EFFECT OF WASTE CERAMIC DUST ON THE STRENGTH CHARACTERSTICS OF THE SUBGRADE OF THE FLEXIBLE PAVEMENT

A Dissertation submitted

in the partial fulfilment of the requirements

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DECLARATION

I, Wasifa Zehra, hereby declare that this thesis entitled **"Effect of Waste Ceramic Dust on the Strength Characteristics of the Subgrade for the Flexible Pavement"** is an authentic record of my study carried out as requirements for the award of degree of **Master of Engineering in Infrastructure Engineering** in the Civil Engineering Department, Thapar University, Patiala under the supervision of **Mr. Rajesh Pathak, Associate Professor and Dr. Tanuj Chopra, Assistant Professor,** Department of Civil Engineering, Thapar Institute of Engineering and Technology, Patiala during 25.07.2018 to 12.07.2019. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

(Wasifa Zehra)

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CERTIFICATE

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

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ABSTRACT

Stabilization of the soil is required if soil has the drawback in its required engineering properties for theintend of the construction or for the use as subgrade in the flexible pavement or rigid pavement. For the improvement of the engineering properties of the considered soil stabilization can be done by mixing some additives for the better results of the soil strength. For economic and environmental reasons solid waste can be used as the stabilizer for the reinforcement of the soil. The solid waste has different kind as per their source of production, e.g. Agricultural wastes, Industrial wastes, Mineral wastes etc. Some of these wastes are harmful for nature but the can have good effect if we use them as the stabilizer for the increase in the strength of the soil.

Many studies had been done on the soil to improve its properties, in this study we are going to observe the change in the properties of the soil by adding an industrial waste named as Ceramic which will be used in the form of dust. Using Ceramic dust as the stabilizer can improve many geotechnical properties of the soil such as Unconfined Compressive strength of the soil and California bearing ratio of the soil these are the properties to determine the strength of the soil.

Results from the CBR tests established that addition of these materials in subgrade soil gives efficient strength to subgrade soil. It was observed that the CBR value increases with increase in Ceramic Dust up to a certain percentage. Flexible pavement has been designed with the modification of the soil with Ceramic dust and observed that at the highest value of CBR at the optimum content of the Ceramic dust there is decrease in the pavement thickness, which leads to the decrease in the cost of construction of the pavement.

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CHAPTER 1

INTRODUCTION

1.1 Definition

Expansive soil is the term used for any soil which have the properties if shrinkage and swelling due to the change in the water condition and severe damage had been observed if the structure was standing on the black cotton soil as it has the dynamic change of swelling and shrinkage with the sudden change of water level.

Stabilization and reinforcement for these kinds of soil can be done to rectify the problem of damage that may occur due to the expansive soil. Stabilization of the soil can be done by mixing different materials which can have the positive observations on the properties of the soil such as swelling and shrinkage. By mixing there should be an improvement in the strength of the soil.

Many methods are applied for the improvement of the properties of the black cotton soil e.g. by stabilization, one of the method is by mixing coarse grained soil with the fine grained soil. There are also some techniques which can be applicable for the stabilization of the soil they are, mechanical stabilization, chemical stabilization and cementing stabilization. The reinforcement of the soil with the process of some mechanical compaction is known as mechanical stabilization. If some chemical such as calcium chloride, sodium chloride etc. are used for the stabilization known as chemical stabilization. In the process of cementing stabilization, the addition of cement, Lime and bitumen/asphalt is done in the soil

The foundation underneath the roads and buildings are the part for the efficient transfer of the load to the sub-soil present in the foundation. The properties and quality of soil have very important impact on the type and style of structure to be constructed. The expansive soils are weak soil which must be used for the construction of highways, bridge, dams and buildings because it covers a large part of the Indian land. There is large volume variation in the expansive soil if there is contact with water.In the rainy season there will be the expansion in the soil and it will shrink in the summer season. This soil is also known by name of “Black Cotton” soil because it has the weak properties because of the clay known as “Montmorillonite”.

It is necessary to remove the weak soil present in that area and replace it with the non- expansive soil, or that soil properties can be improved by mixing stabilizers. Solid wastes are those wastes which can be in the form of solid or semi-solid eliminated by the public. Inappropriate management of solid wastes causes harmful effects on the ecology which may lead to cause possible outbreak of diseases and bacteria. These are generally classified in to three groups named as waste from industries, waste produced from agriculture, and Municipal waste.

Solid wastes are used as stabilizers for the improvement of the properties of the soil is one of the technique for the stabilization.

1.2 Classification of Solid Wastes

There are various types of the solid wastes originating from different areas. Some of them are as follows:

1.2.1 Industrial solid wastes

This is the biggest problem in the countries which are in their developing condition such as India. The waste generated from the industries have the harmful effect on the nature such as land, air and water. These wastes also need a large for their dumping because they contain toxic reagents which had hazardous effect on the environment. Following are some examples for the industrial wastes e.g. waste cement kiln dust, quarry waste, ceramic dust, silica fumes etc.

1.2.2 Agricultural solid waste

The agricultural wastes are the remaining of the material used as raw in growing and processing such as fruits, grains, vegetables, meat, poultry dairy products and crops. Examples for the agriculture are as follows- ash produced from burning bagasse, ash from rice husk, wheat husk, groundnut shell ash etc.

1.2.3 Domestic solid wastes

Solid wastes produced from the residential and household units are known as domestic solid wastes. There are some examples of these wastes such as tire wastes, powder from egg shells, grain storage dust, etc.

1.2.4 Mineral solid wastes

Due to the mining and extraction procedures of ores and minerals there is the generation of the wastes known as solid wastes from minerals. Such as Lime stone dust, granite dust, dust from marbles, ceramic dusts etc.

1.3 Outline of Thesis

In this study waste ceramic dust is used which is generally available from nearby tiles industries. Engineering properties of the soil were studied which was locally available. A series of CBR tests were conducted on soil reinforced with ceramic dust content ranging from 5% to 30%.After getting improved CBR values, possible changes in the design of flexible pavements were studied. This study is categorised in following chapters:

1. Chapter Ist is about Overview of Solid waste Materials.
2. Chapter 2nd is about the literature review based on use of solid waste material such as lime, fly ash, rice husk ash, bagasse ash, ceramic dust, quarry dust, marble dust etc.
3. Chapter 3rd contains the experimental programme and the applications for this study.
4. Chapter 4th is about the results and graphs of the study done and discussion about the results.
5. Chapter 5th includes the design of flexible pavement.
6. Chapter 6th is concluding chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Review on the addition of Industrial Solid Waste

Pandian et, al(2001). In this paper author had used fly ash for the reinforcement of the black cotton soil, by increasing its quantity from 10% to 80% which has positive effect on the properties of the soil. There was decrease in plasticity but improvement in compaction parameters with maximum dry density and CBR increment in the subgrade.

Kalkan and Akbulut (2004) In this paper the author had observed the silica fumes effect on Atterberg's limits, MDD and OMC and porosity of the soil and unconfined compressive strength of the soil is studied and found out that with the addition of silica fumes there was decrease in porosity and increase in UCS.

Peethamparan and olek (2008). In this paper the author had experimented the effect of cement kiln dust on the black cotton soil. It had decreases the index of plasticity and UCS was increased. The important parameters for the stabilization was because of the free lime available in the cement kiln dust.

Cokca et, al(2009) used blast furnace slag in coarse grained form and also blast furnace slag cement for the mixing it with artificially prepared expansive soil. These additives are in the proportion of 25% and 50% at an increment of 5%. Swell index of the given soil was decreased due to the stabilization, but the swell rate had increased. As analysis of the leachates was done and it was turnout that, these stabilizers shouldn't be used if the soil is near drinking water well.

Sabat (2012) observed the reaction of ceramic dust as stabilizers on the expansive soil. Addition of ceramic dust is done up to 30% and there were positive results on plasticity index, strength and swelling properties. There was increase in the strength of the subgrade of flexible pavement when ceramic dust was added up to 30% due to which there was save in the cost.

Abo-Hashema and Abdul-El-Aziz (2013) used lime and crushed clay bricks for the reinforcement of the expansive clay to stabilize it. By using crushed clay bricks and lime there were noticeable increment in CBR, Cohesion and plasticity, maximum dry density and consolidation settlement all these properties are decreased.

Ankur Mudgal et, al (2014). In this paper author had found the effect of stone dust on the expansive soil which was previously stabilized by the lime and experimenting that soil with the addition of stone dust up to 20% and MDD increased as it will decrease with further increment and stone dust had same effect on the UCS and CBR the increment was observed up to 20% and then there is decrease, The reason behind this behaviour was the reaction of pozzolanic present in the lime.

Sabat and Pradhan (2014) had studied the polypropylene fibre effect on the properties such as compaction, UCS, Soaked CBR of soil having expansive properties which was stabilized before with the 20% fly ash had observed that the percentage and length of fibre used for the optimum results are 1% and 12mm, it will improve the strength of subgrade and other important properties.

Yadav R.K and Parte Shivam (2014) examined the effectiveness of dust of marble on the expansive soil by increasing it up to of 10% and it was observed that there is the reduction of swelling from 66.6% to 20% and increase in unconfined compressive strength of the soil and it increased by 58% from its base value. The soaked CBR had also a significant effect as it increased from 1.18% to 4.17% with the addition of marble dust up to 40%.

Vivek Singh et, al (2015) examined the effect of dust obtained from the cement kiln on the black cotton soil, there was change in the parameters of the compaction such as maximum dry density increased and OMC reduced with the addition of cement kiln dust. There is also reduction in the swelling properties of the expansive soil and differential free swell is reduced from 31% to 5%. Soaked CBR of the given soil also increased with the addition of Cement Kiln dust up to 25% as the increment is from 1.5% to 3.5%. Permeability of the Soil also increased up to some value and UCS had also some positive effect with cement kiln dust.

Rakhil Krishna, Devi Krishnan (2016). In this paper the author had observed that the ceramic dust effect on the black cotton soil, by doing different tests in the laboratory, by adding ceramic dust in the given soil with the increment of 5% from 0% to 30%. With the increase in the percentage of the ceramic dust there will be the decrease in the liquid limit from 63% to 34% and there is reduction of plastic limit with the mixing of the ceramic dust in the given soil from 0% to 30% as it can be observed from the graph between plastic limit and ceramic dust percentage.

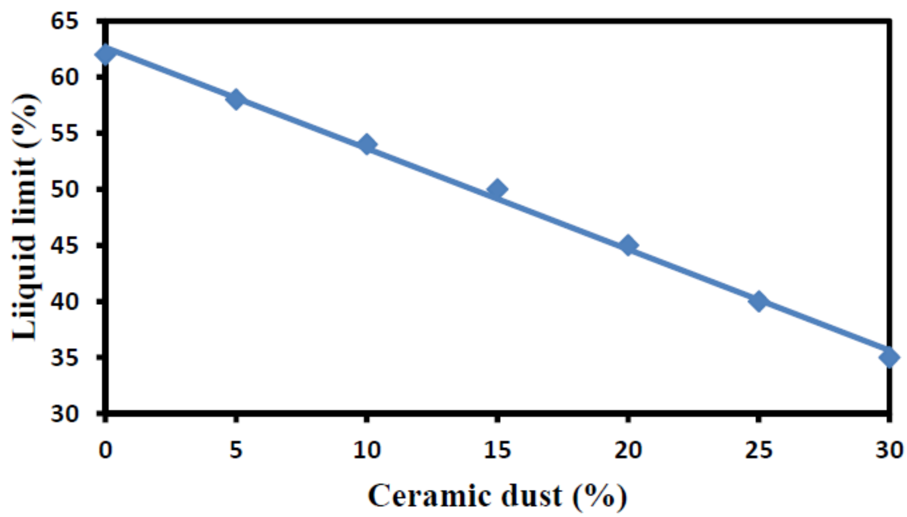

Figure 2.1 Liquid limit variation with the percentage of the Ceramic Dust

It can be seen in figure 2.3 that the plasticity index had a significant change with the increasing percentage of ceramic dust.

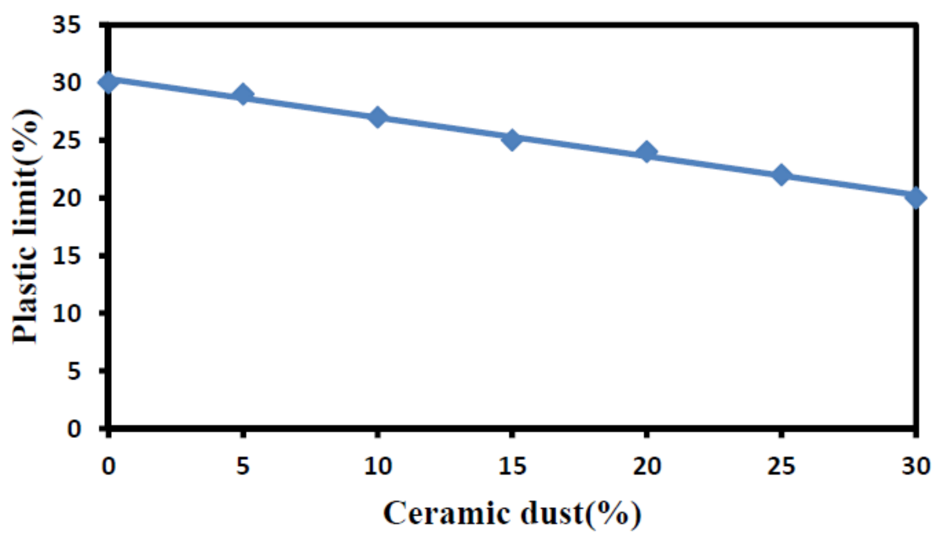

Figure 2.2 Plastic limit variation with the Percentage of ceramic dust

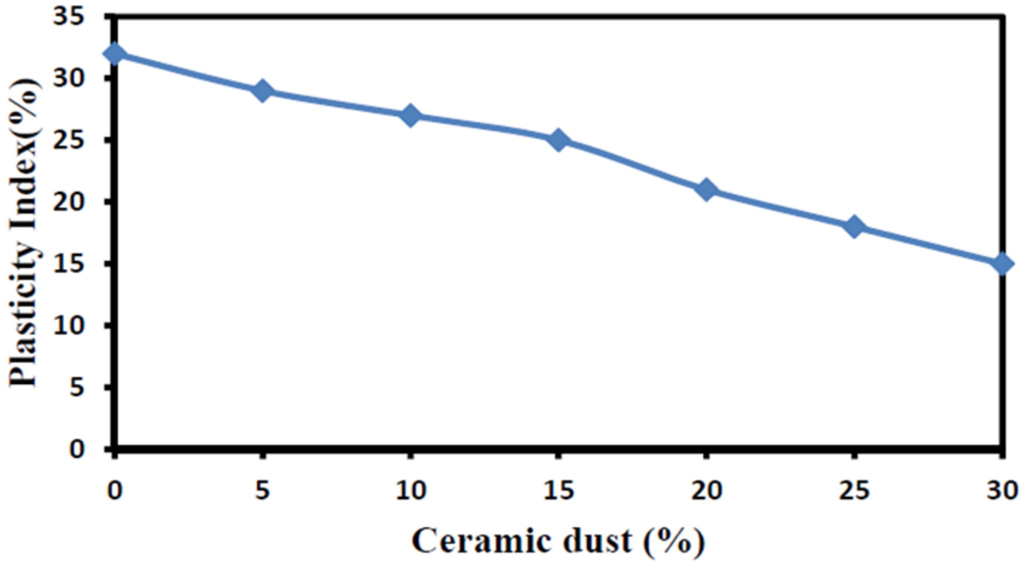

Figure 2.3 Variation of the plasticity index with the increasing percentage of ceramic Dust(Rakhil Krishna, 2016)

After the effect of Ceramic dust on the atterberg's limit it can be seen that the compaction parameters such as MDD of the expansive soil had an increment when ceramic dust was added from 0% to 30% the MDD increased up to 15% as there is an increment 25% from its base value. We can see the effect of ceramic dust in the given Figure. 2.4 and this behaviour of soil in compaction is due to the mixing of soil with the ceramic dust as ceramic dust have higher specific gravity as compare to the black cotton soil.

