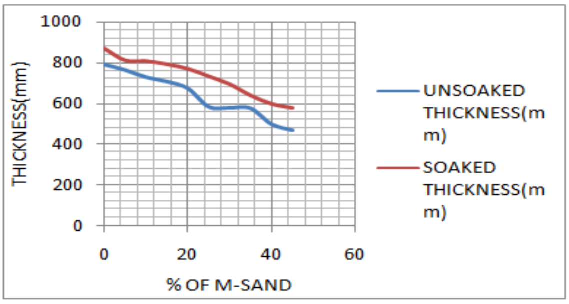

Fig 5.3 Variation of thickness of pavement with percentage of addition of M-sand for location A

Table 5.4 Variation of Young's Modulus of Elasticity Of sub Grade with Percentage of Addition of M-Sand for Location A

% OF M-SAND	$E_{UNSOAKED}$(MPa)	E_{SOAKED}(MPa)
0	20.2	11.47
5	20.1	18.51
10	31.1	19.51
15	35.7	20.62
20	31	23.64
25	50.78	25.54
30	58.43	28.1
35	73.3	35.7
40	78.1	56.31
45	85.1	54.1

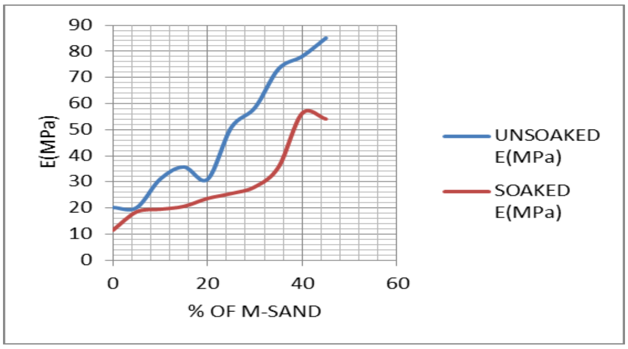

Fig5.4 Variation of young's modulus of elasticity of sub grade percentage of addition of M-sand for location A

Table 5.5 Stress Values Obtained From Three Layer Analysis for Soaked Condition For Location A

% OF M-SAND	σ_{Z1}(MPa)	σ_{Z2}(MPa)	σ_{r1}(MPa)	σ_{r2}(MPa)	σ_{r3}(MPa)	σ_{r4}(MPa)
0	0.00840725	0.004885	0.1614	0.00008275	0.0026225	0.00113235
5	0.009278	0.005412	0.1784	0.0000795	0.0028967	0.001258
10	0.00990125	0.005788	0.18965	0.00007525	0.0031	0.001347
15	0.0104615	0.006127	0.2	0.0000721	0.003269	0.0014289
20	0.010835	0.0065325	0.20726	0.00007	0.0033875	0.0014825
25	0.011615	0.006825	0.22196	0.000065	0.003630625	0.001596875
30	0.013015	0.00767	0.24844	0.0000565	0.00407375	0.00179725
35	0.014259	0.00842	0.2719	-0.000051	0.0046875	0.00197425
40	0.015815	0.0093625	0.30134	0.000042	0.0049575	0.0022
45	0.01675	0.009927	0.31897	0.0000355	0.0051246	0.002765

