"SUBGRADE SOIL STABLIZATION USING LIME AND WASTE PAPER SLUDGE"

A PROJECT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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By

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT SOLAN – 173 234

HIMACHAL PRADESH INDIA

June,2016

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"SUBGRADE SOIL STABLIZATION USING LIME, WASTE PAPER SLUDGE"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by *Avinash pandit [121633]* and *Vijay Karan [121677]* during a period from July 2015 to June 2016 under the supervision of ***MR.Abhilash Shukla*** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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ACKNOWELDEMENT

The success of every project whether big or small is largely due to effort of number of people who have always given their valuable advice and lend a helping hand. I sincerely appreciate the inspiration, support and guidance of those who helped me to choose and carry out this project.

At the very outset, I would like to express my deep gratitude to my Project Guide **Mr. Abhilash Shukla,** laboratory staff and library staff for their co-operation and for giving me the opportunity to work on this ambitious project.

I would also like to thank **Dr. Ashok Kumar Gupta** and all the faculty members of Civil Engineering Department (JUIT) who helped me in giving shape to my ideas, help me understand the various aspects of the project.

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ABSTRACT

Soil is the basic foundation for any civil engineering structures. It is required to bear the loads without failure. In some places, soil may be weak which cannot resist the oncoming loads. In such cases, soil stabilization is needed. Numerous methods are available in the literature for soil stabilization. But sometimes, some of the methods like chemical stabilization; lime stabilization etc. adversely affects the chemical composition of the soil.

In this study lime and waste paper sludge were mixed with clay soil to investigate the relative strength gain in terms of unconfined compression, swelling capacity and compaction. The effect of these chemicals on geotechnical characteristics of soil is investigated by Proctor compaction tests, unconfined compression tests, swelling test. The tests were performed as per Indian Standard specifications.

The following materials will be used for preparing the samples:

- ❖ Clayey soil
- ❖ Lime
- ❖ Waste paper sludge

Lime and waste paper sludge was added in varying percentages and that fraction for which maximum strength is obtained were found out.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Roads are the vital lifelines of the economy. They are the most preferred modes of transportation. To provide mobility and accessibility, all weather roads should connect every nook and corner of the country. To sustain both static and dynamic load, the pavement should be designed and constructed with utmost care. The performance of the pavement depends on the quality of materials used in road construction.

Although there is a tendency to look at pavement performance in terms of pavement structures and mix design alone, the sub grade soils can often be the overriding factor in pavement performance. The construction cost of the pavements will be considerably decreased if locally available low cost materials are used for construction of lower layer of pavements such as sub grade, sub base etc. If the stability of local soils is not adequate for supporting the loads, suitable methods to enhance the properties of soil need to be adopted. Soil stabilization is one such method. Stabilizing the sub grade with an appropriate chemical stabilizer increases sub grade stiffness and reduces expansion tendencies, it performs as a foundation.

SCOPE OF THE PROJECT

The soil used in the study is natural clayey sand (SC) brought from Shoghi Mehli bypass road. Pavement subgrade over there is composed of clayey soil whose bearing capacity is low and as per IS 1904-1978 its allowable bearing capacity value is 100kN/m^2which is close to that of soft clay.

Also since the fine sand shows bulking properties due to which its volume increase considerably relative to its dry state. Due to this reason, the roads require periodic maintenance to take up repeated application of wheel loads. This proves to be costly, and at the same time, conditions of roads during monsoon seasons are extremely poor. Therefore, a thought on how to enhance the stability of roads by cheaper means demands appraisal.

Soil stabilization can be done using different additives, but use of lime and paper sludge which is a waste material and at the same time difficult-to-dispose material will be much significant. Annually, a lot of waste rubber are generated and occupied a great space. It is necessary to find a solution to solve this problem. Based on literature, one of the solutions is use of different size waste rubber in soil reinforcement. Portland cement, lime, fly ash and scrap tyre are low-cost and effective to soil stabilization.

OBJECTIVE OF THE PROJECT

The major objectives of the project are:

-To explore the possibility of using lime and waste paper sludge in road construction programme.

-To study the effect of lime and waste paper sludge on proctor’s density and OMC of soil.

-To study the changes in swelling potential of soil by the addition of lime and waste paper sludge.

-To study the effect of these additives on unconfined compressive strength of soil.

-To evaluate best economical material for improving and enhancing properties of soil sample.

CHAPTER 2
LITERATURE REVIEW

-White (2005) reported; Soil compaction characteristics, compressive strength, wet/dry durability, Freeze/thaw durability, hydration characteristics, rate of strength gain, and plasticity characteristics are all affected by the addition of lime.

-Bernal *et al.* (1996) reported; it has been found that the use of tyre shreds in highway construction offers technical, economic, and environmental benefits. The Salient benefits of using tyre shred include reduced weight of fill, adequate stability, and low settlements, good drainage (avoiding the development of pore water pressure dung loading), separation of Underlying weak or problem soils from sub base or base materials, conservation of energy and natural resources, and usage of large quantities of local waste tyres, which would have a positive impact on the environment.

-About *et al.* (2007) investigated modification of clayey soils using scrap tyre rubber and synthetic fibers. This result showed that the unreinforced and reinforced samples were subjected to unconfined compression, Shear box, and resonant frequency tests to determine their strength and dynamic properties. These waste fibers improve the strength properties and dynamic behavior of clayey soils. The scrap tyre rubber and Polythene fibers can be successfully used as reinforcement materials for the modification of clayey soils.

- Neva Elias **.**Civil Engineering, Cochin University of Science & Technology, (India)
The main objective of this study is to investigate the use of waste materials in geotechnical applications and to evaluate the effects of waste paper sludge on strength development of soft soil. This review discusses the effect of waste paper sludge on stabilized soils. In this paper, attempts are made to utilize the same for the soil improvement. The addition of WPS has increased the strength at 5% and it was found to be a constant and optimum value of strength to soil. In general it was found that WPS is a suitable waste material for strengthening soft soil. The beneficial reuse of the paper sludge also saved landfill space.

-Thomson, M.R.(1977), Final Report Sub grade Stability
Concepts for characterizing field subgrade stability conditions are developed. Subgrade stability requirement are established for construction considering sinkage and compaction . Lime act as a remedial measure by controlling moisture density. CBR data of Illionois soils shows subgrade softening under conditions of high moisture content.

-Beeghly J. (2003). Recent Experiences with Lime- Stabilization of Pavement Subgrade Soils, Bas, and Recycled Asphalt. International Ash Utilization Symposium
While lime alone works well to stabilize clay soils, a combination of lime and fly ash is beneficial for lower plasticity, higher silt content soils. The fly ash provides the pozzolanic reactants, silica and alumina, lacking in such soils.

-Sanni Kumar and Ali Jawaid S. M. (2013) “Paper Mill Sludge Utilization in Ground Improvement - The result obtained in the experiments shows that the paper sludge can be used in place of sand. Paper mill sludge are characterized by a high water content, high compressibility and large amount of organic fibers in the matrix. The experiments performed clearly indicate that with addition of sludge there is an increase in density and permeability of the soil.

CHAPTER 3
EXPERIMENTAL PROGRAMME

Soil is brought from an off track site near Shoghi bypass road. Soil over there is clay and in monsoon season due to increase in water content results in consequent swelling also the traffic load is at peak due to apple season in upper Shimla area and road get deteriorate every year. Therefore the strength of pavement sub grade needs to be ascertained to withstand the compressive load under traffic.

-Properties of soil used in the study are as:-

TABLE 1 - PROPERTIES OF SOIL USED

S.No.	Properties	Value
1	Specific gravity	2.67
2	Liquid limit	37%
3	Plastic limit	25%
4	Plasticity index	12%

The sieve analysis data for the project is as:-

Wt. of soil sample taken = 500g

TABLE 2 - SIEVE ANALYSIS DATA FOR THE SOIL

S. NO.	IS SIEVE	MASS RETAINED (g)	% RETAINED	%CUM RETAINED	%FINER
1	4.75mm	3.7	0.74	0.74	99.26
2	1.18mm	10.4	2.08	2.82	97.18
3	1mm	52.7	10.5	13.32	86.68
4	600µ	46.5	9.3	22.6	77.4
5	425 µ	45.5	9.1	31.7	68.3
6	300 µ	12.4	2.48	34.2	65.8
7	212 µ	50.1	10.02	44.22	55.78
8	150 µ	20	4.1	48.22	51.78
9	75 µ	50	10	58.22	41.78
10	pan	200.8	40.16	98.48	1.62

According to IS 1498-1970 the given soil is **fine sand** with more than 12% passing 75 µ sieve size. Therefore the given soil is clayey sand (SC) according to USCS having plasticity index value >7.whose properties are similar to that of ***soft clay*** and can be improved or modified using lime, tyre scrap and waste paper sludge.