Parameters of the compaction had changed effectively with the addition of ceramic dust. The OMC of the base soil was 20.4% as it decreased with the addition of the ceramic dust in the soil and the decrease was up to 15% as we had observed in the MDD. This variation can be seen in the figure 2.5 and it can be observed that there was decrease in optimum moisture content with increase in the percentage of the ceramic dust.

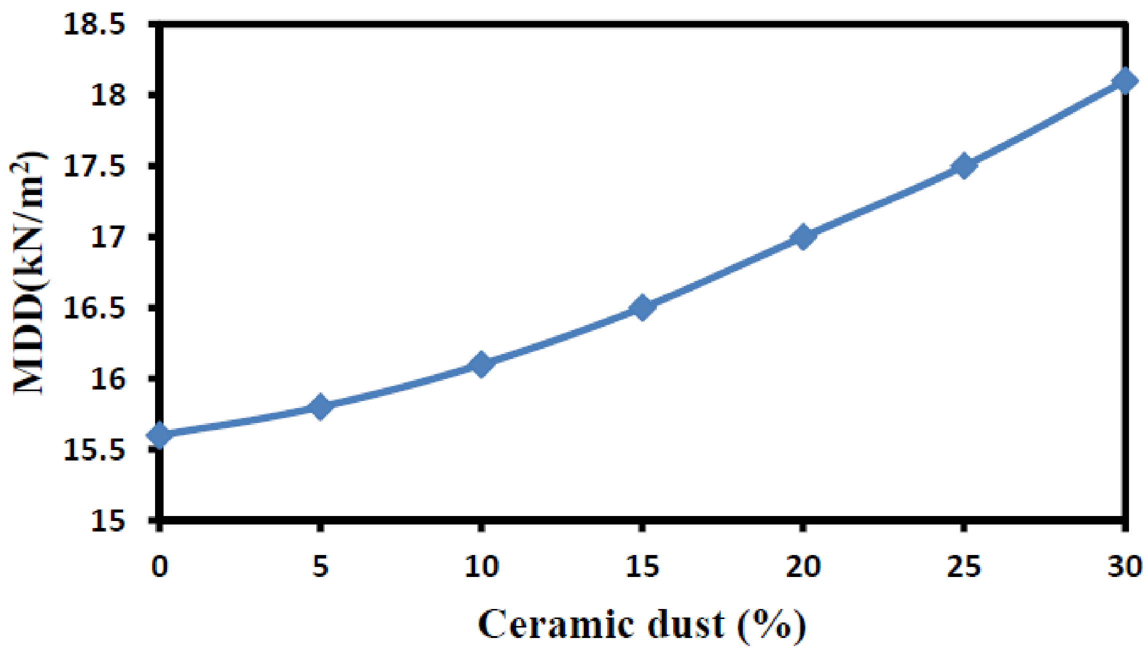

Figure 2.4 Variation of the MDD with the Increased Percentage of Ceramic Dust (Rakhil Krishna, 2016)

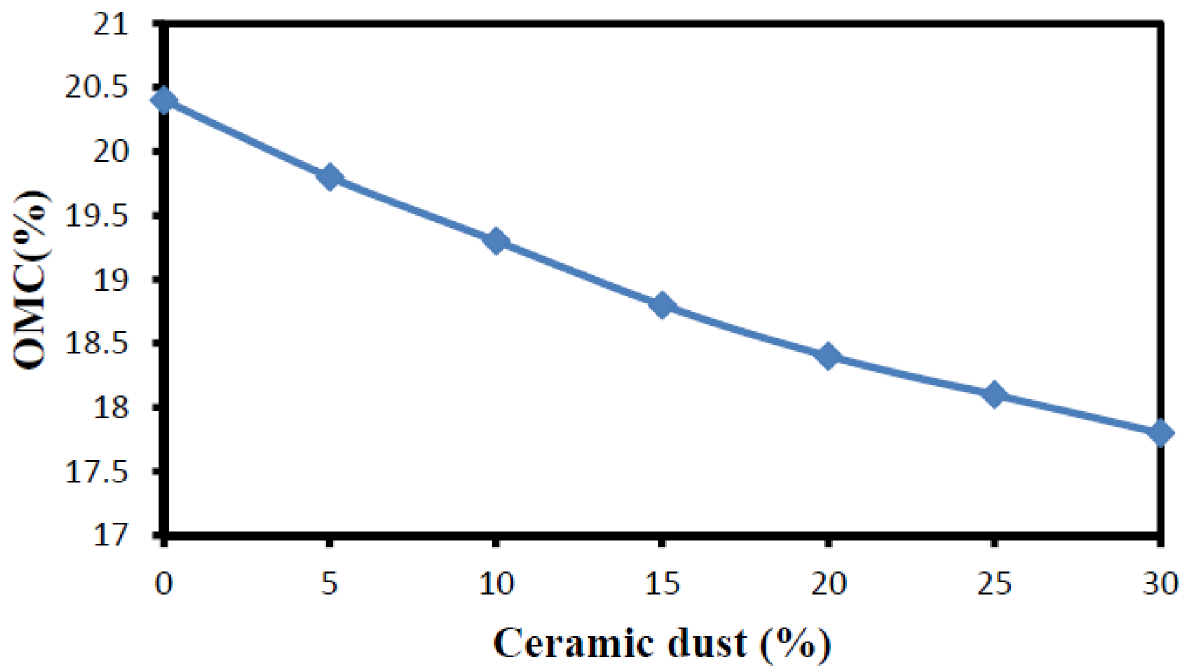

Figure 2.5 Change in OMC with ceramic dust (Rakhil Krishna, 2016)

Unconfined compressive strength test was also conducted for this study as this test was very quick and gives the idea about the strength of the soil. Strength of soil improved with the ceramic dust increasing from 0% to 30%.The increment in the UCS can be seen in the Figure 2.6.

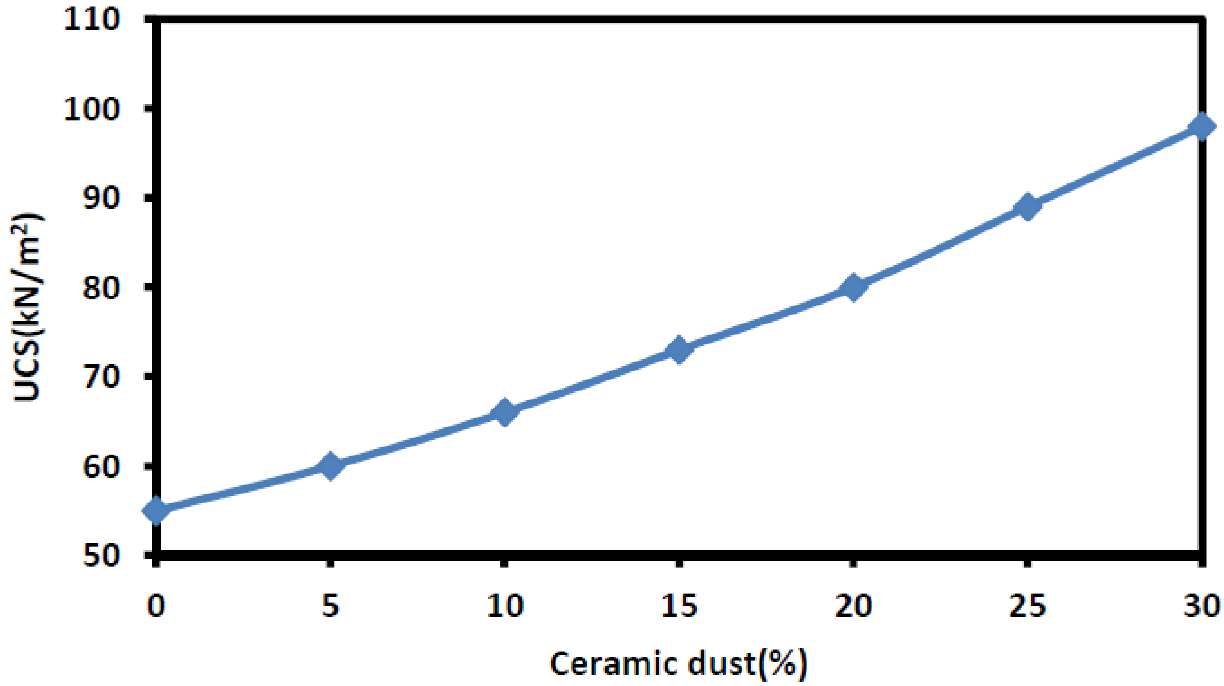

Figure 2.6 Variation of Unconfined Compressive Strength with the increment in Percentage of Ceramic Dust (Rakhil krishna, Devi Krishana,2016)

It was observed from the above graphs that there is significant effect of increased ceramic dust on the parameters of the compaction such as MDD and OMC. There was increase in the UCS and CBR (soaked). This behaviour of black cotton soil is due to the replacement of the clay content with the ceramic dust and due to the increase in the CBR. Due to increase in the CBR the thickness of the pavement is decreased and cost of construction was also decreased.

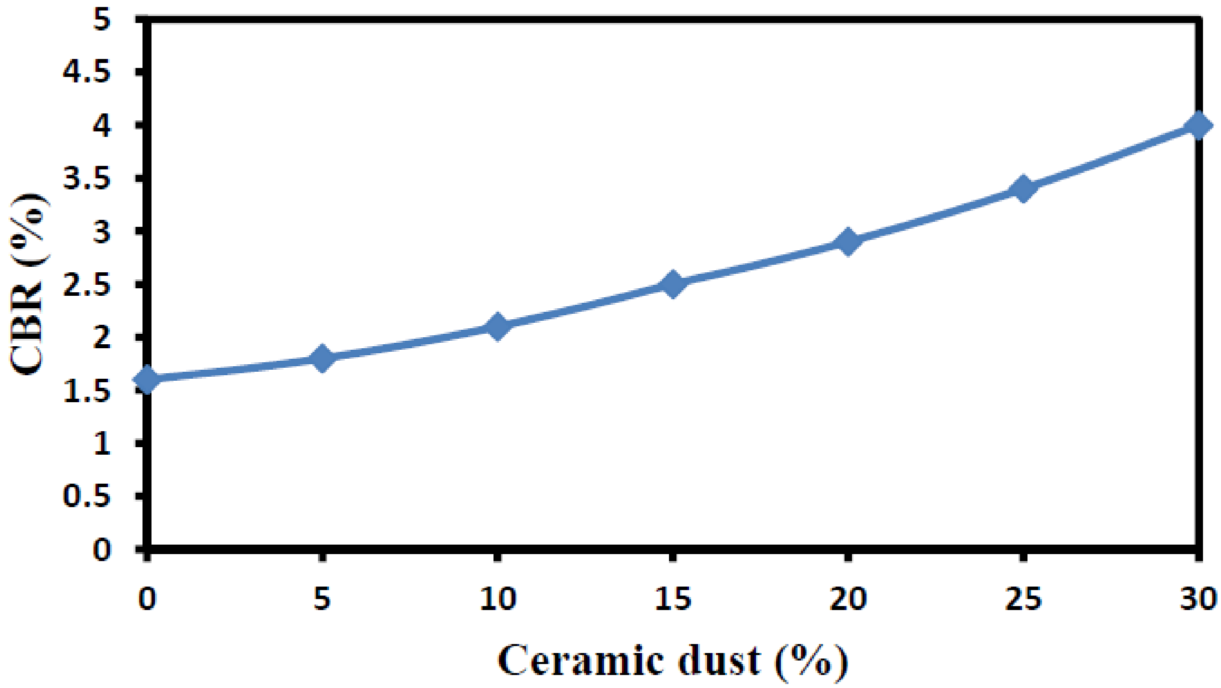

Figure 2.7 Effect of ceramic dust on the soaked CBR (Rakhil Krishna, 2016)

2.2 Literature review on Agriculture solid waste

Bhasin et, al (1988) examined the effect of the ash of rice husk on the expansive soil along with the fly ash, lime sludge bagasse with or without lime. RHA (Rice husk ash) had greater effect and improvement then other wastes due to reactive silica present in higher value in it, RHA improves the properties of soil effectively.

Sharma et, al(2008) had experimented and observed the behaviour of lime stabilized expansive soil including rice husk ash and calcium chloride. Calcium chloride and lime used in the optimum percentage of 1% and 4%without RHA for the stabilization of the expansive soil. Optimum content of RHA with calcium or lime for the CBR and UCS results was 12%.

Oriola and Moses (2010) used the ash of groundnut shell to study its effect on the expansive soil. By the addition of groundnut shell ash up to 4% and 6%, there is an increase in UCS value and standard proctors'. Parameters were also increased. The most effective soaked CBR were obtained at 6% and 0% content of the ground nut shell ash. As per all the observations stabilization with the ground nutshell ash was not so beneficial, strength gained after curing.

*Ijimdiya et, al (2012).*This study was done to observe the effectiveness of the ground nut shell ash used for the stabilization of the expansive soil by performing different tests to determine the its effectiveness on the properties of the soil. Ground nut shell ash was added with increment of 2% from 0% to 10%. With the addition of the ground nut shell in the expansive soil there is an increase in the liquid limit and decrease in the plastic limit and plasticity index as well. As for the CBR it has an increment if curing is done for 7 days.