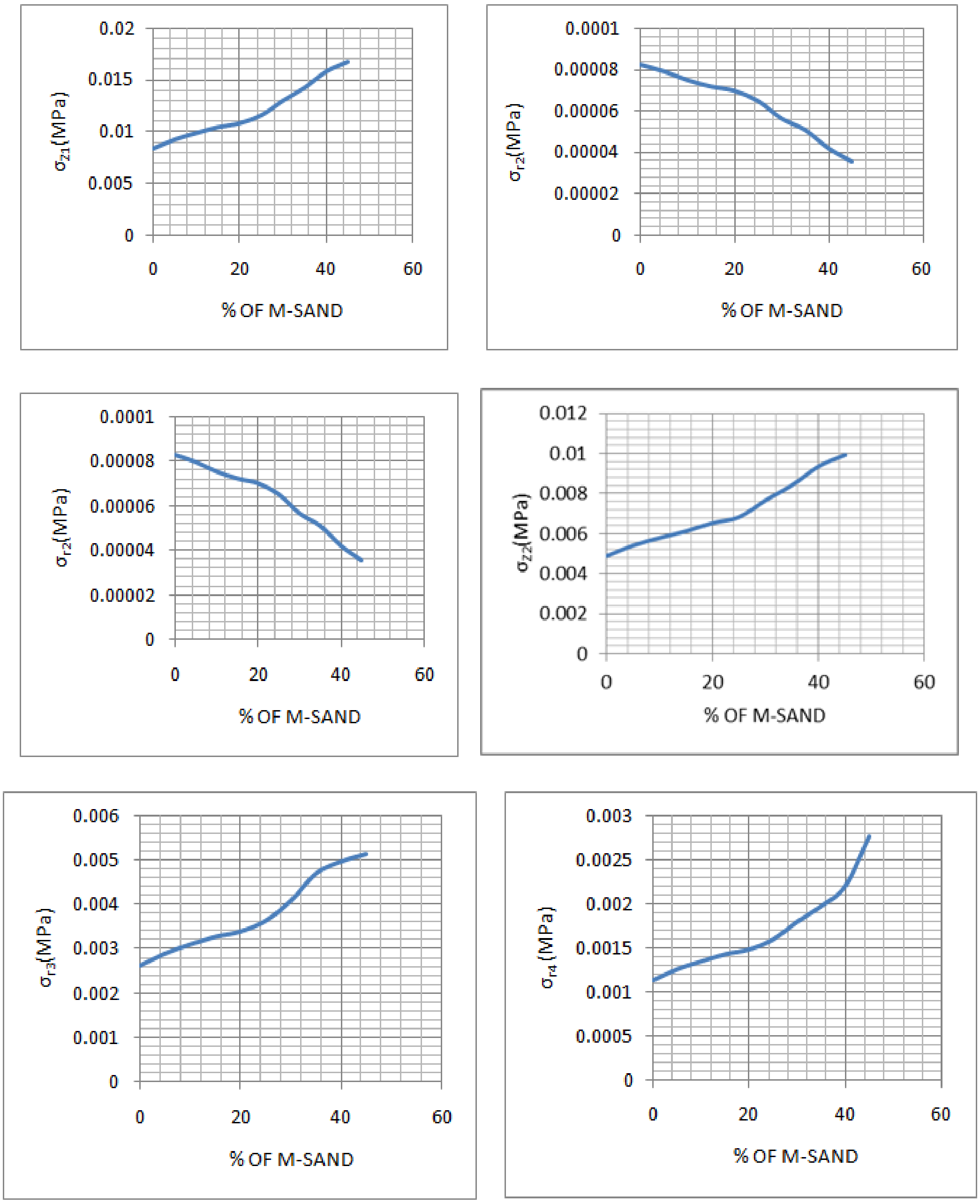

Fig 5.5 variation of stress with percentage of addition of m-sand for soaked condition

Table 5.6 Strain Values Obtained From Three Layer Analysis For Soaked Condition For Location A

% OF M-SAND	ϵ_1	ϵ_2	ϵ_3	ϵ_4
0	0.00037	0.000185	0.000327	0.000164
5	0.000254	0.000127	0.000224	0.000122
10	0.000256	0.000128	0.000227	0.000114
15	0.000254	0.000128	0.000228	0.000114
20	0.000231	0.000153	0.000206	0.000103
25	0.000229	0.000114	0.000205	0.000102
30	0.000233	0.000116	0.000209	0.000104
35	0.0002	0.0001	0.000181	9.03E-05
40	0.000141	7.04E-05	0.000127	6.36E-05
45	0.000155	7.76E-05	0.00014	7.02E-05