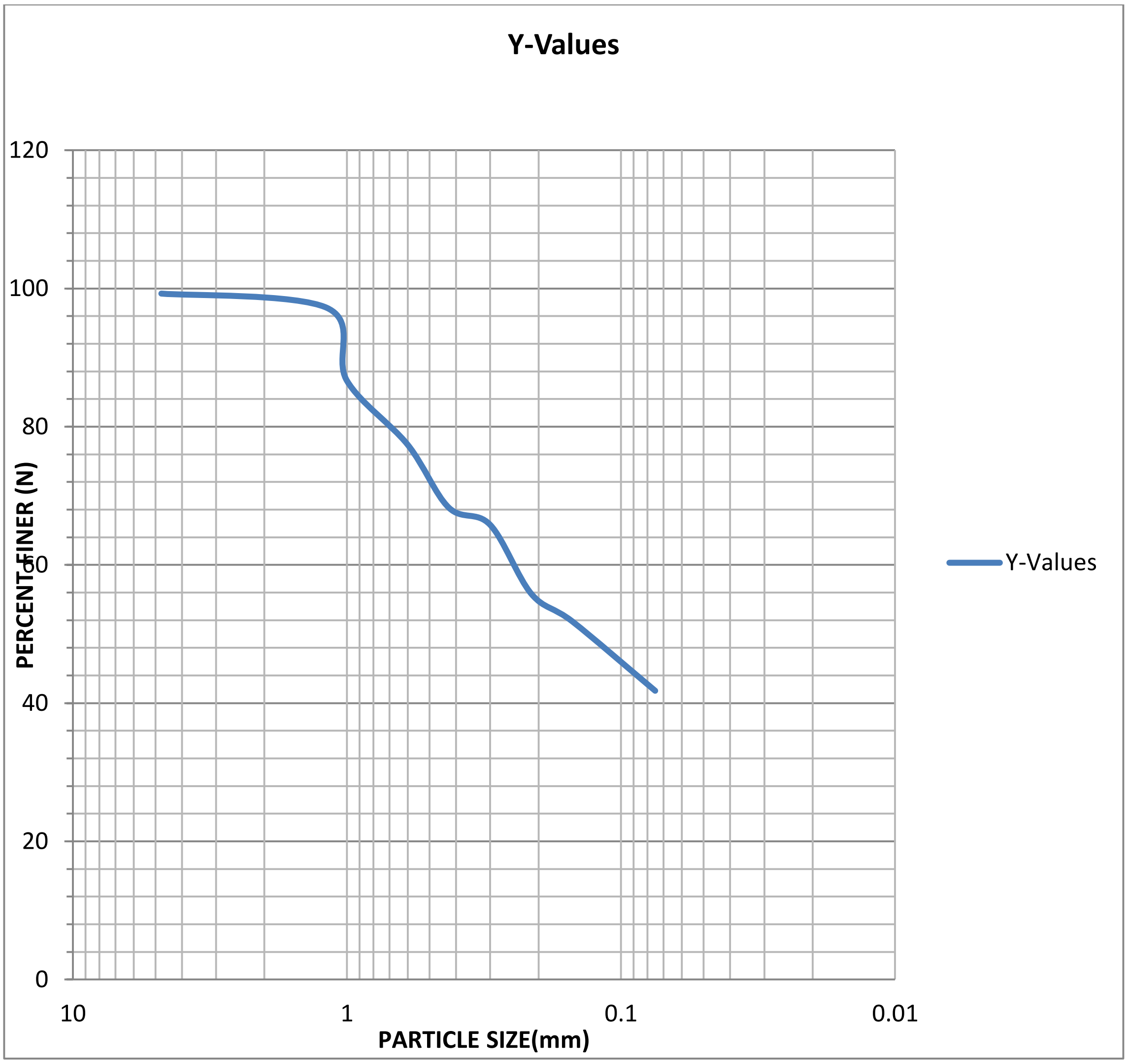


FIGURE 1 - PARTICLE SIZE DISTRIBUTION

The given soil is well graded having good representation of particles of all sizes.

GROUP INDEX VALUE

Group index value is used to find out the soil characteristics as a sub grade material. This test is recommended by highway research board to find out the general rating of soil as a sub grade material.

$G.I = 0.2a + 0.005ac + .01bd$

a = that portion of percentage of subgrade soil passing 75 micron IS sieve greater than 35 and not exceeding 75, expressed as a positive whole number(0 to 40)

b = that portion of percentage of subgrade soil passing 75 micron IS sieve greater than 15 and not exceeding 55 expressed as a positive whole number(0 to 40)

c = that portion of numerical plasticity index greater than 40 and not exceeding 60 expressed as a whole number (0 to 20)

d = that portion of numerical plasticity index greater than 10 and not exceeding 30 expressed as a positive whole number (0 to 20)

a = 5.16

b = 25.16

c = 0

d = 15

Therefore, G.I = 5

Hence the given soil characteristics as a sub grade material for road pavement is poor. Therefore it needs to be stabilized using different methods available.

CHAPTER 4
PLANNING OF LABORATORY WORK

The various tests conducted on the sample are the following:

1. Atterberg limits

2. Specific gravity

3. Proctor compaction test

4. Swelling test

5. Unconfined compression test (UCS)

Firstly the above tests will be conducted on plane soil sample to determine its properties.UCS test is conducted to evaluate it strength. Thereafter, certain percentages of lime, tyre scrap and WPS are added to the sample to stabilize it. And the percentages of the above additives which produce the optimum strength to the soil are chosen by conducting UCS test on them.

SOIL PREPARATION

The soil was collected from site in large sacks. It is brought to the lab and is dried in oven for 24 hours in large pans. This soil due to loss of water formed big lumps which is broken to smaller pieces or even fine powder and is sieved according to the needs of different experiments.

ATTERBERG TEST RESULTS ON CLAY-LIME MIXTURE

Curing period	Liquid limit %	Plastic limit %	Plasticity index %
Native soil	37	25	12
Lime:3 days	35	24	11
7 days	23	18	10
14 days	22	20	5

TABLE 3 - ATTERBERG LIMIT RESULT OF CLAY-LIME MIXTURE

SPECIFIC GRAVITY

The specific gravity of solid particles is defined as the ratio of the mass of a given volume of solids to the mass of an equal volume of water at 4^0C. Specific gravity of soil is between 2.67. Specific gravity of soil mass indicates the average value of all the solid particles present in the soil mass.

NATIVE SOIL PROPERTIES AND ADMIXTURE PERCENTAGES

Soil characteristics were determined using atterberg limits, hydrometer analysis, specific gravity, standard proctor compaction and unconfined compression tests. The test results is shown the table

TABLE 4 - SOIL PROPERTIES AFTER ADDITION OF LIME

S. No.	Properties	Values
1	Max.dry density	1517 kg/m^3
2	Optimum moisture content	20%
3	Liquid limit	37%
4	Plastic limit	25%
5	Plasticity index	12

COMPACTION TEST

Compaction is the densification of soil by reduction of air voids. The purpose of a laboratory compaction test is to determine, the quantity of water to be added for field compaction of soil and resultant density expected. When water is added to dry fine grained soil, the soil absorbs water. Addition of more water helps in sliding of particles over each other. This assists the process of compaction. Up to a certain point, additional water helps in reduction of air voids, but after a relatively high degree of saturation is reached, the water occupies the space, which could be filled with soil particles, and the amount of entrapped air remains essentially constant. Therefore, there is an optimum amount of water for a given soil and compaction process, which gives rise to maximum dry density.

Compaction of clay and clay-lime were carried out using standard proctor test with three layers on each 25 blows. Samples for conducting compaction tests were prepared using moulds of dimensions 10 cm diameter and 15 cm height. In this study, lime is added for about 10% and cured for 3, 7, and 14 days. The values of optimum moisture content and maximum dry density are obtained in a plot of dry density versus moisture content

MAXIMUM DENSITY AND OPTIMUM MOISTURE CONTENT

Optimum moisture content and maximum density for native soil and each of the soil additive combination at different curing period is presented in the table and the variation of maximum density and optimum moisture content is plotted.

NATIVE SOIL

TABLE 5 - PROCTOR COMPACTION TEST DATA

S. no.	Water content %	Dry density (kg/m^3)
1	16	1408
2	18	1490
3	20	1517

4	22	1467
5	24	1427

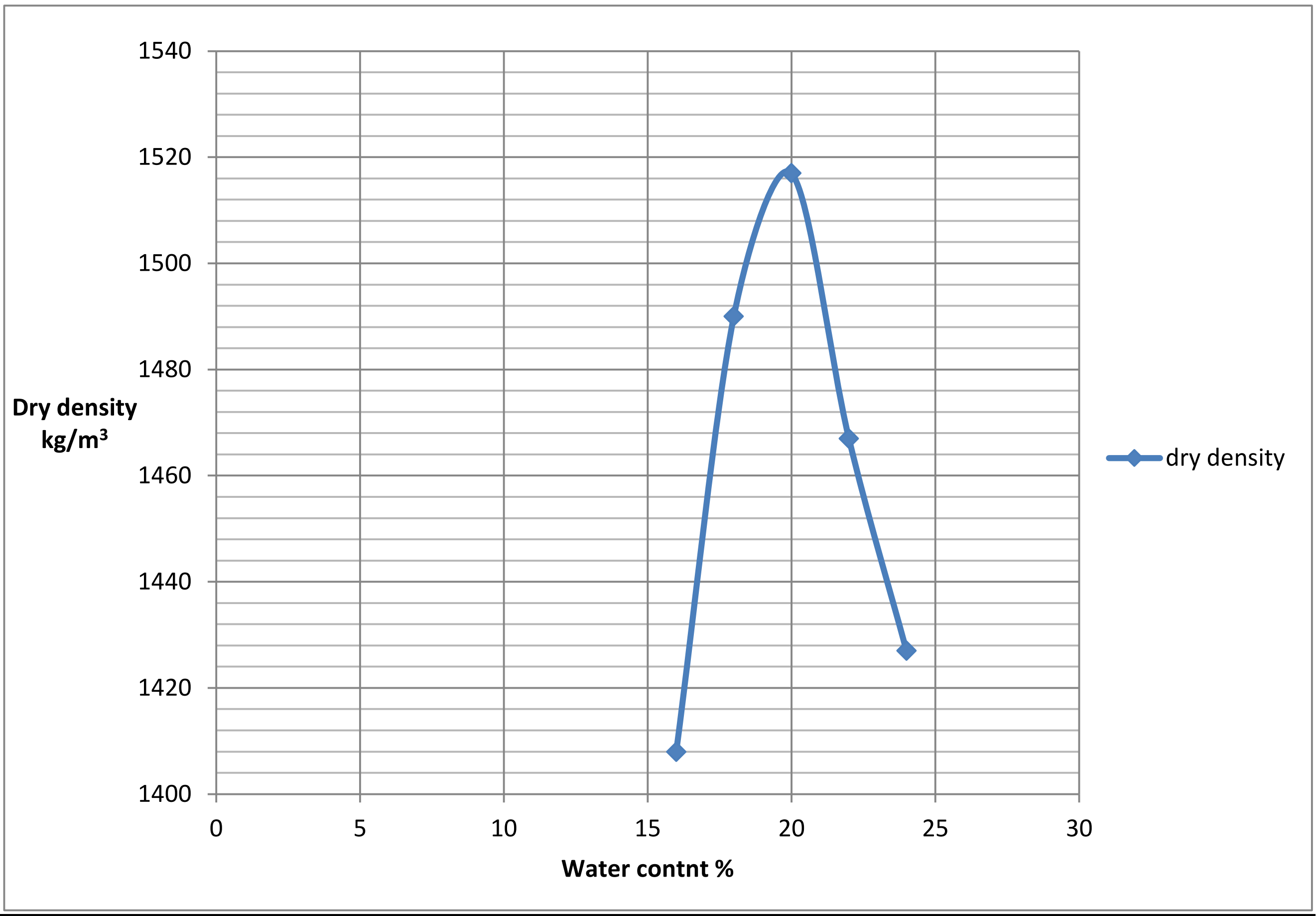


FIGURE 2 - OPTIMUM MOISTURE CONTENT

The maximum density and optimum moisture content for the native soil are 1517 kg/m^3 and 20%.