Sabat (2012) had experimented that what effect can be obtained when bagasse ash and lime sludge was used for the stabilization of the expansive soil. To determine the effect of the stabilizers the OMC, MDD, UCS, soaked CBR experiments were done. By adding bagasse ash and lime sludge at the significant value of 8% and 16% a good effect on compaction parameters and soaked CBR can be observed. The addition of these stabilizers at an optimum value was also cost effective.

Amit S. Kharade1, Vishal V. Suryavanshi (2014). In this research paper the use of agricultural waste for the stabilization of the black cotton soil was studied. To increase the strength properties of the soil by adding additives combining it with cement and lime has been attempted, but for the economic and environmental reasons some cheaper and nearly available material for the stabilization must be used is the main motive of this study.

A fibrous material bagasse which is obtained after grinding of the juice from the sugar cane, a lot of sugar crushed sugar cane can find in the various part of our country. The amount of 30% can be produced from a lot of sugar cane. For the manufacture of the paper the crushed sugar cane can be used. If we burn that bagasse we can obtain the “Bagasse Ash”. Composition of bagasse ash contain amorphous silica which has a pozzolanic property, the property which is used to hold the soil grains together for the effective shear strength of the soil. Various test was performed such as compaction, CBR, UCS, atterberg’s limit etc., to find the effect of the bagasse ash on the soil for its stabilization.

Replacing soil with bagasse ash from 3% to 6% there is an improvement in maximum dry density was observed but if the percentage of bagasse ash increase their will be the decrease in the MDD. The results of MDD and OMC can be seen from the Table. 2.1

Table 2.1 MDD and OMC values with the replacement of bagasse ash (Amit s Kharadel, Vishal V., 2014)

Percentage	Expansive Soil		Expansive + Bagasse ash	
	MDD (g/cc)	OMC (%)	MDD (g/cc)	OMC (%)
0	1.305	30.5	Nil	Nil
3	-	-	1.34	35.05
6	-	-	1.38	34.50
9	-	-	1.29	28.10
12	-	-	1.23	27.40

From above table we can see there is decrease in MDD because of low specific gravity of the bagasse ash, and it was observed that with the increase in the percentage of bagasse ash there is also decrease in OMC (optimum moisture content).Variation of maximum dry density with the replacement of bagasse ash can be seen from the graph in Figure.2.8 and 2.9.

As the strength and bearing capacity of soil can be obtained by unsoaked CBR-Table 2.2 and figure 2.10 shows the increasing value of CBR with 3% to 6% replacement with bagasse ash but drop to lower value if percentage of bagasse ash increased further.

Compressive strength variation can be obtained after 24 hours of curing and after that testing is done in unconfined compressive strength testing machine. The strength of the soil increases with 6% bagasse ash replacement but, if the percentage of bagasse ash increases from its optimum value there will be decrease in the strength. This variation can be seen in the graph of Figure.2.11

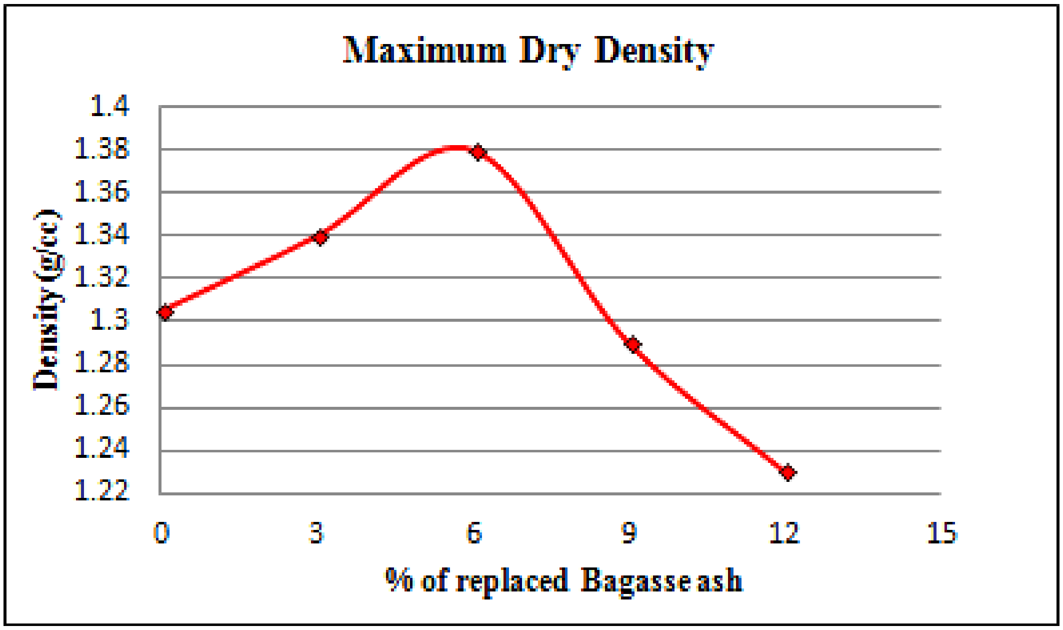

Figure 2.8 MDD with the replacement of Bagasse ash (Vishal.V Suryavanshi,2014)

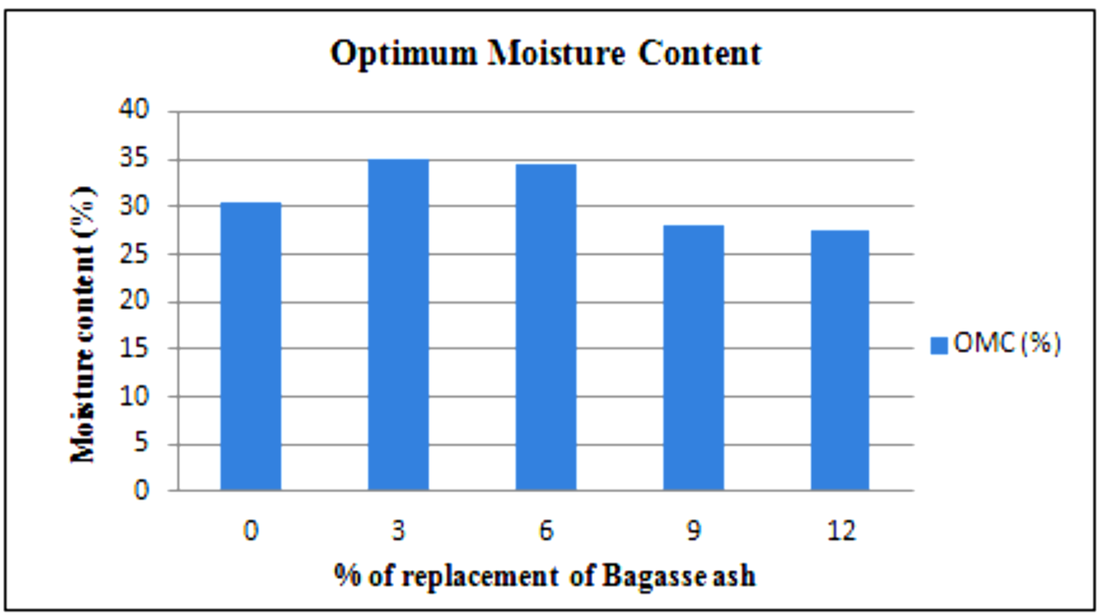

Figure 2.9 Variation in optimum moisture content with % replacement of Bagasse ash

Table 2.2 CBR with replacement of Bagasse Ash

(Amit S. Kharade1, Vishal V. Suryavanshi (2014)

% Replacement	Black cotton soil + % Bagasse ash **CBR Values**
0	12.88
3	15.93
6	22.04
9	17.39
12	12.58

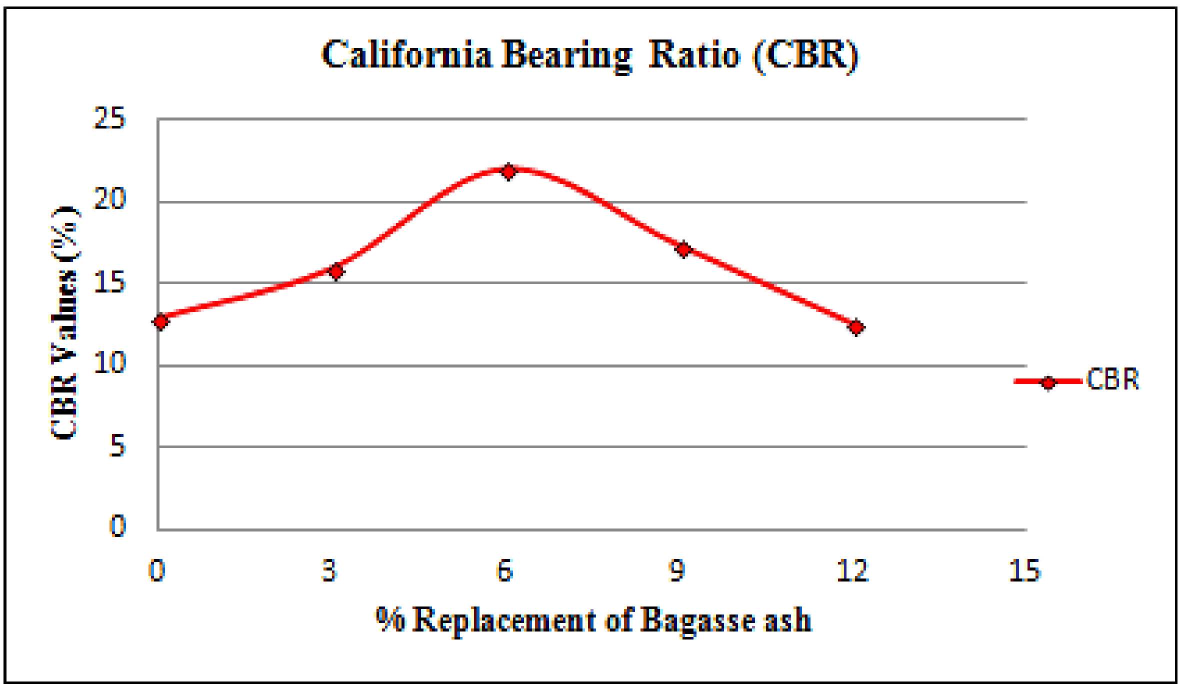

Figure 2.10 CBR variation with bagasse ash (Amit S. Kharade1, Vishal V. Suryavanshi (2014))

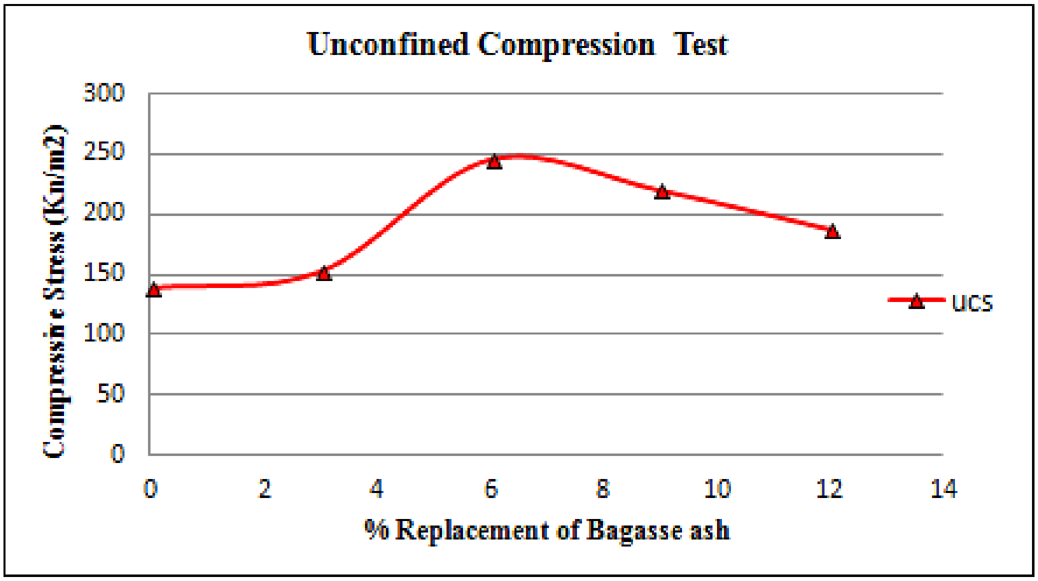

Figure 2.11 Variation UCS with the replacement of bagasse ash

Ashango and Patra (2014) had experimented and observed the properties of clay by static and cyclic ways on the subgrade as it was stabilized with the rice husk ash and Portland slag cement. The use of these stabilizer had the significant effect on the strength of the soil and also the durability of the stabilized soil increased. For the stabilization of the soil to gain maximum strength 10% of RHA and 7.5% of Portland slag cement was added. The construction of stabilized subgrade with RHA and Portland slag cement has improved strength and decreased cost also.

2.3 Literature review on Domestic solid waste

Al-Rawas(2004) had studied the effect of kiln ash (ash obtained due to the burning of municipal solid waste) for the stabilizing the soil and experimenting it by atterberg's limits after one day curing and doing direct shear test at the curing of 1,7,and 14 days.There was an increase in the friction angle of the soil grains and reduction in the cohesion and shrinkage properties of the soil with the increase in the curing period and the percentage of the incinerator waste ash.

Abu- Ashour and Mughieda (2006) observed the effect of dust waste from the grain storage (dust produced due to the loading and unloading of the grains in the grain storage) on the virgin soil used . The mixing of this dust with soil is done with the percentage of 0% to 8% and many changes were observed such as there is the reduction in the shrinkage limit as well as shrinkage index and increase in the frictional angle but decrease in the cohesion.

Eberemu et al (2006) had experimented the mixing of glass cullet for the stabilizing of the expansive soil and its effect on the properties of the soil. As glass cullet is added with the increment of 5% up to 20%. There is the constant decrease in the liquid limit, plastic limit, OMC, Cohesion and continuous increase in plasticity index, specific gravity, MDD, UCS, CBR and frictional with the increase glass cullet percentage.

2.4 Literature review on Mineral solid waste

Srinivasulu and Rao (1995) had examined the baryte powder effect on the soil when used as stabilizers. The baryte powder was used up to 20% in the expansive soil, with the increase in the percentage of the baryte powder there is an increase in the CBR, UCS, frictional angle and maximum dry density and decrease in the OMC, swell index and cohesion.

Sabat and Das (2009) used quarry dust for the stabilization of the expansive soil and for the strengthening of the subgrade. As different test was performed on the stabilized soil such as compaction, UCS, soaked CBR and atterberg's limits. The strengthening of the subgrade is obtained from their stabilizers and it was cost efficient for the construction of rural roads having low traffic volume.