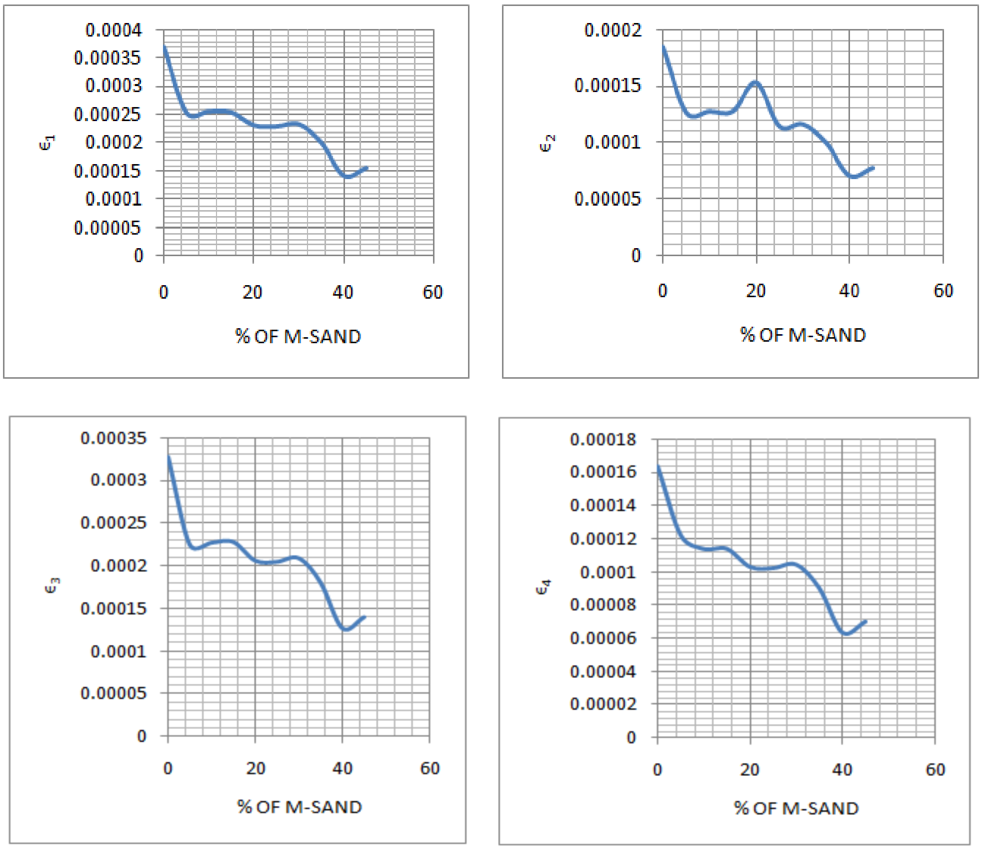

Fig 5.6 Variation of strain with percentage of addition of m-sand for soaked condition for location A

Table 5.7 Stress Values Obtained From Three Layer Analysis for Unsoaked Condition For Location A

% OF M-SAND	σ_{Z1}(MPa)	σ_{Z2}(MPa)	σ_{r1}(MPa)	σ_{r2}(MPa)	σ_{r3}(MPa)	σ_{r4} (MPa)
0	0.0104615	0.006127	0.2	0.0000721	0.003269	0.0014289
5	0.010835	0.0065325	0.20726	0.00007	0.0033875	0.0014825
10	0.011615	0.006825	0.22196	0.000065	0.003630625	0.001596875
15	0.01239	0.007293	0.2366	0.00006	0.00387	0.001707
20	0.013325	0.0078575	0.254275	0.000056	0.0041725	0.0018415
25	0.016344	0.009682	0.311306	0.000041	0.0051246	0.002276
30	0.01675	0.009927	0.31897	0.0000355	0.0051246	0.002765
35	0.01706	0.010115	0.32485	0.000035	0.00535	0.00238
40	0.02175	0.0135	0.405	0.0004125	0.00682	0.00334
45	0.025	0.01587	0.461	0.0007	0.00785	0.00402