MOISTURE-DENSITY RELATIONSHIP OF CLAY-LIME MIXTURES

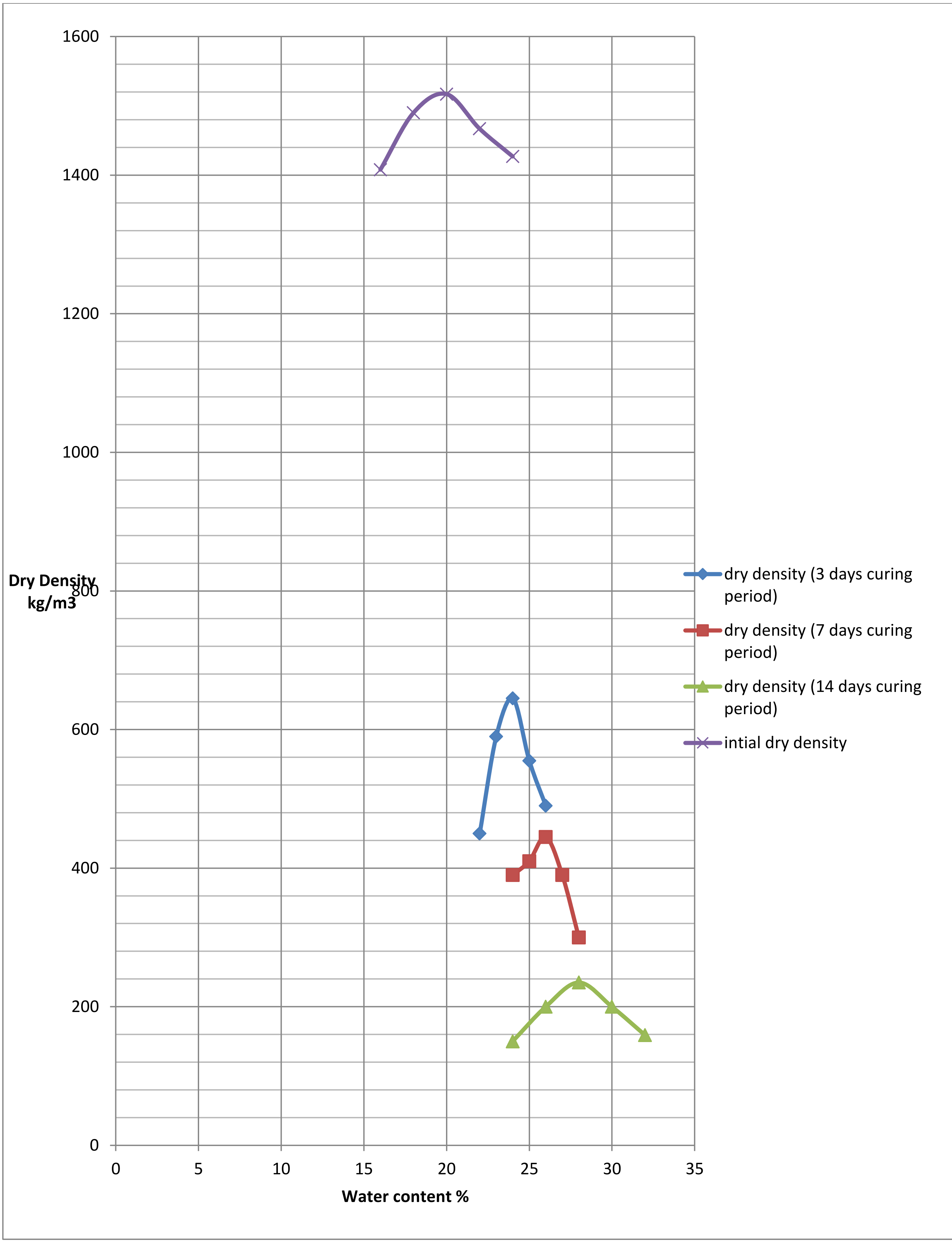
(Lime content 10%)

TABLE 6 - MOISTURE DENSITY RELATIONSHIP OF CLAY-LIME MIXTURES

3 days curing		7 days curing		14 days curing	
Water content %	Dry density kg/m^3	Water content %	Dry density kg/m^3	Water content %	Dry density kg/m^3
22	450	24	390	24	150
23	590	25	410	26	200
24	645	26	445	28	235
25	555	27	390	30	200
26	490	28	300	32	159

FIGURE 3 - OPTIMUM MOISTURE CONTENT OF CLAY-LIME MIXTURE

When mixed with lime, the optimum moisture content is increased and the maximum dry density is decreased. The maximum density is 645 kg/m^3 at a n optimum moisture content of 24% in 3 days. In 7days the maximum density is 445 kg/m^3 at an optimum moisture content of 26%.The maximum density is decreased to 235 kg/m^3 and optimum moisture content increased to 28%


1600
1400
1200
1000
800
600
400
200
0
Dry Density
kg/m3
0
5
10
15
20
25
30
35
Water content %
dry density (3 days curing period)
dry density (7 days curing period)
dry density (14 days curing period)
intial dry density

UNCONFINED COMPRESSION TEST

This test is conducted on undisturbed or remolded cohesive soils that are normally saturated. This test may be considered as a special case of triaxial compression test when the confining pressure is zero and the axial compressive stress only is applied to the cylindrical specimen. The stress may be applied and the deformation and load readings are noted until the specimen fails. The area of cross section of specimen for various strains may be corrected assuming that the volume of the specimen remains constant and it remains cylindrical. The following equations were used:

Axial strain (ε) $=\Delta L/L_0$

L_0=initial length of sample (cm)

Corrected area of cross section (A) $=A_0/1-\varepsilon$

A_0=initial area of cross section of the sample (cm^2)

Axial stress (qu) =P/A (kg/cm^2)

P=axial load (kg)

Graphs are plotted between axial strain (ε) Vs axial stress (qu), the maximum value of axial stress is the unconfined compressive strength of soil sample.

Samples for conducting unconfined compression test were prepared. Soil sample without additives were tested to find out the optimum moisture content based on compressive stress. The stress is applied and the deformation and load readings are noted until the specimen fails.

Do=4.6cm

A_0= 16.61cm2

Lo = 7cm

Proving Ring Constant = 0.24 kg/div

Stress vs. strain plot for native soil is as:-

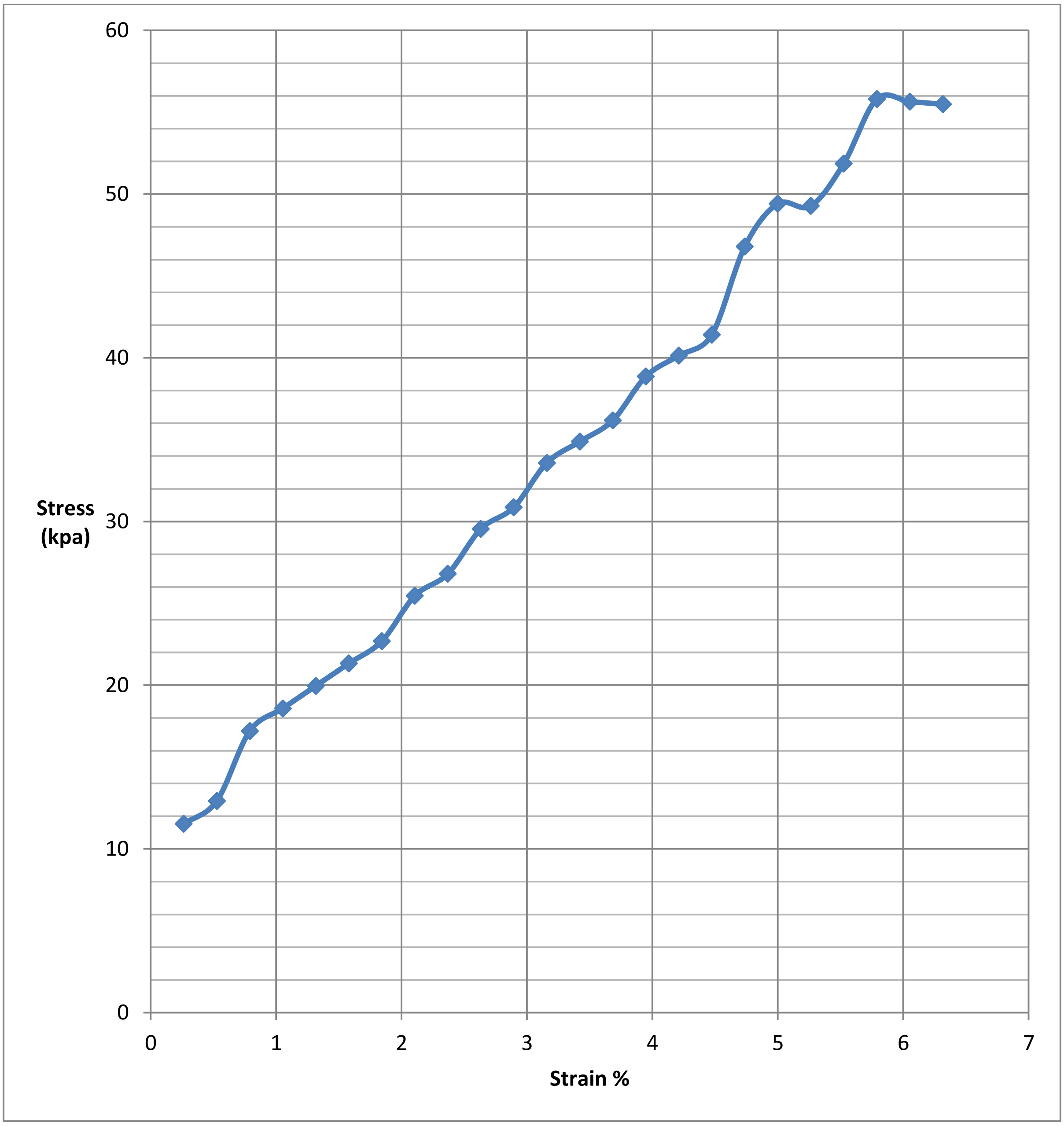


FIGURE 4 - STRESS-STRAIN RELATIONSHIP OF SOIL

Hence, unconfined compressive strength of native soil is 55.81 kpa.

UNCONFINED COMPRESSION TEST AFTER ADDITION OF LIME

The percentage of lime for stabilization is determined from the unconfined compression test.