Ene and Okagbue (2009) had utilized the pyroclastic rocks for the stabilizing of the expansive soil. The pyroclastic rock dust was added in the expansive soil up to 12% with the increment of 4% weight of the soil. The decrease in the plasticity and shrinkage limit was observed with the increase in the percentage of the pyroclastic rock dust. There was the increase in maximum dry density, OMC, Shear strength and CBR were increased with the increasing percentage of the dust.8% of the pyroclastic rock dust was optimum value for the maximum CBR.

Sabat and Nanda (2011) had experimented the effect of the marble dust on already Rice husk ash stabilized expansive soil and observed that there is an increase in the strength of the soil by the addition of the marble dust and decrease in the swell pressure due to the marble dust increment. The optimum proportion of expansive soil: Rice husk ash: Marble dust is found out to be 70:10:20.

Akshay Kumar Sabat (2012). In this study the author had observed the effect of lime has been observed on the quarry dust stabilized expansive soil. Different test such as compaction, UCS, CBR, Shear strength and durability had been performed on the quarry dust stabilized soil with the addition of the lime. The shear strength was tested at the 7- and 14-days curing.

Variation in the liquid limit, plastic limit and plasticity index of quarry dust stabilized soil when mixed with the lime can be observed, as with 40% quarry dust in the expansive soil there is decrease in liquid limit, plastic limit and plasticity index but increase in the shrinkage limit, when lime added there is also decrease in the liquid limit and plasticity index but there is increase in plastic limit and shrinkage limit which can be seen in the below graph on figure 2.12

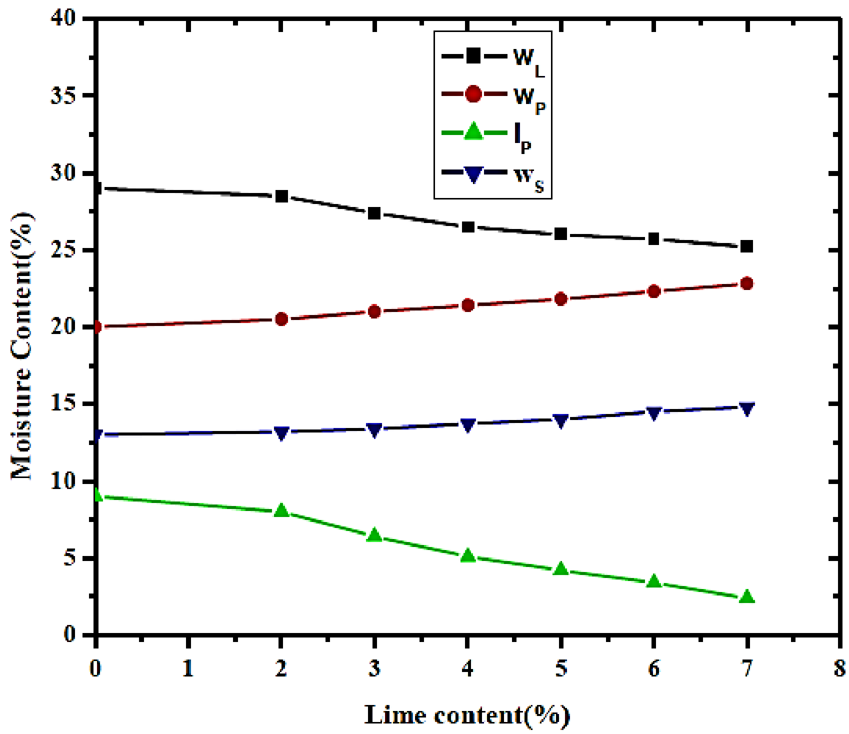

Figure 2.12 Liquid Limit, Plastic Limit and Plasticity index varies with the lime increment in the 40% quarry dust stabilized soil (Sabat, 2012)

The variance of OMC and MDD of quarry dust stabilized expansive soil can be observed when there is 40% of quarry dust only in the expansive soil there is an increase in MDD and decrease in OMC and when lime is also added the OMC goes on increasing and MDD decreased when lime content increased, and this can be seen in the graph shown in the figure.2.13 and figure. 2.14

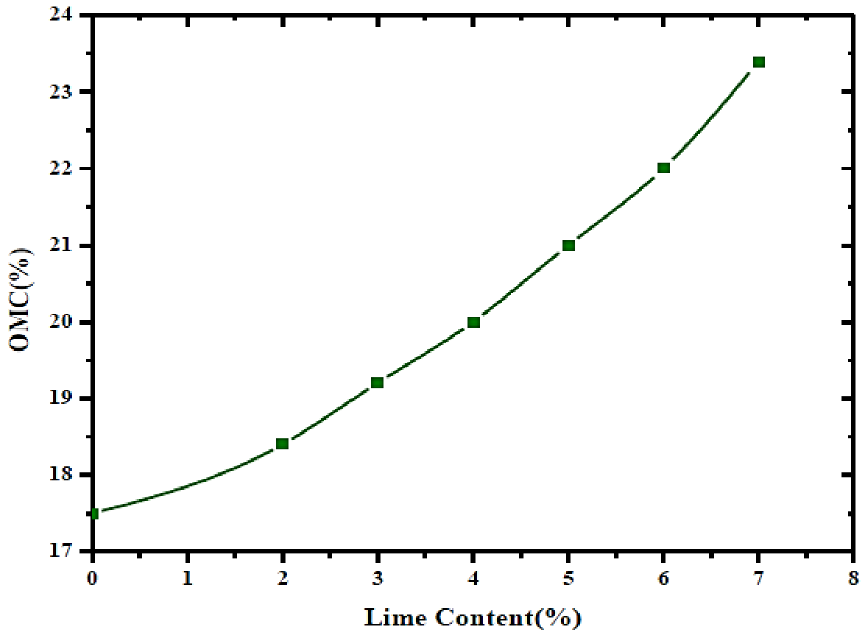

Figure 2.13 Variation of OMC with lime content

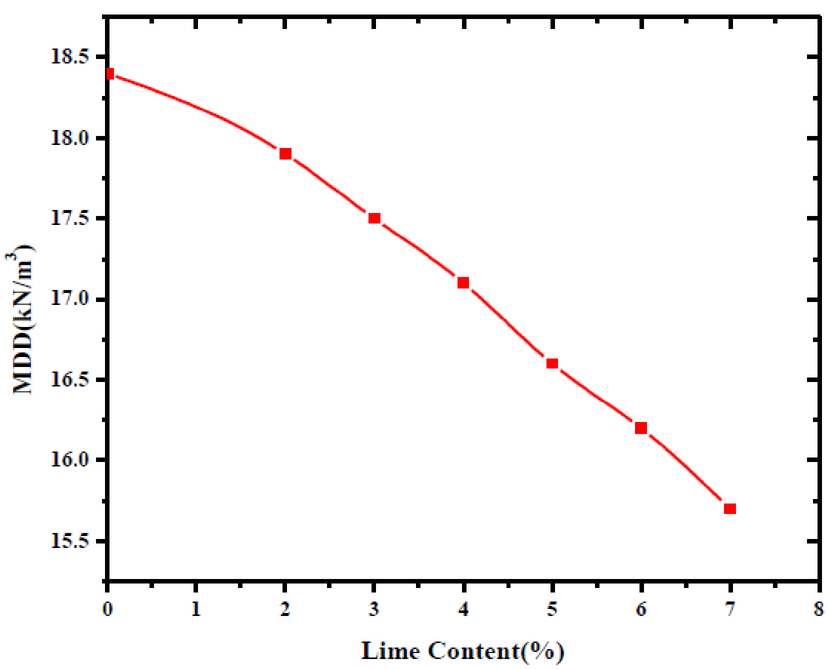

Table 2.14 MDD variation with the addition of Lime content

CHAPTER 3
EXPERIMENTAL PROGRAMME

3.1 Materials

The materials used for the experimental programme will be the virgin soil and the stabilizer has to be used for the stabilizing of the soil. Mostly to improve the drawback properties of the soil and strengthen the soil to use is as the subgrade of the flexible pavement.

3.1.1 Clayey Soil

Properties of soil

Table 3.1 Soil properties

Properties	Values
Liquid Limit (%)	34
Plastic Limit (%)	16.67
Plasticity Index	17.3
Classification	CL
OMC (%)	17.74
MDD (kN/m^3)	17.9
CBR (%)	3.13

3.1.2 Ceramic Dust

Locally collected waste ceramic tiles from the industries around the Patiala were used in the experiment. The properties of the ceramic dust are given below:

Properties of Ceramic

Table 3.1 Properties of Ceramic Dust

Properties	Values
Grain Size Analysis	
Sand size	46%
Clay size	31%
Silt size	23%
Specific Gravity	2.82

3.2 Compaction

It is the test as per IS: 2720-Part viii(1995) to determine the maximum dry density and optimum moisture content of the soil when it undergoes in the compaction in the given mold with the specific weight of the hammer when dropped from a specific height. The results obtained from the compaction will be very helpful in increasing the bearing capacity and strength of the foundation. The settlement in the structure can be decreased. There will be the control in abrupt volume changes. Hydraulic conductivity can be reduced, and slope stability is attained.

3.2.1 Applications

By compacting the soil there will be increase in their strength, density, bearing capacity and reduction of the void ratio, permeability, porosity as well as settlement of the soil used. For the stability of the soil these tests are the requirement for the structures like earthen dams, roads and embankments.

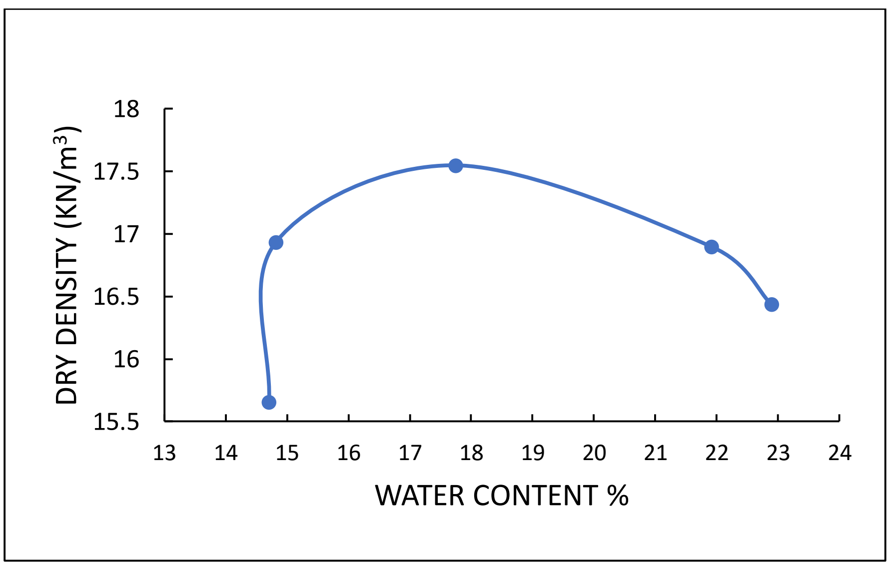

Figure 3.1 Compaction Curve of base soil

3.3 Unconfined Compression Test

This is quick test to find the strength of the soil in the drained condition as there is loading on the soil sample axially and deformation in the soil sample at continuously varying loading can be obtained. This test is only for the fine-grained soil.

3.3.1 Significance

1. It is a fast test to find the parameters of shear strength of the cohesive soil either in disturbed or undisturbed condition
2. This test is a strain-controlled test by loading the sample rapidly due to which the water present in the soil known as pore pressure changes quickly and it doesn't have enough time to drain out.
3. That's why this test is important for the soils on construction sites were pore water pressure doesn't get any chance to drain out as the speed of construction is too high.

3.3.2 Applications

1. Relative consistency can be obtained from thus test.
2. To estimate the rough analysis of the strength of the soil for the benefit of the geotechnical design properties this test can be effective
3. Undrained Shear Strength or Undrained Cohesion (C_u) = $q_u/2$ can be obtained.

3.3.3 Equipment for the Test

1. Unconfined Compressive Test Machine
2. Split mould having height 71mm and diameter of 36mm is used
3. Tubes are used to extrude sample from Proctor mould.
4. Dial gauge having Least count of 0.01
5. Stop watch
6. Weighing machine
7. Oven
8. Knife for the trimming of the sample.

3.3.4 Procedure

1. Put the sample in the mixing pan and add suitable quantity of water and mix it properly until you see the consistency in the colour of the soil
2. Put the soil in the proctor mould in three layers by compacting each layer with the hammer evenly.
3. Put the sampling tube above the trimmed surface of the soil in the mould and push the sampling tube in the mould for the undisturbed soil sample.
4. Remove the tubes from the mould containing soil in each tube, then extrude the sample in the split samples with the help of extruder and we will get the 3 sample
5. After trimming it along the edges of the split sampler, make the samples accurate.
6. Then put the sample under unconfined compressive strength testing machine and set the dial gauge to zero and start the loading
7. Note the readings and do the same for the other two samples.

Figure 3.2 Testing of the UCS sample

Figure 3.3 Failed sample of UCS

3.4 California Bearing Ratio Test

This is the test performed to find out the strength or bearing ratio of the soil used as the subgrade of the pavement constructed and for this California bearing ratio it the procedure for testing.IS: 2720- Part xvi (2002) is applicable for this test.

As the results from the CBR test will help in finding the thickness of the pavement to be constructed and its composite layers thickness can also be determined from the plates of CBR present in the IRC: 37-2012. This test is used mostly for the design of the flexible pavement.

3.4.1 Equipment’s and tool required.

1. Mold with the inner diameter of 150mm and height of 175 mm with the removable extension collar and a perforated base plate
2. Space disk having diameter of 148 mm
3. Hammer weighing 2.6 kg dropping from the height of 310mm
4. A machine for the penetration testing of capacity 5000kg with movable head and base and at the rate of 1.255mm/minute with a load indicating device.

5. A penetration piston of diameter 50mm.

3.4.2 California Bearing Ratio:

California bearing ratio is the ratio of the force required per unit area to penetrate in the soil with a circular piston at the rate of 1.25mm/ minute.

C.B.R. = Test load/Standard load * 100

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

Figure 3.4 Penetration test for CBR sample

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Liquid and Plastic Limit

For Liquid Limit and Plastic Limit, we added ceramic dust in the soil gradually increasing from 0% to 25% with the increment of 5%.