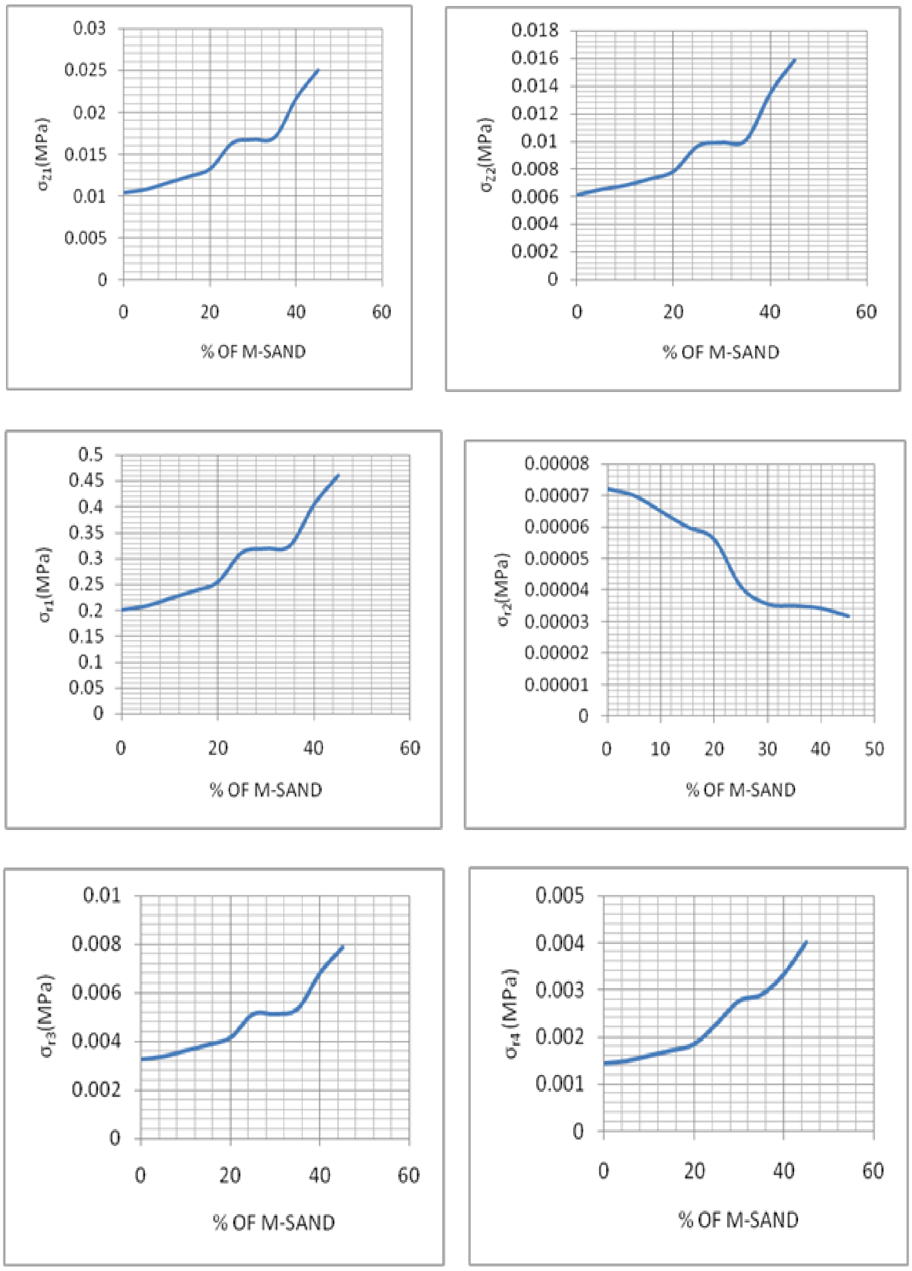

Fig 5.7: variation of stress with percentage of addition of m-sand for unsoaked condition for location A

Table 5.8 Strain Values Obtained From Three Layer Analysis For Unsoaked Condition For Location A

% OF M-SAND	ϵ_1	ϵ_2	ϵ_3	ϵ_4
0	0.000261	0.00013	0.000232	0.000116
5	0.000271	0.000136	0.000242	0.000121
10	0.000188	9.39E-05	0.000168	8.41E-05
15	0.000174	8.72E-05	0.000156	7.82E-05
20	0.000216	0.000108	0.000194	9.7E-05
25	0.000161	8.61E-05	0.000146	7.29E-05
30	0.000144	7.18E-05	0.00013	6.5E-05
35	0.000166	5.83E-05	0.000105	5.28E-05
40	0.000137	6.83E-05	0.00013	0.000065
45	0.000143	7.14E-05	0.000139	6.96E-05