Stress vs. strain plot in addition of 5% lime:-

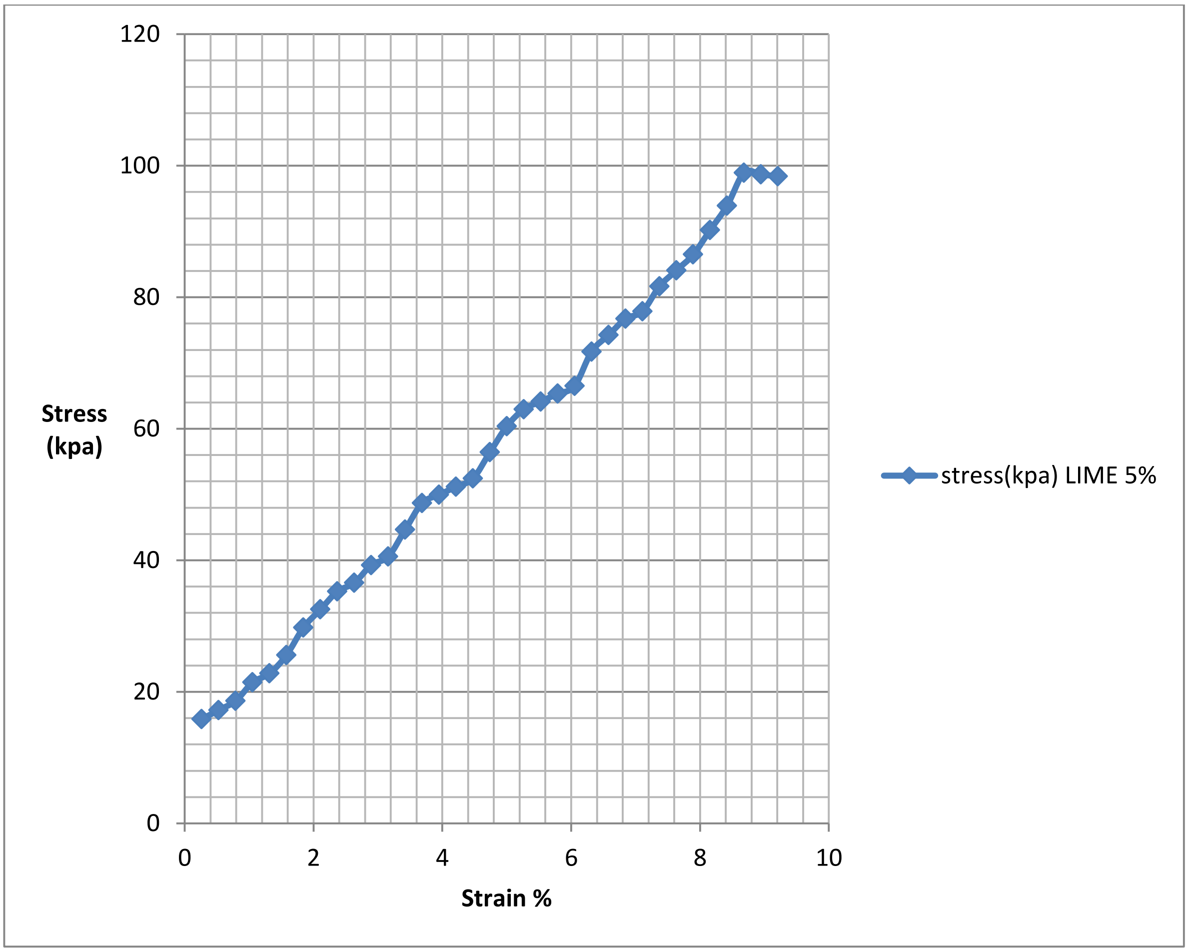


FIGURE 5 - STRESS-STRAIN RELATIONSHIP WITH 5%LIME IN SOIL

Hence on addition of 5% lime the stress increases to 98.95kpa.

Now, on increasing the content of lime to 10% variation observed on stress vs. strain plot is as:-

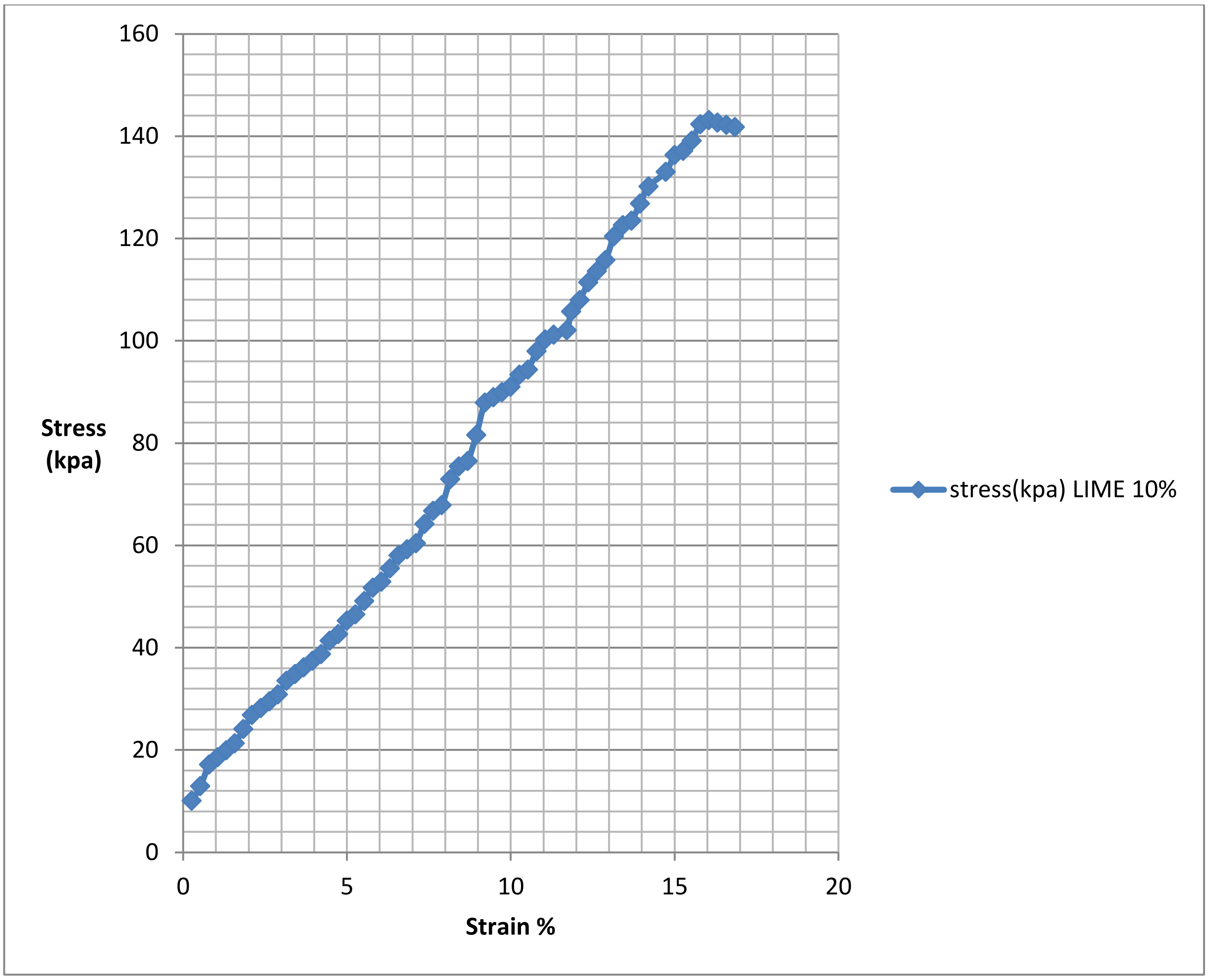


FIGURE 6 - STRESS-STRAIN RELATIONSHIP WITH 10% LIME ADDITION

Hence on addition of 10% lime the stress increases to 143kpa.

Now, on increasing the content of lime to 15% variation observed on stress vs. strain plot is as:-

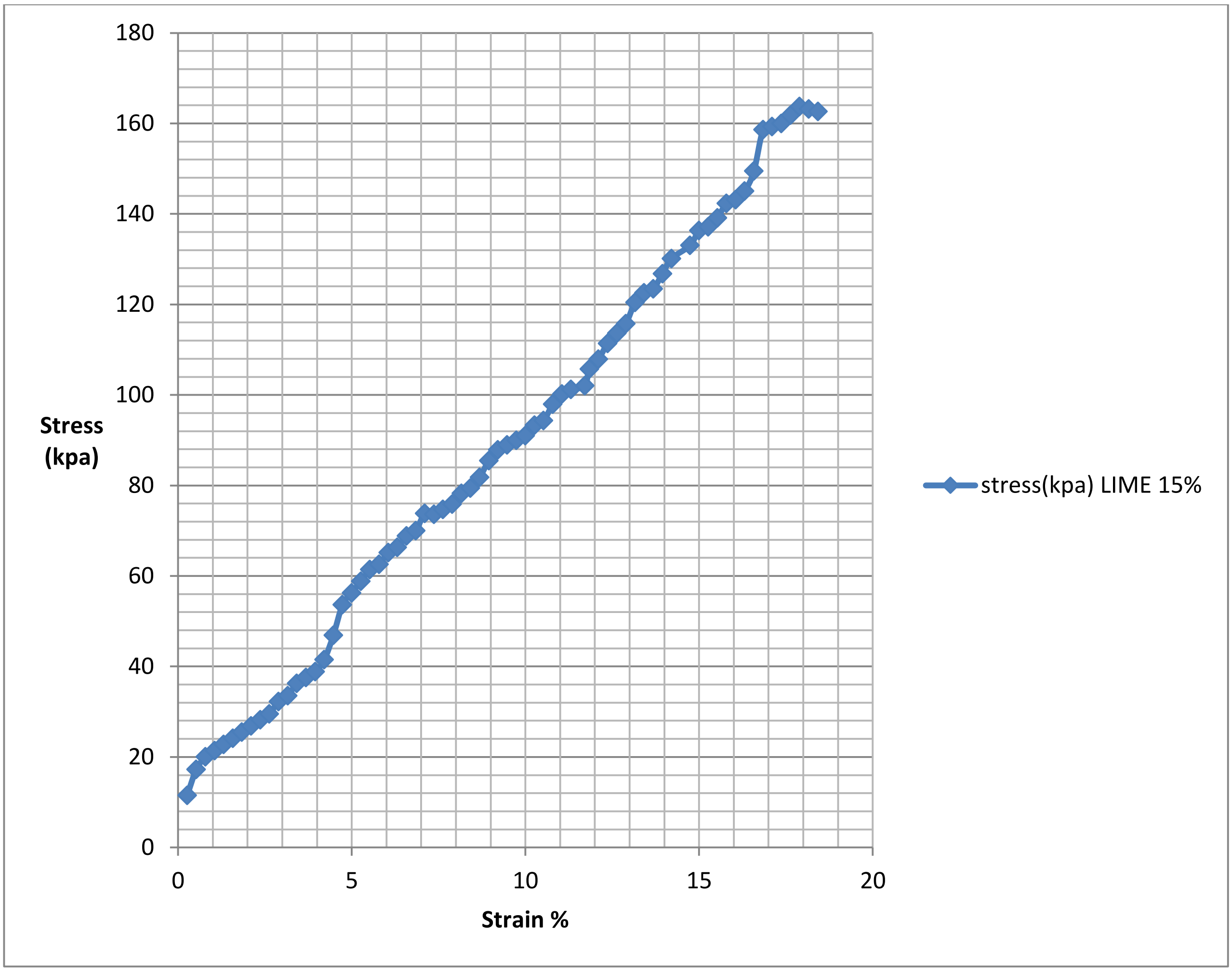


FIGURE 7 - STRESS-STRAIN RELATIONSHIP WITH 15% LIME ADDITION

Hence on addition of 15% lime the stress increases to 180.2kpa.