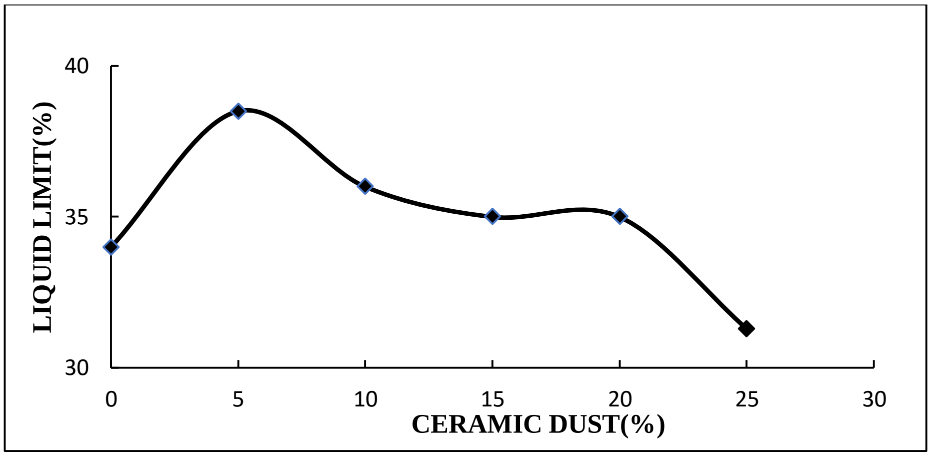

Figure 4.1 Variation of liquid limit with the increment of ceramic

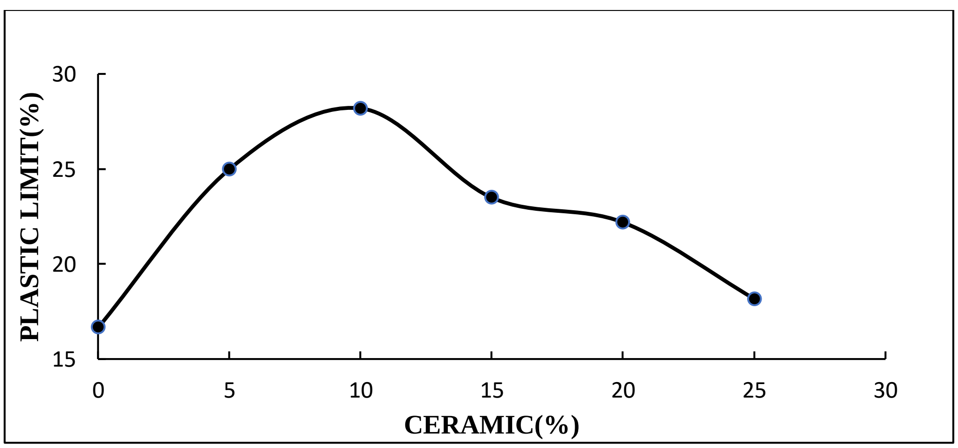

Figure 4.2 Variation of Plastic limit with the increment of Ceramic Dust

From the graphs of the liquid limit and plastic limit it can observe that there is a decrease in the liquid limit from 34% to 31% with the addition of the ceramic dust in the soil when it increases up to 25%. There is very different variations in the plastic limit as it has increases from 16% to 23.5%

up to 15 % of the ceramic dust addition but there is decrease from 23.5% to 18% when ceramic dust content is added from 20% to 25%.

4.2 Compaction

Different Maximum dry Densities and Optimum moisture content obtained with the reinforcement of soil with the ceramic dust. As the soil is replaced by ceramic dust with the percentage of 0% to 30% with the increment of 5% and results of OMC and MDD are obtained.

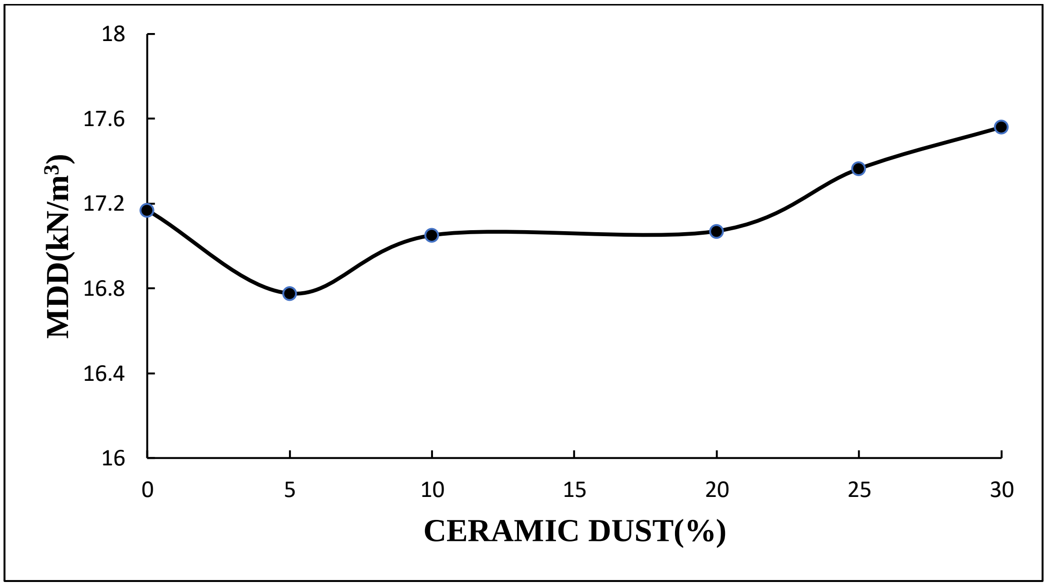

Figure 4.3 Variation of MDD with Ceramic Dust

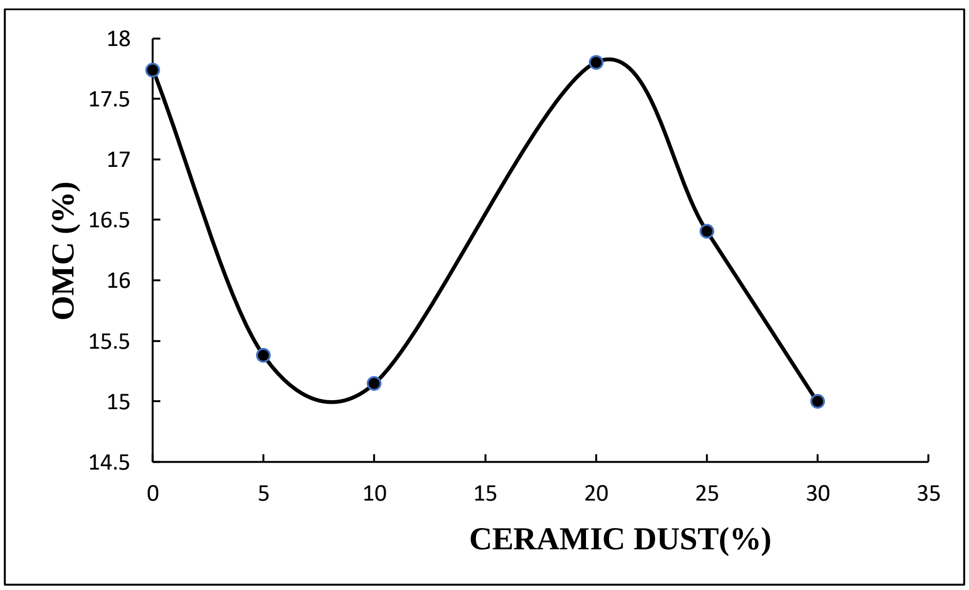

Figure 4.4 Variation of OMC with Ceramic

Table 4.1 Variation of MDD and OMC with Ceramic Dust

Ceramic Dust (%)	0	5	10	20	25	30
Maximum dry density (kN/m^3)	17.5	17.1	17.38	17.4	17.7	17.9
Optimum Moisture Content (%)	17.74	15.38	15.15	17.8	16.41	15

From the above results obtained from the proctor test it can be seen that there is a slight increase in the Maximum dry density from 17.5 kN/m^3 to 17.9 kN/m^3 when ceramic dust increases from 0% to 30% and decrease in the Optimum moisture content.

4.3 Unconfined Compressive Strength

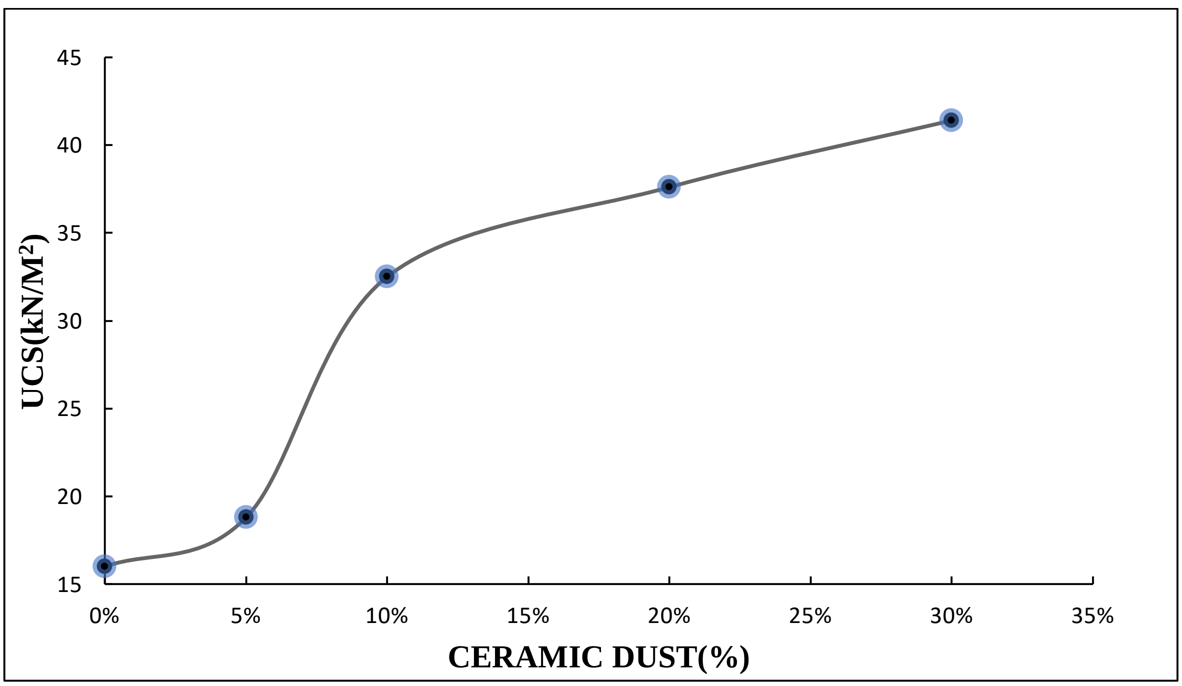

Figure 4.5 Variation of UCS with Percentage of Ceramic dust

From Figure 4.5 it can be observed that there is a significant increase in the unconfined compressive strength of the soil with the addition of the ceramic dust from 0% to 30% and there is continuous increment in the unconfined compressive strength of the soil from 16kN/m^2 to 41.4 kN/m^2 with each 5% increment of the ceramic dust.

4.4 California Bearing Ratio

As reinforcing the given soil with Ceramic, we can see the variations of CBR curve according to the increment of Ceramic Dust from 5% to 30%.

4.4.1 Load Penetration curves for unreinforced sample

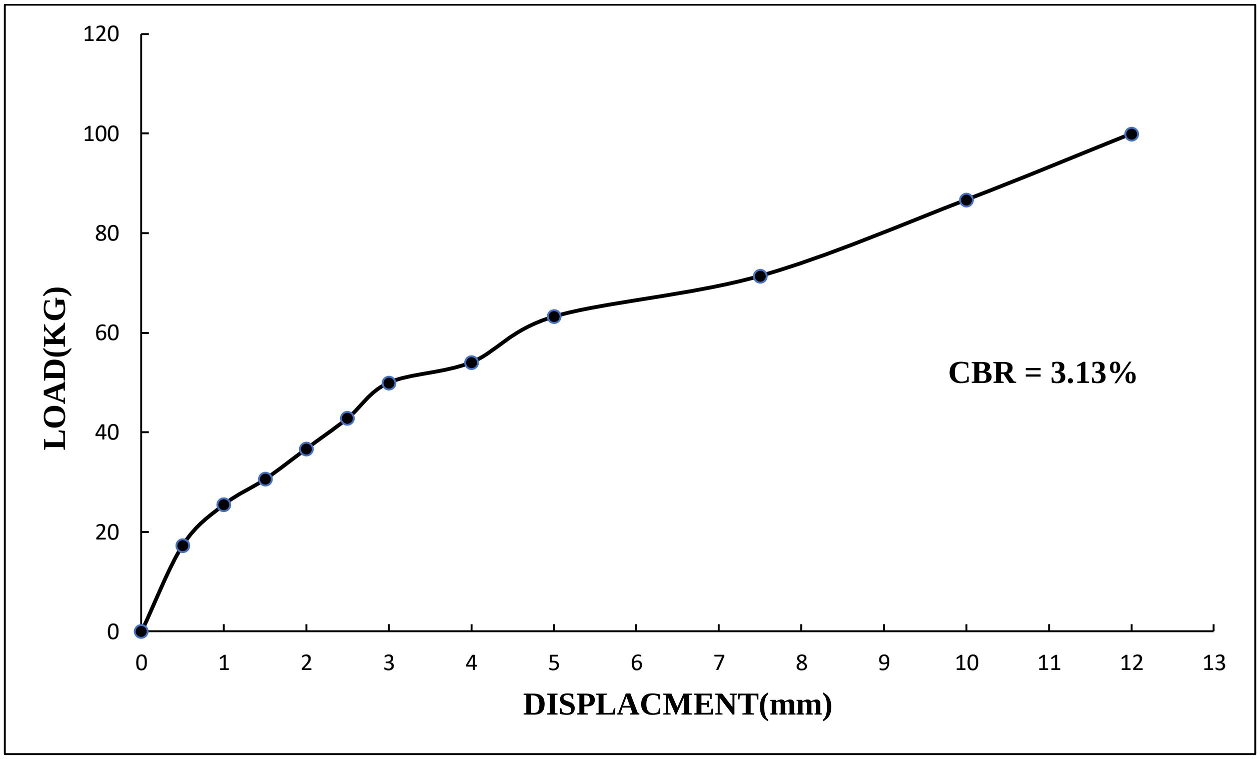

Figure 4.6 Load Penetration Curve for Base Sample

In this study different percentage of waste ceramic dust with the increment of 5% replacement was mixed with soil for CBR testing. After the mixing, water is added, and sample is prepared by compacting the soil into three layers. Load penetration curves obtained by adding various percentages are as follows:

4.4.2 Load Penetration Curve for 5% replacement with waste Ceramic Dust

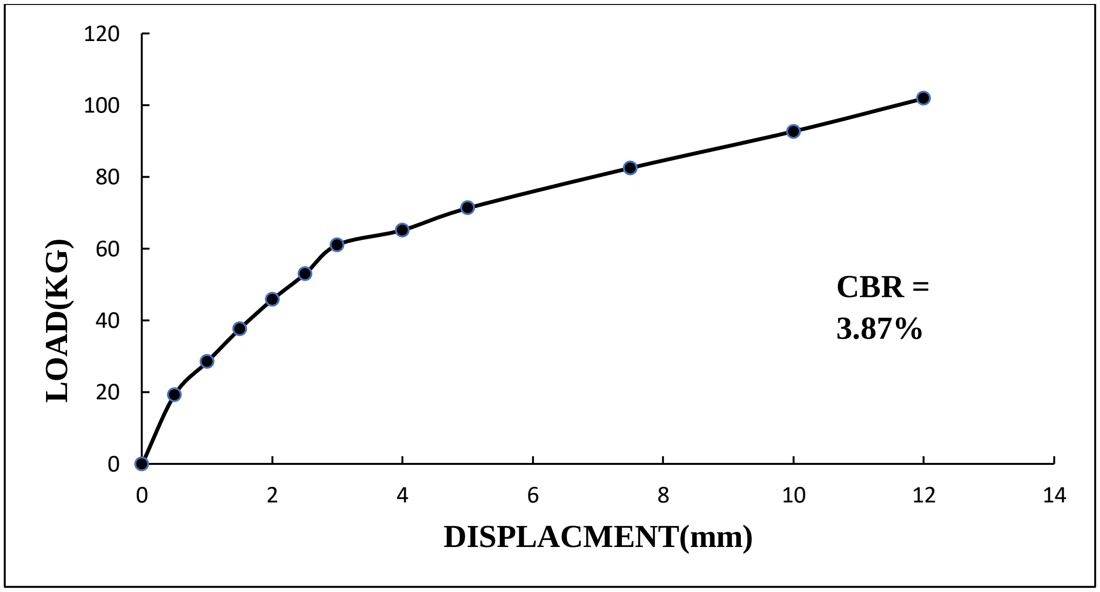

Figure 4.7 Load penetration Curve by Reinforcing 5% of Ceramic Dust

4.4.3 Load Penetration Curve for 10% replacement with waste Ceramic Dust

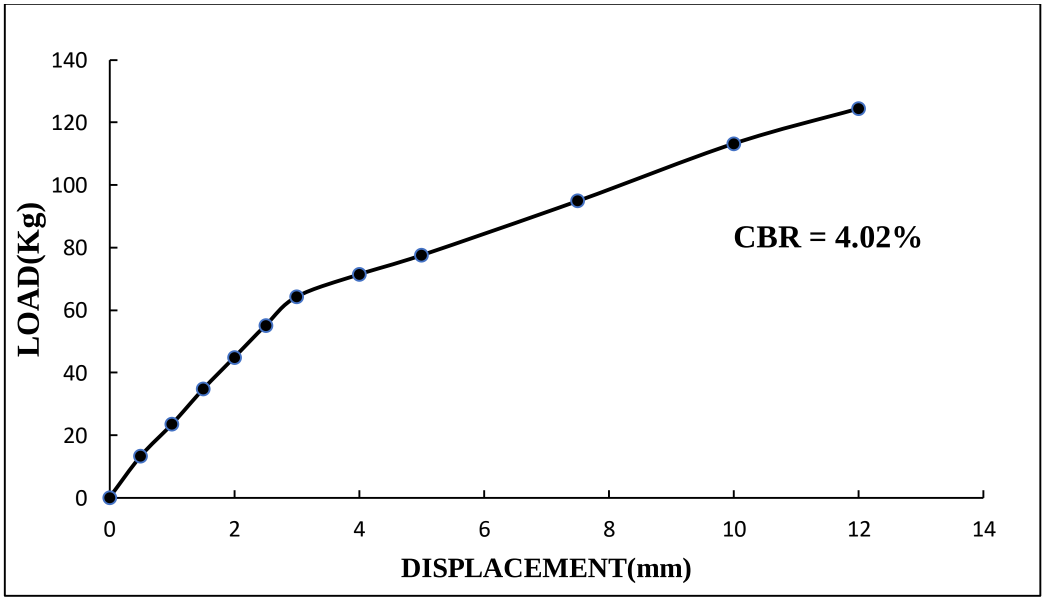

Figure 4.8 Load Penetration Curve with 10 % replacement of Ceramic Dust

4.4.4 Load Penetration Curve for 20% replacement with waste Ceramic Dust

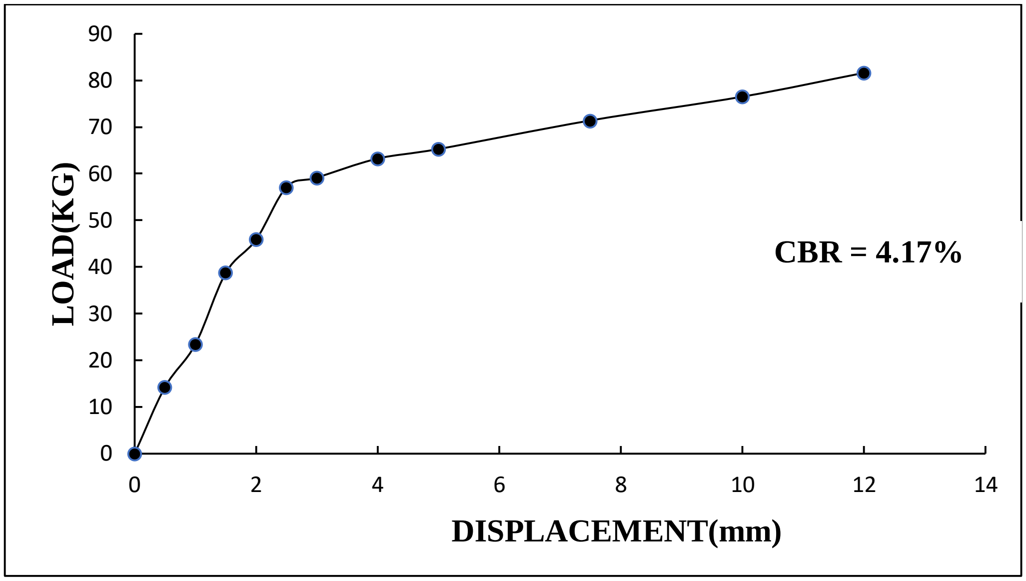

Figure 4.9 Load Penetration Curve for 20% replacement with waste Ceramic Dust

4.4.5 Load Penetration Curve for 30% replacement with waste Ceramic Dust

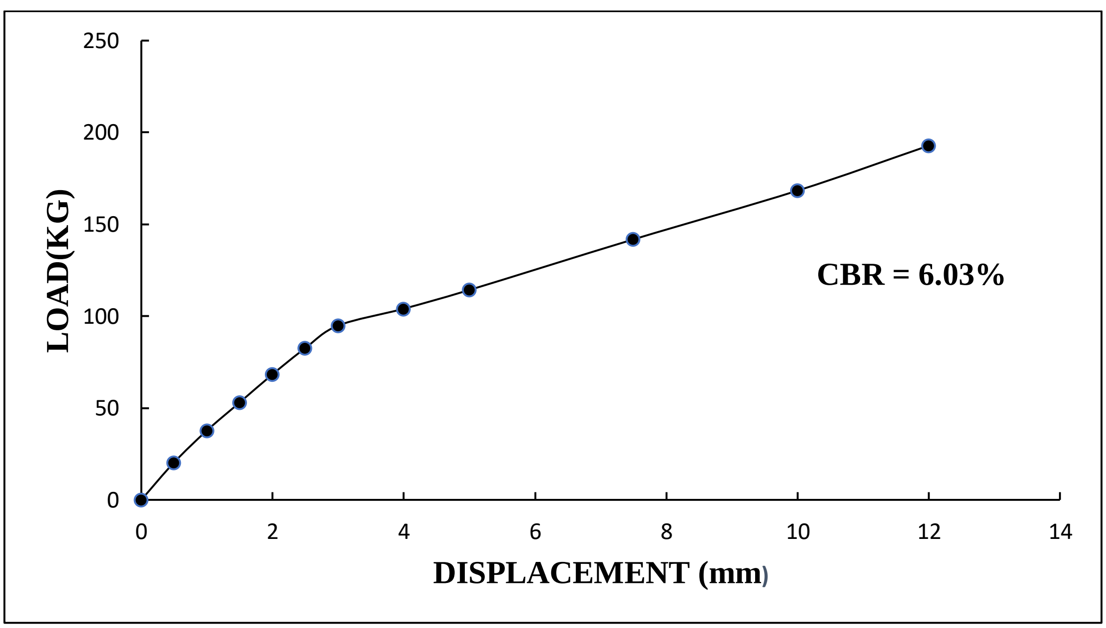

Figure 4.10 Load Penetration Curve for 30% replacement with waste Ceramic Dust

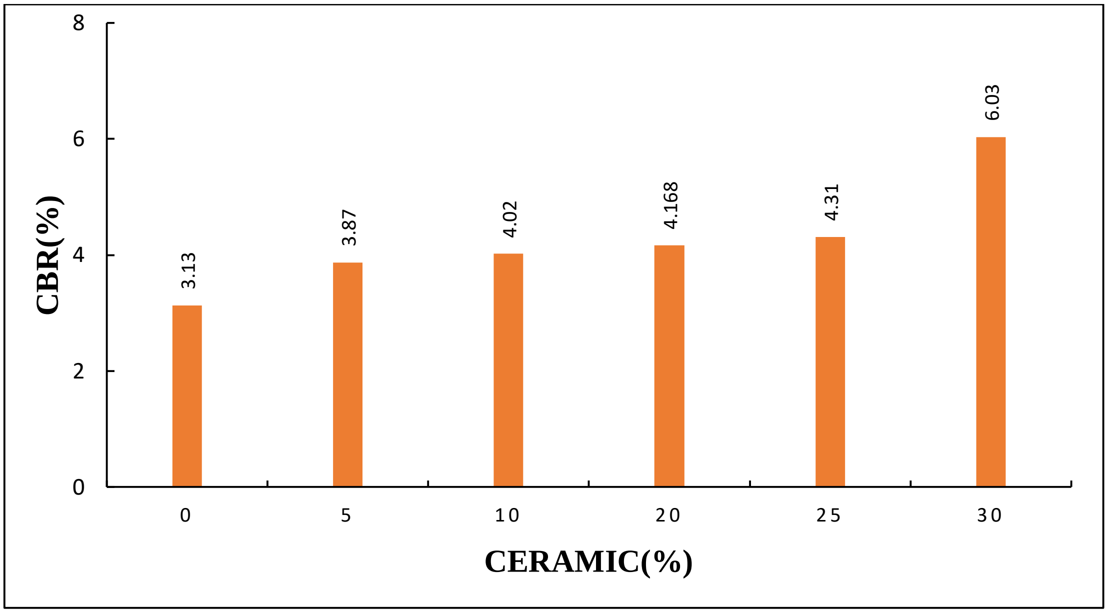

Figure 4.11 Variation of CBR with Ceramic

Table 4.2 Effect on CBR by replacing soil with Ceramic Dust

Ceramic Dust (%)	0	5	10	20	25	30
CBR (%)	3.13	3.87	4.02	4.11	4.31	6.03

From the graphs of the load and displacement with the addition of the ceramic dust in the soil can be seen and from the Figure 4.11 it can be observed that there is significant change in the CBR with the increase of ceramic dust in the soil as stabilizer from 0% to 30% with the increment of 5%.

California baring ratio increases from 3.13% to 6.03% as this is an increment of 92% when it deal with the virgin soil, due to increase in the CBR there will be the increase in the strength of the subgrade for which this stabilized soil can be used.

CHAPTER 5

DESIGN OF FLEXIBLE PAVEMENT

5.1 Introduction

Design of flexible pavement is done by using IRC-37:2018 – Guidelines for the Design of flexible Pavement. For this, a flexible pavement has been designed for cumulative traffic of 20, 55 and 110 msa (million standard axles) for CBR values of both unstabilized and stabilized soil.

5.2 Pavement Design

A flexible pavement is a multilayer elastic structure. The critical locations of the stress and strain computed with the help of layered elastic models. IITPAVE software for the stress analysis is used for the calculation of stress and strain in the flexible pavement. **Horizontal Tensile strain ($€_t$)**, at the bottom of the bituminous layer and the **vertical compressive strain ($€_v$),** on the top of the subgrade. There are critical parameters for the process of design of the pavement and help in limit the rutting and cracking in the subgrade and bituminous layer. It is also obtained from the calculations that the surface close to the edge of the wheel have tensile strain large enough to start longitudinal cracking which followed with the cracking in transverse direction before the flexure cracking

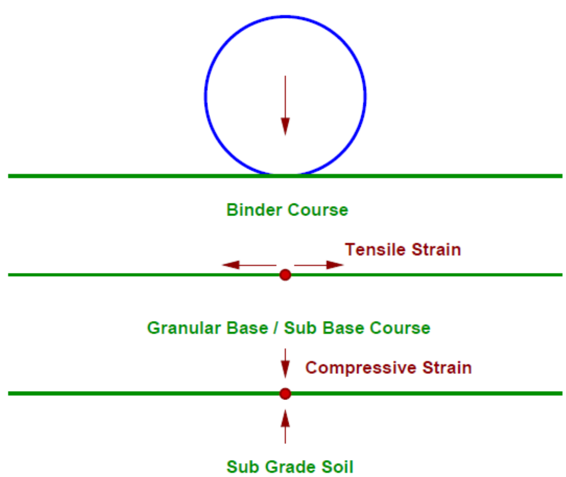

Figure 5.1 Critical Locations in Pavement

5.2.1 Failure Criteria

1. **Fatigue Criteria**: Bituminous surfacing of pavements display flexural fatigue cracking if the tensile strain at the bottom of the bituminous layer is beyond certain limit. The relation between the fatigue life of the pavement and the tensile strain in the bottom of the bituminous layer was obtained as:

   For the traffic up to 30 msa equation 5.1 is used and for traffic greater than 30msa equation 5.2 is used according to the Clause 6.2.2 of IRC 37:2012

$$N_f = 2.21 \times 10^{-4} \times (1/€_t)^{3.89} \times (1/E)^{0.854} \quad (5.1)$$

$$N_f = 0.711 \times 10^{-4} \times (1/€_t)^{3.89} \times (1/E)^{0.854} \quad (5.2)$$

N_f is the allowable number of load repetitions to control fatigue cracking and E is the Elastic modulus of bituminous layer.