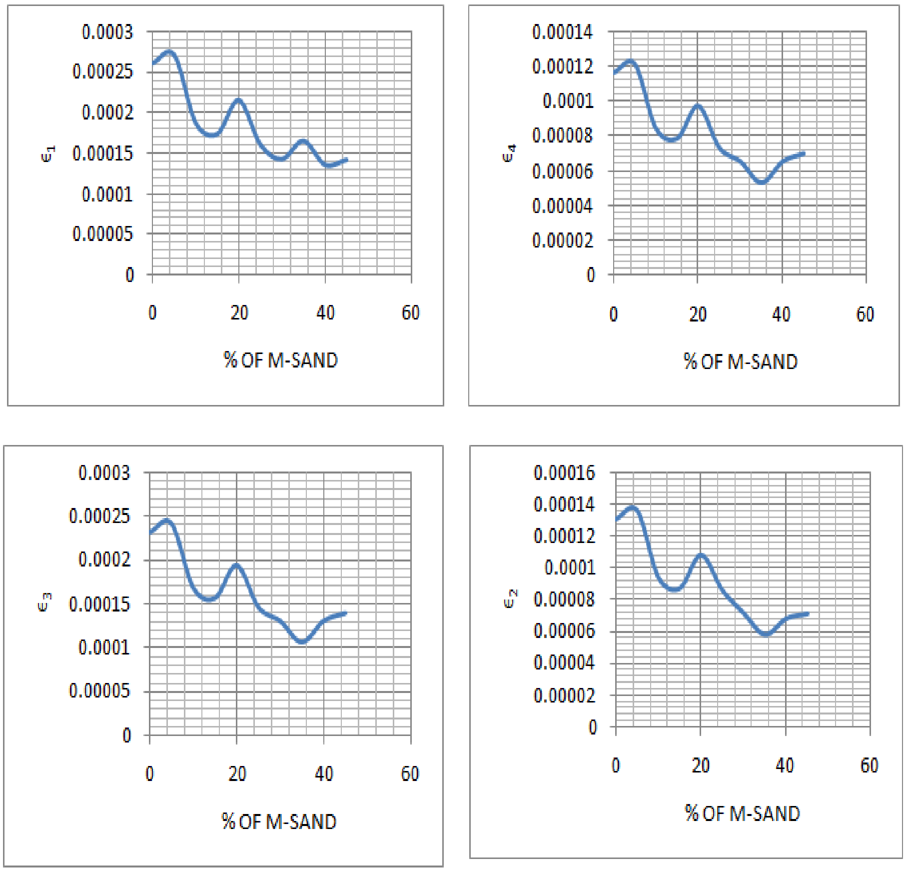

Fig 5.8: variation of strain with percentage of addition of m-sand for unsoaked condition for location A

VI. CONCLUSION

1. For replacement combination 55% natural soil + 45%M-sand unsoaked CBR value has increased from 3.12 % to 14.63% for location A and soaked CBR value from 2.22% to 8.73% for location A which suggest that adding M-sand there will be improvement in CBR.
2. For replacement combination is 50% natural soil + 50%M-sand unsoaked CBR value decreased from 14.63% to 13.19% and soaked CBR value from 8.73 % to 7.78% for A which do suggest that optimum replacement combination is 55% natural soil +45%M-sand.
3. From the relationships established between CBR and Properties of soil we can conclude that CBR which is considered as dependent variable shows increasing trend with properties such as Specific gravity, coefficient of uniformity and coefficient of curvature , Plastic limit ,Maximum dry density(MDD) and decreasing trend with properties such as liquid limit, ,plasticity index , optimum moisture content (OMC).
4. Vertical, radial stress and strain at first and second interface obtained are within permissible limit not exceeding the stress 0.5MN/m2 and deformation not exceeding 0.5cm.
5. For replacement combination 55% natural soil + 45%M-sand percentage reduction in pavement thickness obtained for unsoaked condition is 40.1% for soil samples.
6. For replacement combination 55% natural soil + 45%M-sand percentage reduction in pavement thickness obtained for soaked condition is 34.5% for soil A samples respectively.
7. In the light of above observations, it is concluded that replacement combination of 55% natural soil + 45%M-sandpossessed certain properties which enables it to be used in stabilization during pavement constructions in sandy clay sites. Hence the use of M-sand in road construction is economically viable and environmentally advantageous.

REFERENCES

[1]. Amrendra Kumar, Dr. Ravi Kumar Sharma, Babita Singh (2013)"Compaction and Sub-grade Characteristics of Clayey Soil Mixed with Foundry Sand and Fly Ash and Tile waste "IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278-1684, p-ISSN: 2320-334X PP 01-13

[2]. B. Ahmed, A. Rahman, J. Das(2015)"Improvement of sub grade CBR value by using Bagasse ash and Eggshell powder" International Journal of Advanced Structures and Geotechnical Engineering ISSN 2319-5347, Vol. 04, No. 02, April 2015.

[3]. Bureau of Indian Standards (1973).Methods of Tests for Soil, Part II, Determination of Water Content of Soil, IS: 2720, B.I.S,New Delhi.

[4]. Bureau of Indian Standards (1975), Methods of Tests for Soil, Part IV, Grain Size Analysis, IS 2720, B.I.S, New Delhi.