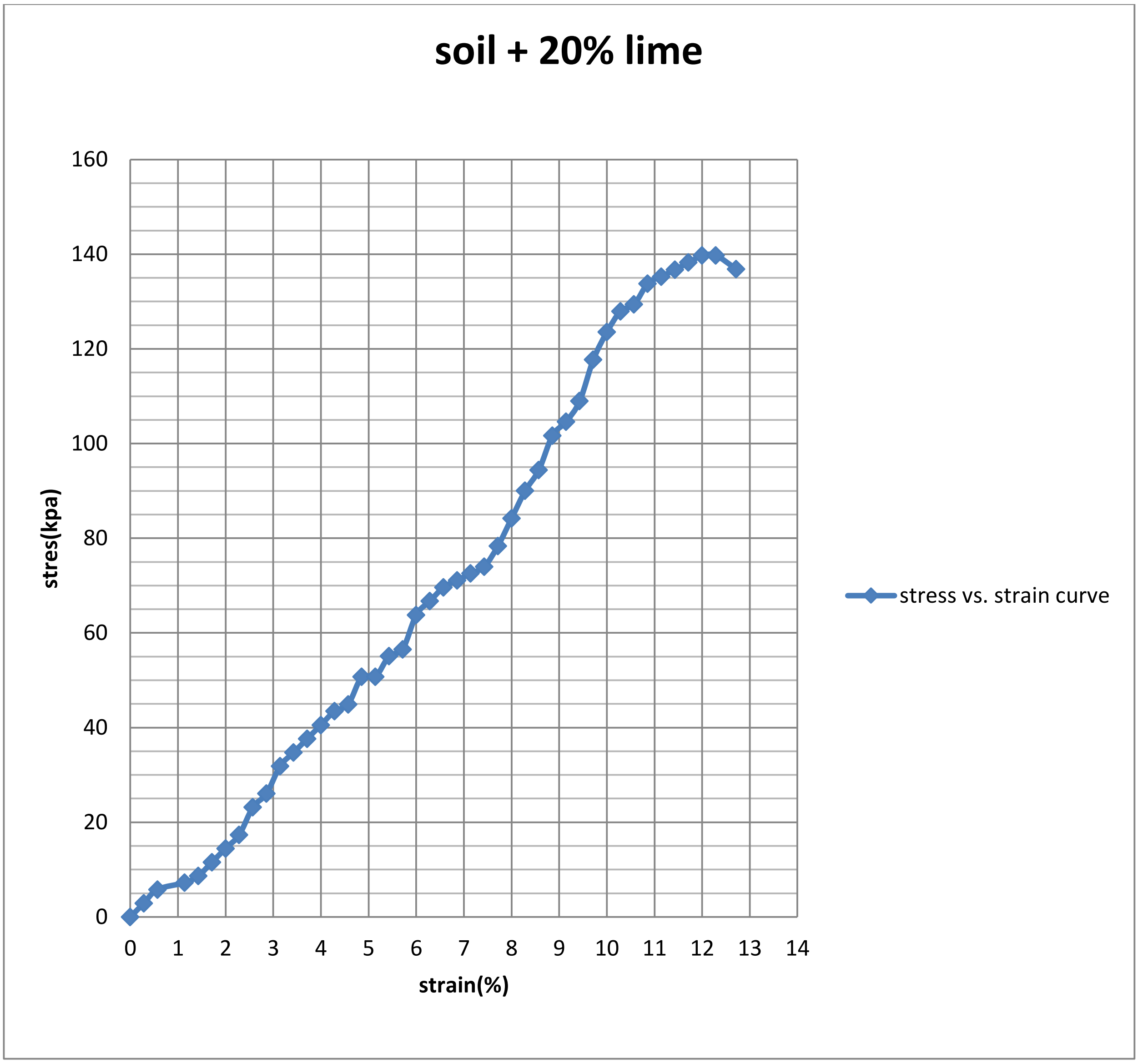


FIGURE 8 -STRESS-STRAIN RELATIONSHIP WITH 20% LIME ADDITION

Hence on addition of 20% lime the stress increases to 180.2kpa

Based on the above data following results are obtained:-

The test results are shown.

TABLE 7 - UNCONFINED COMPRESSIVE STRENGTH OF LIME-CLAY MIXTURE

S.no.	% of lime	Unconfined Compressive strength (kpa)	% Increase
1	0	58.51	–
2	5	98.95	68.4
3	10	143	144
4	15	163.7	179
5	20	140	139

The native soil has an unconfined compression of 58.51kpa. This increased by the addition of lime. The maximum strength is obtained by the addition of 15% lime i.e. 179kpa.

Since there is only 25% change in increase on addition of 15% lime as compared to 75.4% increase on addition of 10% lime w.r.t their previous lime content. Therefore 10% lime should be the optimum lime content as it will be economical to use less quantity of lime and at the same time providing more strength.

FREE SWELL INDEX

To determine the free swell index of soil as per IS: 2720 – 1977 is the increase in volume of soil without any external constraint when subjected to submergence in water.

Free swell index = $[V_d – V_k] / V_k \times 100\%$

where,

V_d = volume of soil specimen read from the graduated cylinder containing distilled water.

V_k = volume of soil specimen read from the graduated cylinder containing kerosene.

V_d = 5.5ml

V_k = 4ml

Therefore;

Free swell index = 37.5%

Hence the given soil is having a degree of expansiveness from moderate to high as per IS: 2720 – 1977. Hence the properties of soil need to be improved.

FREE SWELL INDEX ON ADDITION OF LIME

TABLE 8 - FREE SWELL INDEX AFTER LIME ADDITION

S.NO	% OF LIME	FREE SWELL INDEX	% DECREASE
1	-	37.5%	-
2	5%	25%	12.5
3	7%	18%	19.5
4	10%	15%	22.5

Hence to achieve minimum potential of expansiveness of the soil need to be treated with soil to reduce its swelling potential.

Therefore 10% of lime by weight of soil is added as the free swell index is very low as per IS: 2720 – 1977 to make sub grade soil able to sustain incoming load with respect to its swelling potential.

COMPACTION TEST

Compaction is the densification of soil by reduction of air voids. The purpose of a laboratory compaction test is to determine, the quantity of water to be added for field compaction of soil and resultant density expected. When water is added to dry fine grained soil, the soil absorbs water. Addition of more water helps in sliding of particles over each other. This assists the process of compaction. Up to a certain point, additional water helps in reduction of air voids, but after a relatively high degree of saturation is reached, the water occupies the space, which could be filled with soil particles, and the amount of entrapped air remains essentially constant. Therefore, there is an optimum amount of water for a given soil and compaction process, which gives rise to maximum dry density.

Compaction of clay and clay-lime were carried out using standard proctor test with three layers on each 25 blows. Samples for conducting compaction tests were prepared using moulds of dimensions 10 cm diameter and 15 cm height. In this study, is added for about 2%,5%,7%,10%,15% & 17%.The values of optimum moisture content and maximum dry density are obtained in a table given below;

MAXIMUM DENSITY AND OPTIMUM MOISTURE CONTENT

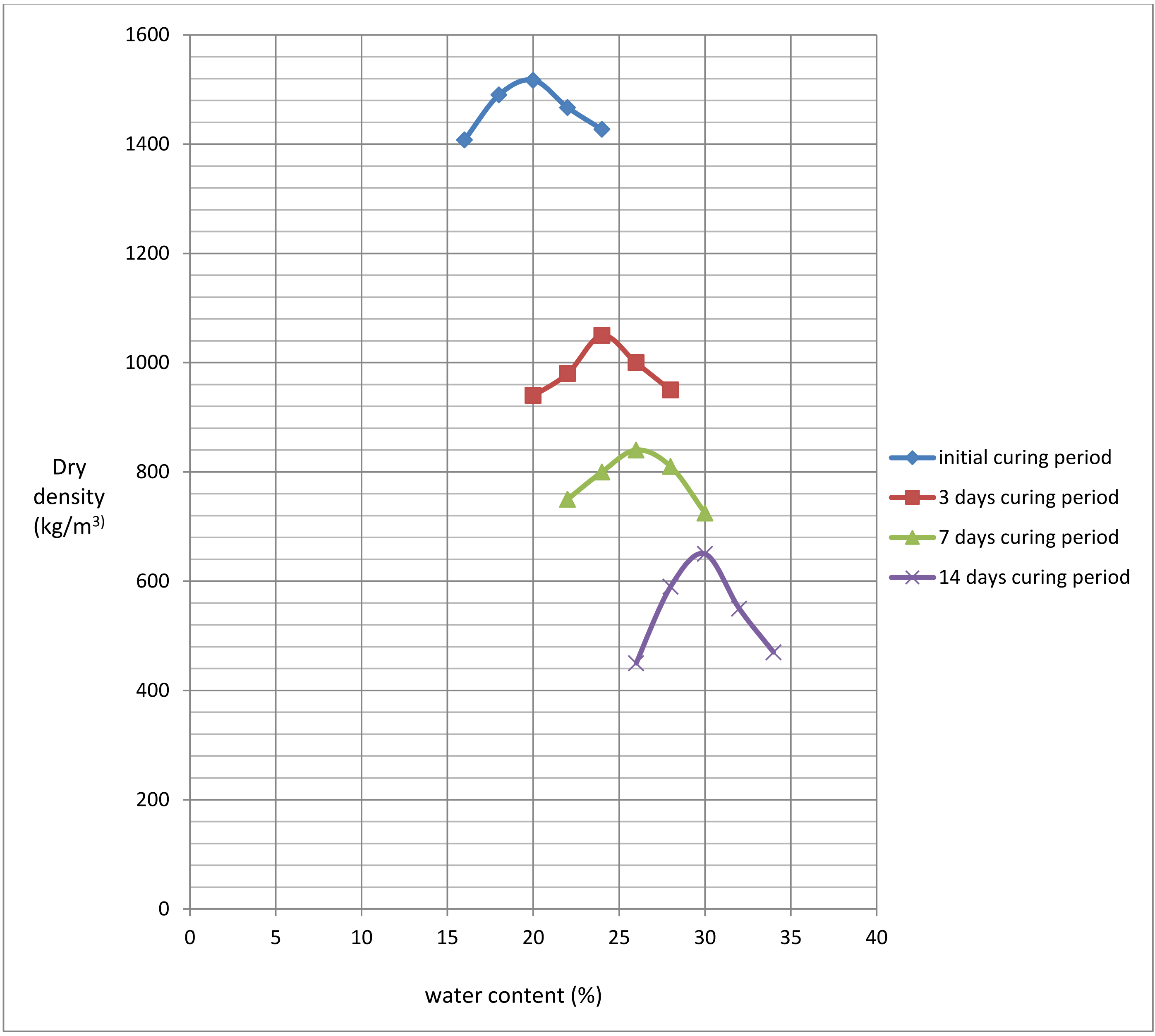
Optimum moisture content and maximum density for native soil and each of the soil additive combination at different curing period is presented in the table and the variation of maximum density and optimum moisture content is plotted.Moisture-density relationship of soil-mixtures

MOISTURE-DENSITY RELATIONSHIP OF WASTE PAPER SLUDGE-LIME MIXTURES

(waste paper sludge content 5%)

TABLE 9 - MOISTURE DENSITY RELATIONSHIP OF WASTE PAPER SLUDGE -LIME MIXTURES

3 days curing		7 days curing		14 days curing	
Water content %	Dry density kg/m^3	Water content %	Dry density kg/m^3	Water content %	Dry density kg/m^3
20	940	22	390	26	450
22	980	24	410	28	590
24	1050	26	445	30	650
26	1000	28	390	32	550
28	950	30	300	34	470


1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40
Dry density (kg/m3)
water content (%)
initial curing period
3 days curing period
7 days curing period
14 days curing period

UNCONFINED COMPRESSION TEST

This test is conducted on undisturbed or remolded cohesive soils that are normally saturated. This test may be considered as a special case of triaxial compression test when the confining pressure is zero and the axial compressive stress only is applied to the cylindrical specimen. The stress may be applied and the deformation and load readings are noted until the specimen fails. The area of cross section of specimen for various strains may be corrected assuming that the volume of the specimen remains constant and it remains cylindrical. The following equations were used:

Axial strain (ε) $=\Delta L/L_0$

L_0=initial length of sample (cm)

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Axial stress (qu) =P/A (kg/cm^2)

P=axial load (kg)

Graphs are plotted between axial strain (ε) Vs axial stress (qu), the maximum value of axial stress is the unconfined compressive strength of soil sample.