2. **Rutting Criteria:** It is the deformation in pavement occurring longitudinally along with the wheel path. Rutting is mostly due to the deformation occur in the subgrade. According to the clause 6.3.1 in IRC:37-2012

$$N_r = 4.1656 \times 10^{-8} \times (1/€_v)^{4.5337} \quad (5.3)$$

   Nr is the number of cumulative standard axles to produce rutting of 20 mm

5.2.2 Thickness of Pavement:

a) msa = 20

Thickness of pavement is calculated from the Code IRC: 37-2018 in which the Plates for different CBR are given with the msa and the IIT-Pave software is used to compare the strain calculated. Allowable strain are as follows:

1. Allowable Horizontal Tensile Strain at the bottom of Bituminous Layer is **263 x 10^{-6}** for VG40 mixes
2. Allowable Vertical Compressive Strain on top of Subgrade is **560 x 10^{-6}**

Table 5.1 Composition of pavement crust of CBR 3.13% without waste Ceramic Dust

<table>
<tr><td colspan="5">Composition of Pavement as Per IRC: 37:2012</td></tr>
<tr><td colspan="5">Soil Sample with CBR 3.13% Without Ceramic Dust</td></tr>
<tr><td>Case 1</td><td colspan="2">CBR = 3.13%(plate-1)</td><td colspan="2">msa = 20</td></tr>
<tr><td colspan="5">Crust thickness According to CBR and MSA</td></tr>
<tr><td colspan="2">msa</td><td colspan="3">Pavement Thickness(mm)</td></tr>
<tr><td colspan="2">20</td><td colspan="3">790</td></tr>
<tr><td colspan="5">Composition of Layers of Pavement</td></tr>
<tr><td>GSB</td><td>WMM</td><td>DBM</td><td>BC</td><td>Total</td></tr>
<tr><td>250</td><td>380</td><td>120</td><td>40</td><td>790</td></tr>
<tr><td colspan="5">Calculated Strains by IIT-PAVE:
Horizontal Tensile Strain is 228 × 10⁻⁶
Vertical Compressive Strain is 205 ×10⁻⁶</td></tr>
</table>

From the table 5.1 it can be seen that the unreinforced soil has the crust thickness of 790mm with the sub- base layer having thickness 450mm and DBM as 120mm and bituminous layer as 40mm.

Table 5.2 Composition of pavement crust of CBR 4.02% with 10% waste Ceramic Dust

<table>
<tr><td colspan="5">Composition of Pavement as Per IRC: 37:2012</td></tr>
<tr><td colspan="5">Soil Sample with CBR 4.02% with 10% replacement of Ceramic Dust</td></tr>
<tr><td>Case 2</td><td colspan="2">CBR = 4.02(Plate-2)</td><td colspan="2">msa = 20</td></tr>
<tr><td colspan="5">Crust thickness According to CBR and MSA</td></tr>
<tr><td colspan="2">msa</td><td colspan="3">Pavement Thickness(mm)</td></tr>
<tr><td colspan="2">20</td><td colspan="3">730</td></tr>
<tr><td colspan="5">Composition of Layers of Pavement</td></tr>
<tr><td>GSB</td><td>WMM</td><td>DBM</td><td>BC</td><td>Total</td></tr>
<tr><td>250</td><td>330</td><td>110</td><td>40</td><td>730</td></tr>
<tr><td colspan="5">Horizontal Tensile Strain is 231 × 10⁻⁶
Vertical Compressive Strain is 351 ×10⁻⁶</td></tr>
</table>

From Table 5.2 with the addition of ceramic up to 10% there is change in the cbr as well the thickness of the pavement will decrease to 730mm in which Granular base has the thickness of 580mm and DBM is 110 mm and BC is 40mm.

Table 5.3 Composition of pavement crust of CBR 6.03 % with 30% waste Ceramic Dust

<table>
<tr><td colspan="5">Composition of Pavement as Per IRC: 37:2012</td></tr>
<tr><td colspan="5">Soil Sample with CBR 6.03% with 30% replacement of Ceramic Dust</td></tr>
<tr><td>Case 3</td><td colspan="2">CBR = 6.03%</td><td colspan="2">msa = 20</td></tr>
<tr><td colspan="5">Crust thickness According to CBR and MSA</td></tr>
<tr><td colspan="2">MSA</td><td colspan="3">Pavement Thickness(mm)</td></tr>
<tr><td colspan="2">20</td><td colspan="3">640</td></tr>
<tr><td colspan="5">Composition of Layers of Pavement</td></tr>
<tr><td>GSB</td><td>WMM</td><td>DBM</td><td>BC</td><td>Total</td></tr>
<tr><td>250</td><td>260</td><td>90</td><td>40</td><td>640</td></tr>
<tr><td colspan="5">Calculated Strains by IIT-PAVE:
Horizontal Tensile Strain is 217×10^{-6}
Vertical Compressive Strain is 334×10^{-6}</td></tr>
</table>

From Table 5.3 it can be seen there is an increase in the percentage of ceramic dust up to 30% with this increment the CBR increased and the thickness of the pavement crust decreases and it reduced from 730m to 640mm which have GSB 250mm, WMM as 260 mm DBM is 90mm.

b) msa= 55

1) Allowable horizontal tensile strain at the bottom of the bituminous layer is **151×10^{-6}** for VG40 mixes
2) Allowable vertical compressive strain on the top of the subgrade is **363×10^{-6}.**

Table 5.4 Composition of Crust of CBR 3.13% without waste Ceramic Dust

<table>
<tr><td colspan="5">Composition of Pavement as Per IRC: 37:2012</td></tr>
<tr><td colspan="5">Soil Sample with CBR 3.13% with replacement of Ceramic Dust</td></tr>
<tr><td>Case 1</td><td colspan="2">CBR = 3.13%</td><td colspan="2">MSA = 55</td></tr>
<tr><td colspan="5">Crust thickness According to CBR and MSA</td></tr>
<tr><td colspan="2">MSA</td><td colspan="3">Pavement Thickness(mm)</td></tr>
<tr><td colspan="2">55</td><td colspan="3">798</td></tr>
<tr><td colspan="5">Composition of Layers of Pavement</td></tr>
<tr><td>GSB</td><td>WMM</td><td>DBM</td><td>BC</td><td>Total</td></tr>
<tr><td>250</td><td>380</td><td>127</td><td>41</td><td>798</td></tr>
<tr><td colspan="5">Calculated Strains by IIT-PAVE:

Horizontal Tensile Strain is 134 × 10^{-6}
Vertical Compressive Strain is 338 ×10^{-6}</td></tr>
</table>

With change in the msa there will also be the change in the thickness of the crust. Without ceramic dust addition we can see there is thickness of 798mm for the pavement.

But with the addition of the ceramic dust 10% and 30% there is change in the CBR as well as the pavement crust thickness will change significantly from 798mm at 0% to 752mm at 10% of the ceramic and 4.02% of the CBR. With the addition of the ceramic dust up to 30% there is increase in CBR as 6.03% and decrease in the pavement crust thickness to 654mm which it can be seen from the Table 5.5 and table 5.6.

Table 5.5 Crust Thickness of CBR 4.02% with 10% waste Ceramic Dust

Composition of Pavement as Per IRC: 37:2012				
Soil Sample with CBR 4.02% with 10% replacement of Ceramic Dust				
Case 2	CBR = 4.02%		MSA = 55	
Crust thickness According to CBR and MSA				
MSA		Pavement Thickness(mm)		
55		752		
Composition of Layers of Pavement				
GSB	**WMM**	**DBM**	**BC**	**Total**
250	330	131	41	752
Calculated Strains by IIT-PAVE: **Horizontal Tensile Strain is 119 $\times 10^{-6}$** **Vertical Compressive Strain is 296 $\times 10^{-6}$**				

Table 5.6 Crust thickness for CBR 6.03% with 30% waste Ceramic Dust

Composition of Pavement as Per IRC: 37:2012				
Soil Sample with CBR 6.03% with 30% replacement of Ceramic Dust				
Case 2	CBR = 6.03%		MSA = 55	
Crust thickness According to CBR and MSA				
MSA		Pavement Thickness(mm)		
55		654		
Composition of Layers of Pavement				
GSB	**WMM**	**DBM**	**BC**	**Total**
250	260	103	41	654
Calculated Strains by IIT-PAVE: **Horizontal Tensile Strain is 128 $\times 10^{-6}$** **Vertical Compressive Strain is 311 $\times 10^{-6}$**				

c) **msa = 110**

1. Allowable Horizontal Tensile Strain at the bottom of Bituminous Layer is **130×10^{-6}** for VG 40 mixes

2. Allowable Vertical Compressive Strain on top of Subgrade is **315×10^{-6}**

Table 5.7 Crust thickness at CBR 3.13% without waste Ceramic Dust

Composition of Pavement as Per IRC: 37:2012				
Soil Sample with CBR 3.13% without waste Ceramic Dust				
Case 1	CBR = 3.13%(Plate-1)		MSA = 110	
Crust thickness According to CBR and MSA				
MSA		Pavement Thickness(mm)		
110		838		
Composition of Layers of Pavement				
GSB	**WMM**	**DBM**	**BC**	**Total**
250	380	158	50	838
Calculated Strains by IIT-PAVE: **Horizontal Tensile Strain is 105×10^{-6}** **Vertical Compressive Strain is 278×10^{-6}**				

As for the msa 110 there will be the increase in the thickness of the crust when there is no stabilization is done but with the increment of the ceramic from 0% to 10% there is decrease in the thickness from 838mm to 773mm and with the further increase in the percentage of the ceramic up to 30% the thickness of the pavement further decrease to 688mm with decrease in the layer thickness of WMM and DBM. It can be seen that variation from the Table 5.8 and 5.9 and as well from the Table 5.10.

Table 5.8 Crust Thickness of CBR 4.02% with 10% Waste Ceramic Dust

Composition of Pavement as Per IRC: 37:2012				
Soil Sample with CBR 4.02%% with 10% waste of Ceramic Dust				
Case 2	CBR = 4.02%(Plate-2)		MSA = 110	
Crust thickness According to CBR and MSA				
MSA		Pavement Thickness(mm)		
110		773		
Composition of Layers of Pavement				
GSB	**WMM**	**DBM**	**BC**	**Total**
250	330	143	50	773
Calculated Strains by IIT-PAVE: **Horizontal Tensile Strain is 104 × 10^{-6}** **Vertical Compressive Strain is 272 × 10^{-6}**				

Table 5.9 Crust thickness at CBR 6.03% with 30% Waste Ceramic Dust

Composition of Pavement as Per IRC: 37:2012				
Soil Sample with CBR 6.03%% with 30% waste of Ceramic Dust				
Case 2	CBR = 6.03%(Plate-2)		MSA = 110	
Crust thickness According to CBR and MSA				
MSA		Pavement Thickness(mm)		
110		688		
Composition of Layers of Pavement				
GSB	**WMM**	**DBM**	**BC**	**Total**
250	260	128	50	688
Calculated Strains by IIT-PAVE: **Horizontal Tensile Strain is 103 × 10^{-6}** **Vertical Compressive Strain is 262 × 10^{-6}**				

Table 5.10 Pavement thickness with different MSA and 30% of Waste Ceramic Dust

S.No.	Description	Layers	Thickness (mm)	msa
1	(i) Soil Sample without waste Ceramic Dust CBR = 3.13%	GSB	250	20
		WMM	380	
		DBM	120	
		BC	40	
		Total	790	
	(ii) Soil sample with 30% waste Ceramic Dust CBR = 6.03%	GSB	250	20
		WMM	260	
		DBM	90	
		BC	40	
		Total	640	
2	(i) Soil Sample without waste Ceramic Dust CBR = 3.13%	GSB	250	55
		WMM	380	
		DBM	127	
		BC	41	
		Total	768	
	(ii) Soil sample with 30% waste Ceramic Dust CBR = 6.03%	GSB	250	55
		WMM	260	
		DBM	103	
		BC	41	
		Total	654	
3	(i) Soil Sample without waste Ceramic Dust CBR = 3.13%	GSB	250	110
		WMM	380	
		DBM	158	
		BC	50	

		Total	838	
	(ii) Soil sample with 30% waste Ceramic Dust CBR = 6.03%	GSB	250	110
		WMM	260	
		DBM	128	
		BC	50	
		Total	687	

5.3 Charts based on msa and ceramic dust used

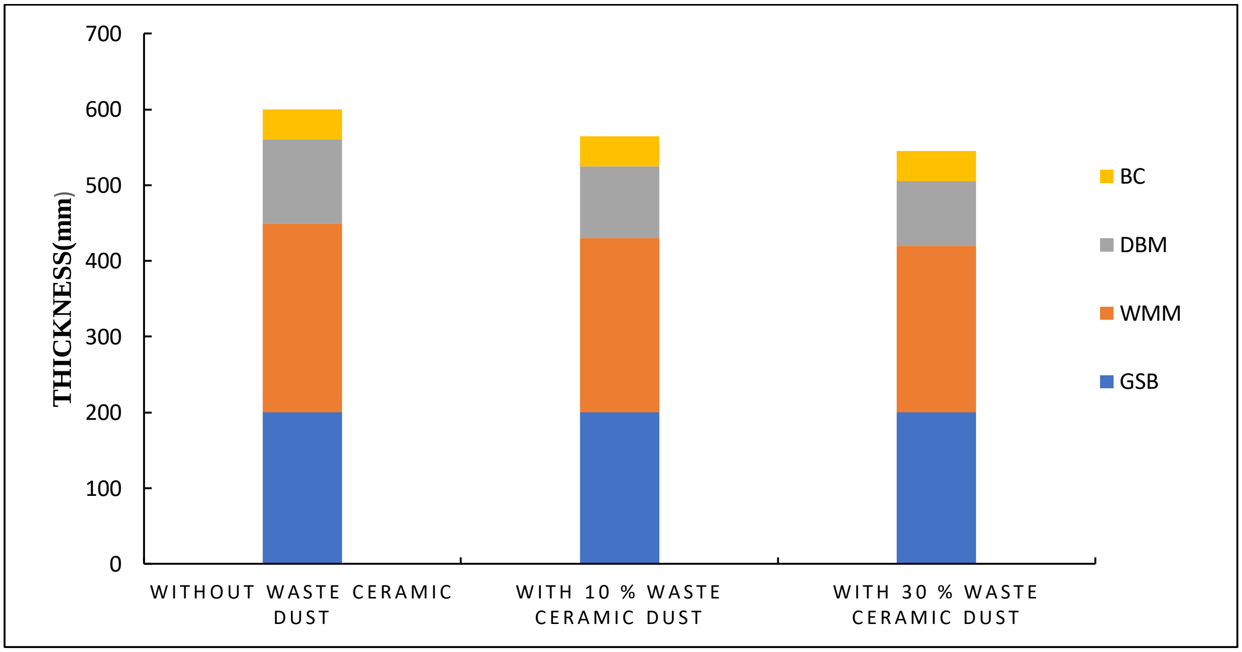

Figure 5.2 Pavement Thickness with Ceramic dust at 20 msa

From the Figure 5.2 it can be seen that there is decrease in the thickness of the pavement at 20msa with the increase in the ceramic dust from 0% to 30%the thickness decrease from 790mm to 640mm.