Samples for conducting unconfined compression test were prepared. Soil sample without additives were tested to find out the optimum moisture content based on compressive stress. The stress is applied and the deformation and load readings are noted until the specimen fails.

Do=4.6cm

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Stress vs. strain plot for native soil is as:-

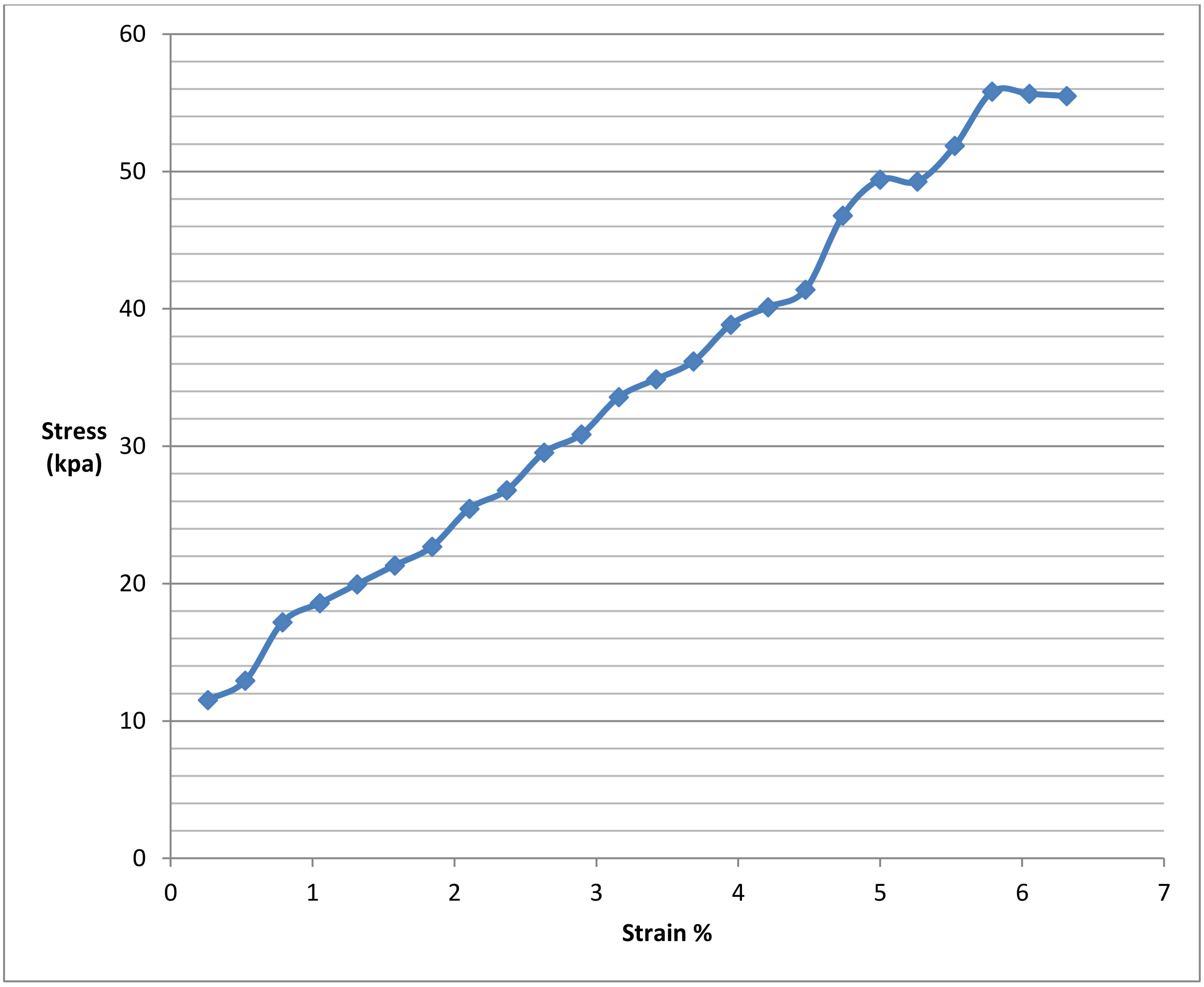


FIGURE 9 - STRESS-STRAIN RELATIONSHIP OF SOIL

Hence, unconfined compressive strength of native soil is 55.81 kpa.

UNCONFINED COMPRESSION TEST AFTER ADDITION OF WASTE PAPER SLUDGE

The percentage of waste paper sludge for stabilization is determined from the unconfined compression test.

Stress vs. strain plot in addition of 2% waste paper sludge:-

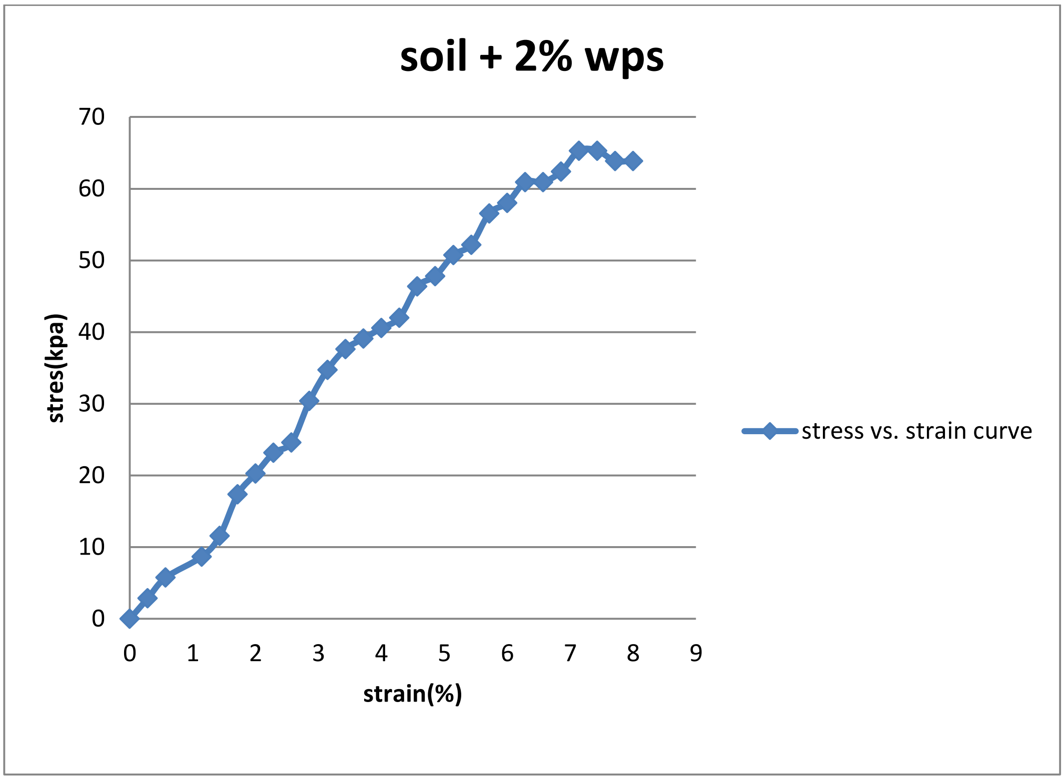


FIGURE 10 - STRESS-STRAIN RELATIONSHIP WITH 2%WASTE PAPER SLUDGE IN SOIL

Hence on addition of 2% waste paper sludge the stress increases to 65.31kpa.

Now, on increasing the content of waste paper sludge to 4% variation observed on stress vs. strain plot is as:-

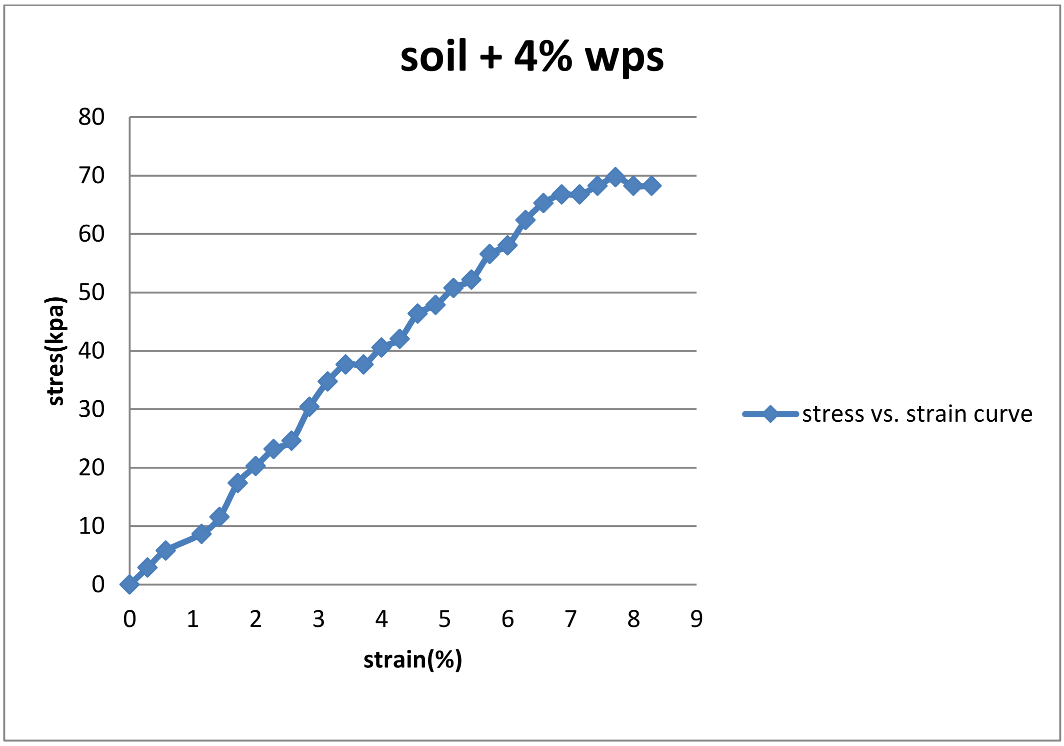


FIGURE 11 - STRESS-STRAIN RELATIONSHIP WITH 4% WASTE PAPER SLUDGE ADDITION

Hence on addition of 4% waste paper sludge the stress increases to 69.67kpa.

Now, on increasing the content of waste paper sludge to 5% variation observed on stress vs. strain plot is as:-

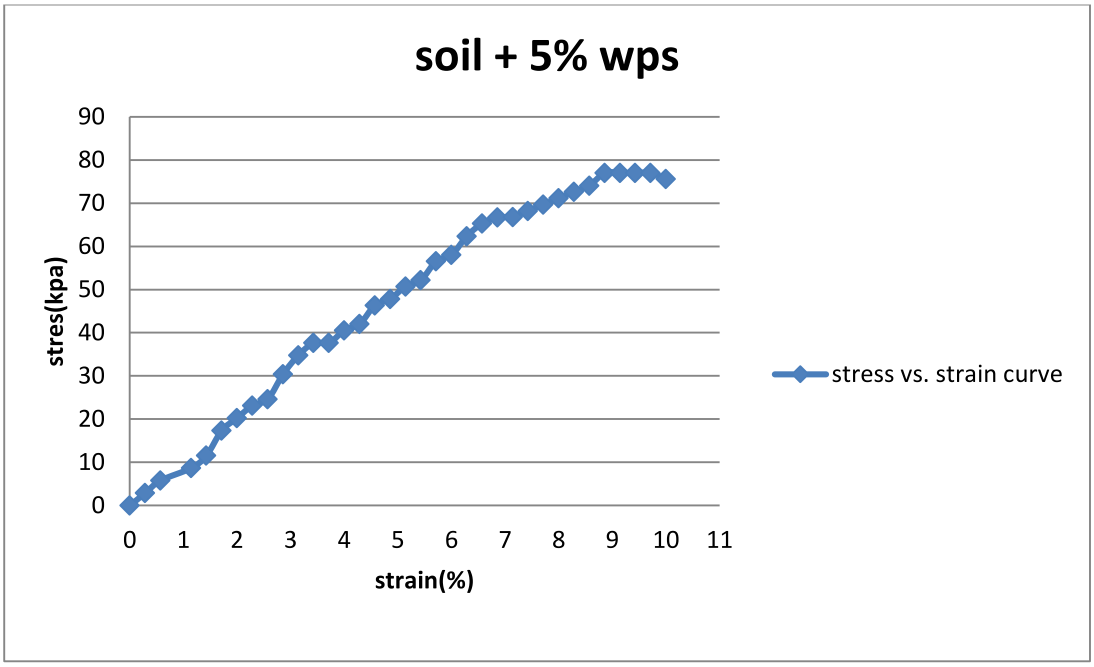


FIGURE 12 - STRESS-STRAIN RELATIONSHIP WITH 5% WASTE PAPER SLUDGE ADDITION

Hence on addition of 5% waste paper sludge the stress increases to 77.1kpa.

Now, on increasing the content of lime to 7% variation observed on stress vs. strain plot is as:-

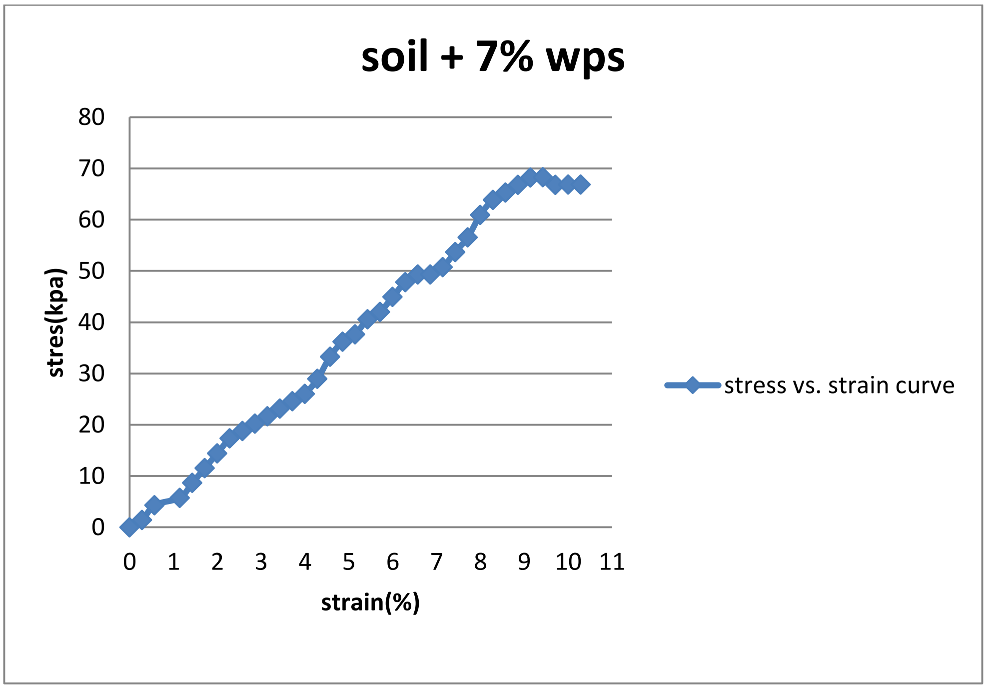


FIGURE 13 - STRESS -STRAIN RELATIONSHIP WITH 7 % WASTE PAPER SLUDGE ADDITION

Hence on addition of 7% lime the stress increases to 68.29kpa.

Now, on increasing the content of lime to 10% variation observed on stress vs. strain plot is as:-

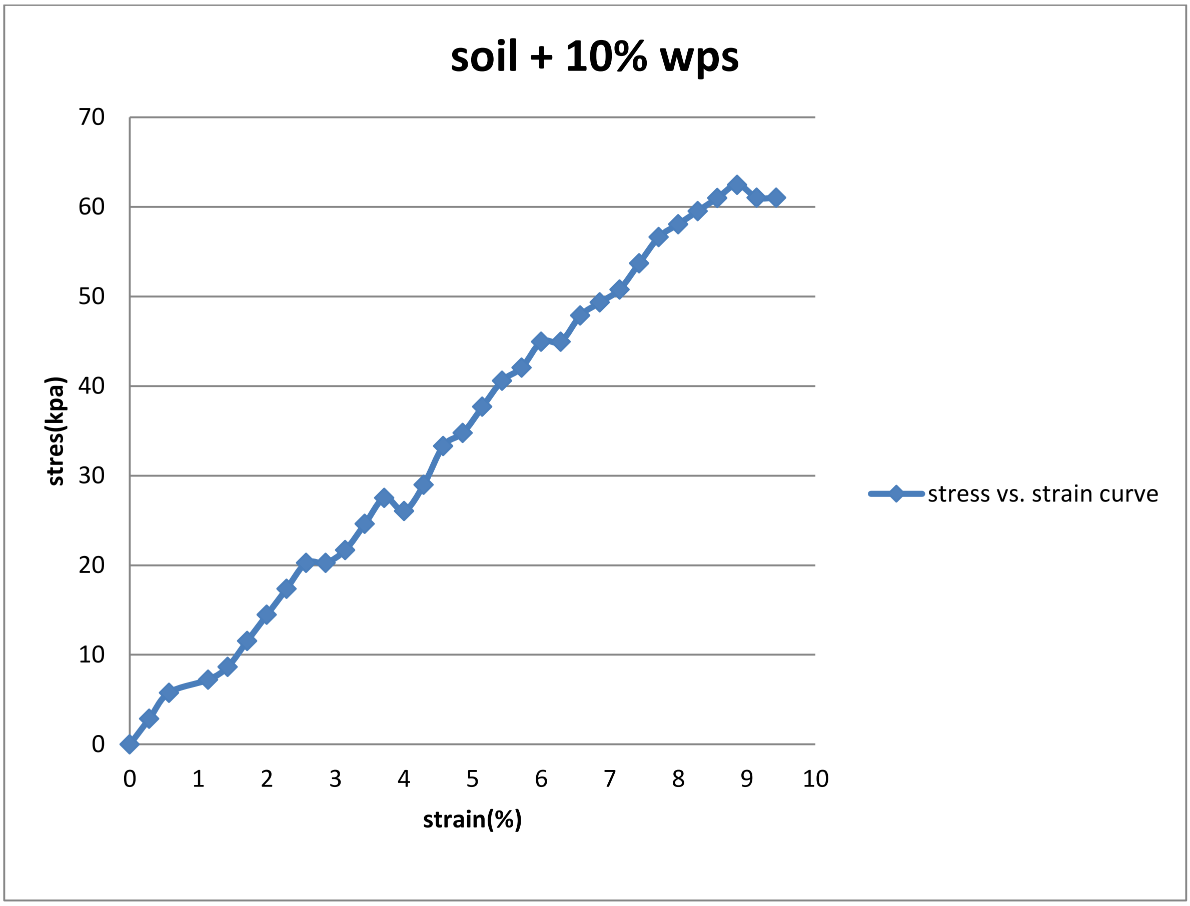


FIGURE 14 - STRESS -STRAIN RELATIONSHIP WITH 10 % WASTE PAPER SLUDGE ADDITION

Hence on addition of 10% waste paper sludge the stress increases to 62.4kpa.

Based on the above data following results are obtained:-

The test results are shown.

S.no.	% of waste paper sludge	Unconfined Compressive strength (kpa)	% Increase
1	0	58.51	_
2	2	65.31	11.6
3	4	69.67	19
4	5	77.1	31.8
5	7	68.29	16.71
6	10	62.4	6.7

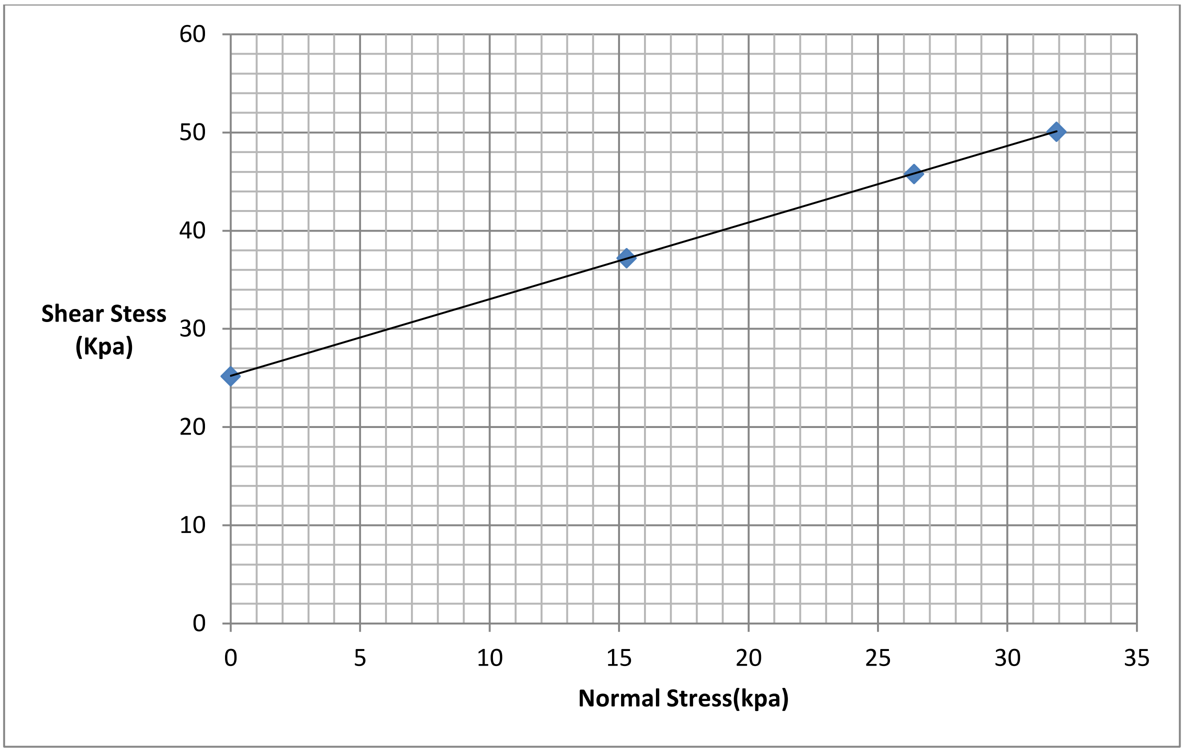
TAEBLE 10 - UNCONFINED COMPRESSIVE STRENGTH OF WASTE PAPER SLUDGE-SOIL MIXTURE

The native soil has an unconfined compression of 58.51kpa. This increased by the addition of waste paper sludge. The maximum strength is obtained by the addition of 5% waste paper sludge i.e. 77.1kpa.