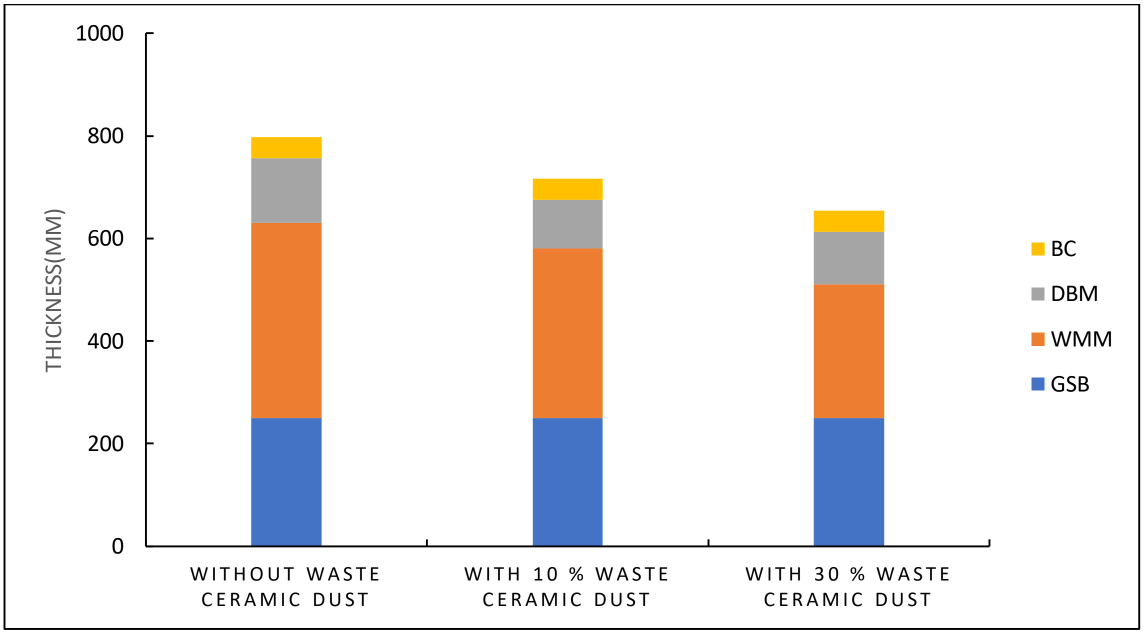

Figure 5.3 Pavement thickness at 55 msa with ceramic dust

From the Figure 5.3 it can be seen that with 55msa traffic and increase in the addition of the ceramic dust there will be decrease in the thickness of the pavement from 768mm to 654mm.

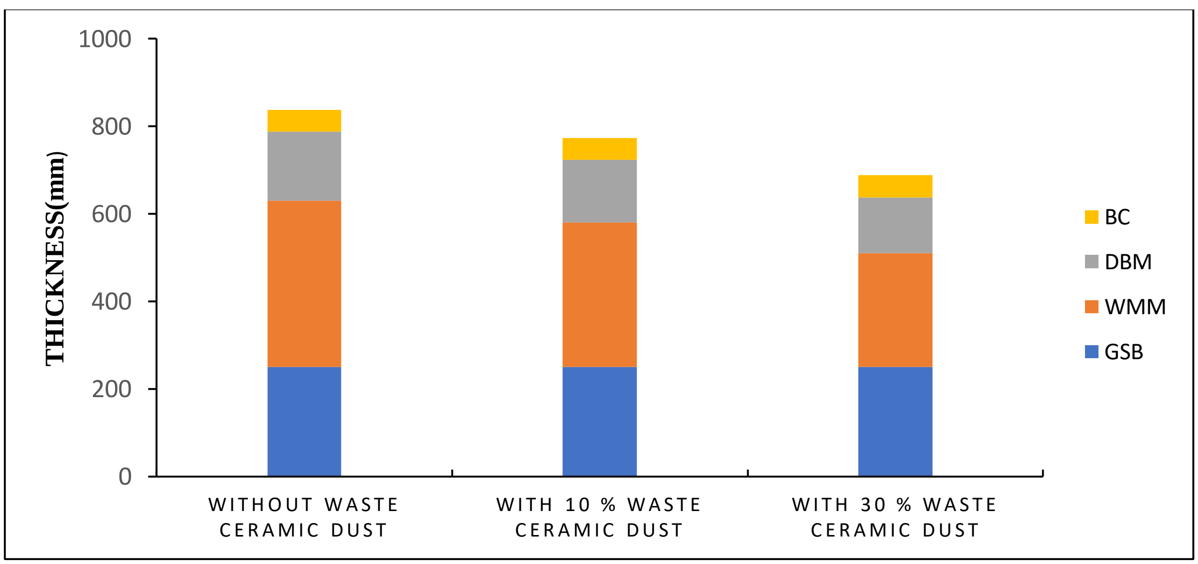

Figure 5.4 Pavement thickness at 110 msa with ceramic dust

5.4 Charts based on the variation of strain

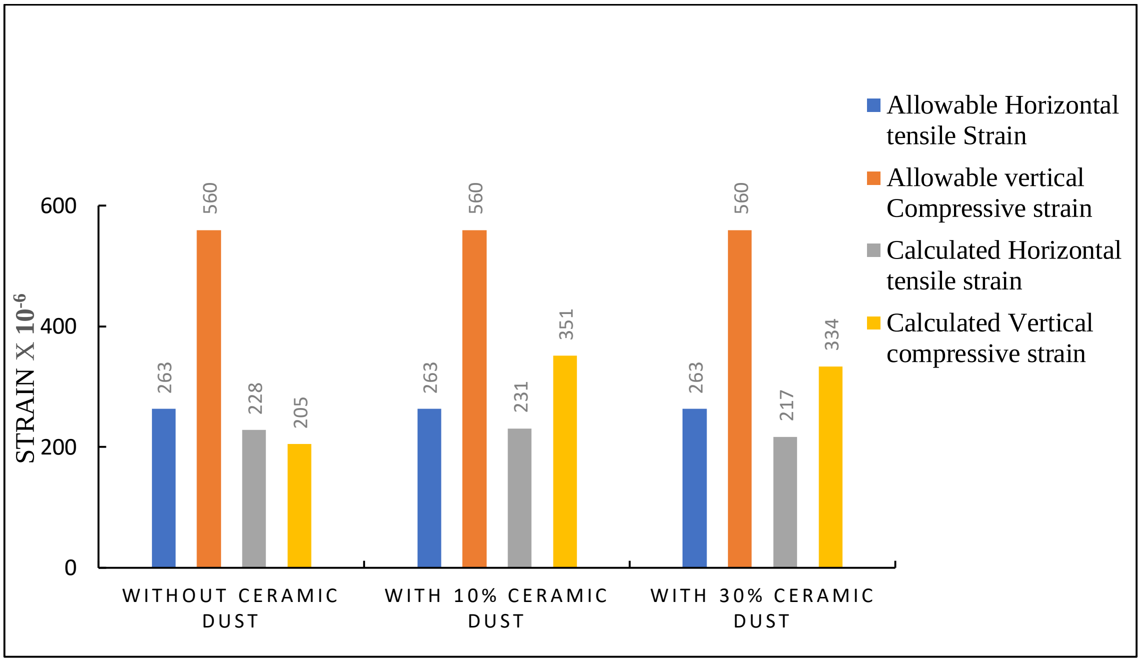

Figure 5.5 Comparison of calculate and allowable strain at 20 msa

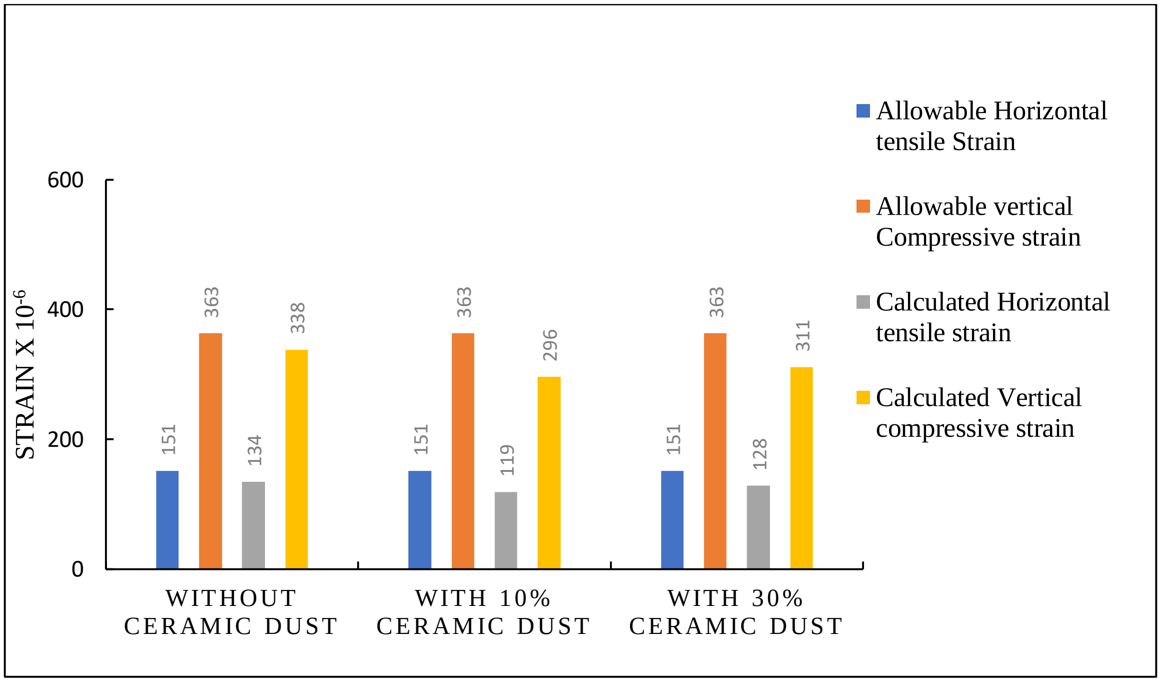

Figure 5.6 Comparison of calculated and allowable strain at 55 msa

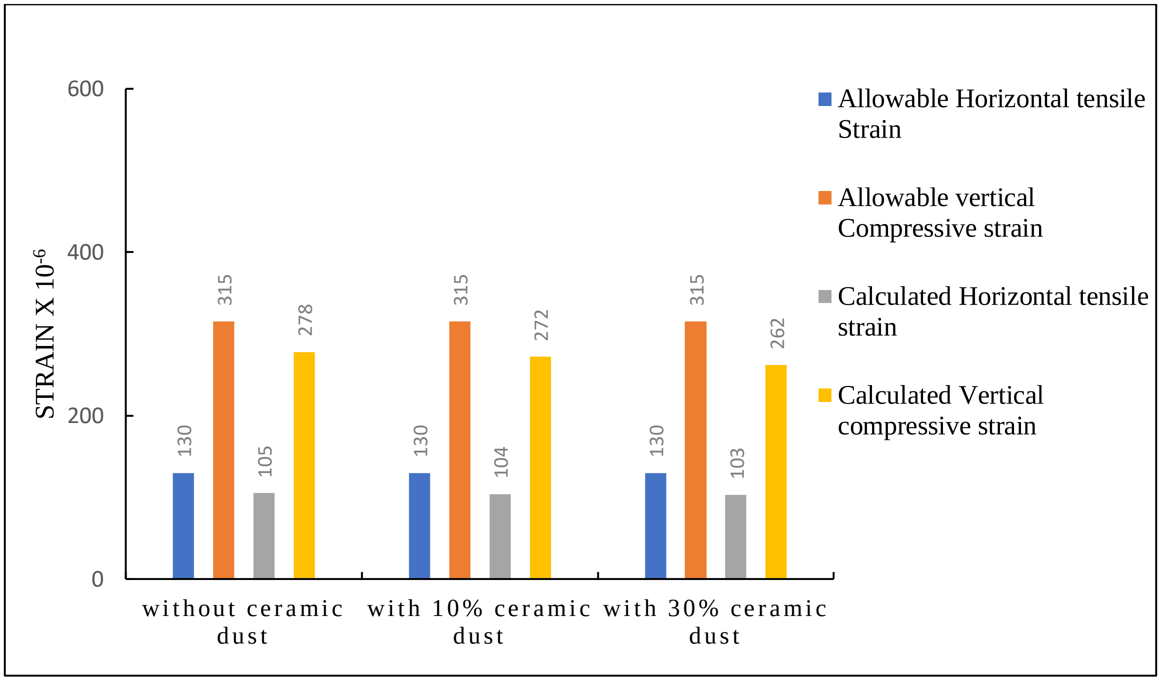

Figure 5.7 Comparison of calculated and allowable strain at 110msa

From the Graphs of the Figure 5.4, 5.5 and 5.6 it can be seen that there is change in the strain calculated with IIT-Pave with the change in the msa and with the addition of the ceramic dust from 0% to 30%.

It can be seen from the graphs that there is reduction in the calculated vertical strain with the addition of the ceramic dust up to 30% for 110msa.

CHAPTER 6

CONCLUSION

In this study for the strengthening the subgrade replaced some of the quantity of soil with the waste ceramic dust was use as stabilizer. The properties of soil such as liquid limit, plastic limit, maximum dry density and optimum moisture content, UCS and CBR are changed effectively by adding the waste ceramic dust from 5% to 30% with the increment of 5%.

1. Liquid limit is decreased from 34% to 31% with the increase in the percentage of ceramic dust.
2. The MDD increased from 17.5 kN/m^3 to 17.9 kN/m^3 and OMC decreases from 17% to 15%.
3. Unconfined compressive strength has also showed some positive effect on the addition of the ceramic dust as it increases up to 30%. There was increase of 260% from its base value.
4. California Bearing Ratio has doubled with the increment of waste ceramic dust from 0% to 30%. The value of CBR increases from 3.13% at 0% ceramic dust to 6.03% at 30% ceramic dust.
5. With the addition of the ceramic dust up to 30% in subgrade there was maximum decrease of 19% in the thickness of the crust at msa 110.

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