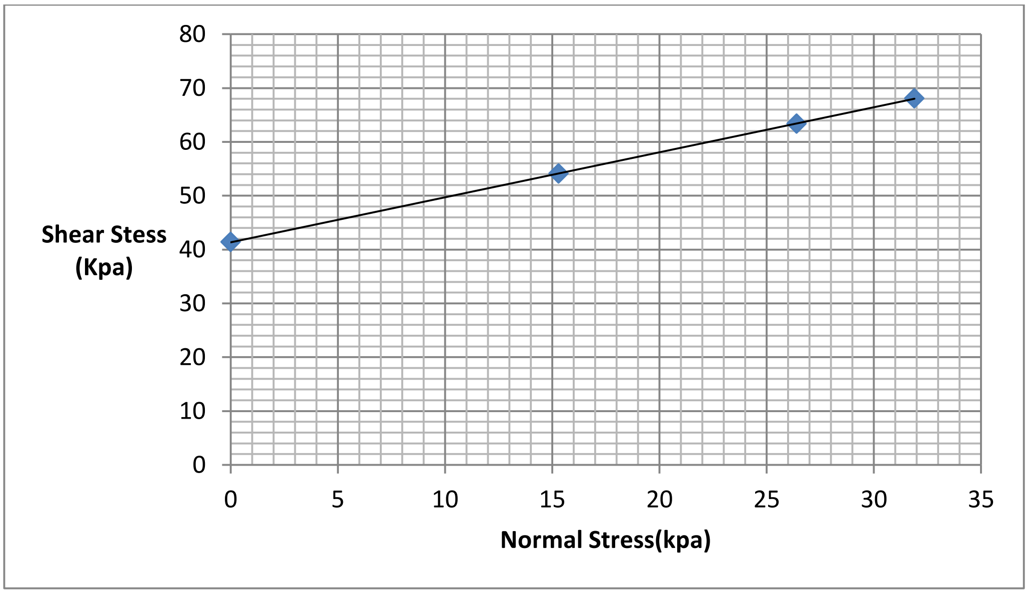
Since there is only 6.7% change in increase on addition of 10% waste paper sludge as compared to 31.8% increase on addition of 5% waste paper sludge w.r.t their previous waste paper sludge content. Therefore 5% waste paper sludge should be the optimum waste paper sludge content as it will be economical to use less quantity of waste paper sludge and at the same time providing more strength.

SHEAR STRENGTH PARAMETERS OF SOIL

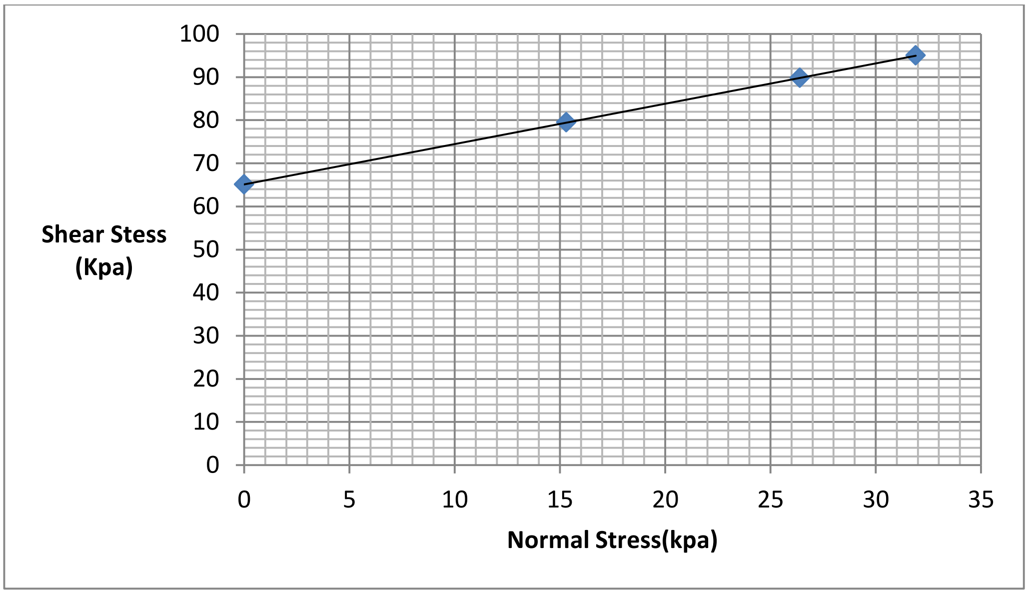
NATIVE SOIL



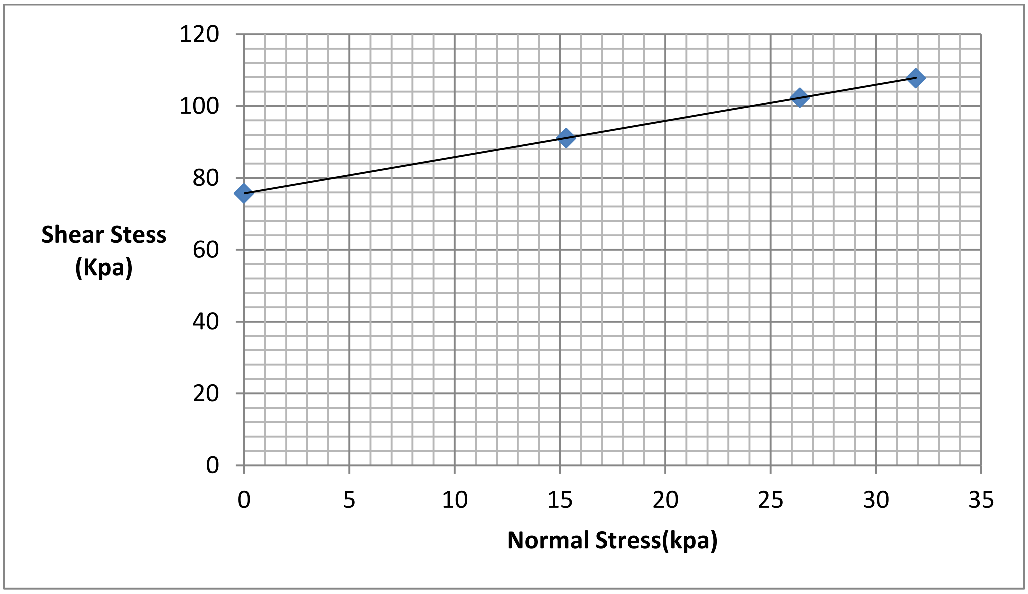
1)**C-ϕ VALUES ON 5% LIME ADDITION**



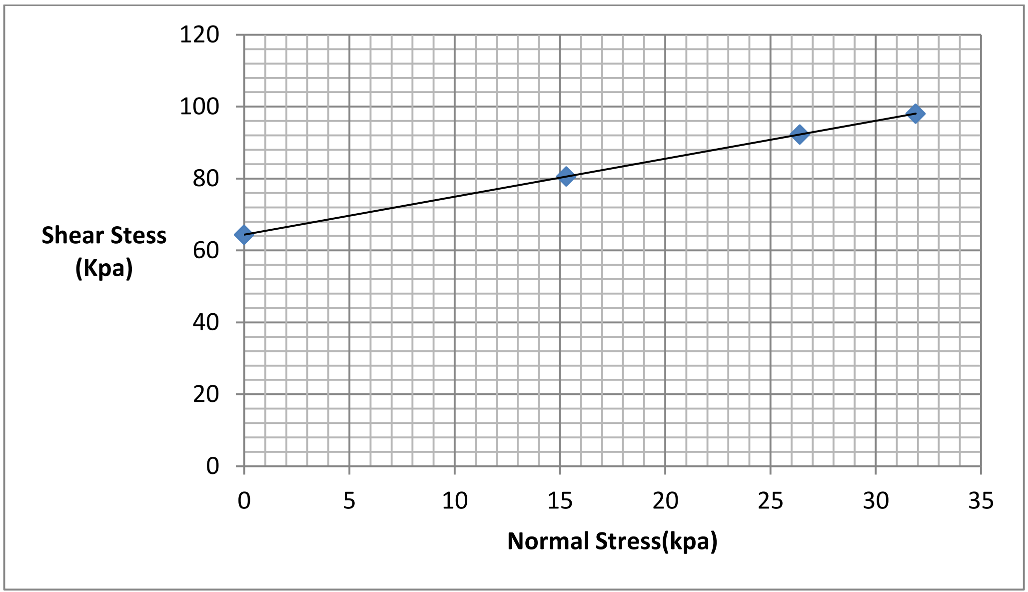
3)C-ϕ VALUES ON 10% LIME ADDITION



5)C-ϕ VALUES ON 15% LIME ADDITION



5)C-ϕ VALUES ON 20% LIME ADDITION



COMPARISON OF C-ϕ CHARACTERSTICS OF SOIL ON ADDITION OF LIME

TABLE 11 C-ϕ CHARACTERSTICS OF SOIL ON ADDITION OF LIME

S.NO	% OF LIME	C (COHESION)	ϕ (ANGLE OF INTERNAL FRICTION IN DEGREE)
1	-	25.2	38.1
2	5	41.4	40.35
3	10	65.1	43.26
4	15	75.7	45.18
5	20	64.4	46.7

Above experiment indicate that **C-ϕ** values of soil+lime is found to be increasing with increasing lime content which concludes that shear strength of soil is increasing . Hence the shear properties of soil has been enhanced. Optimum lime content for best stabilization is found to be 10 % .

This was the reason that unconfined compressive strength of soil has increased.

SHEAR STRENGTH PARAMETERS OF SOIL

1)Soil + 2%wps

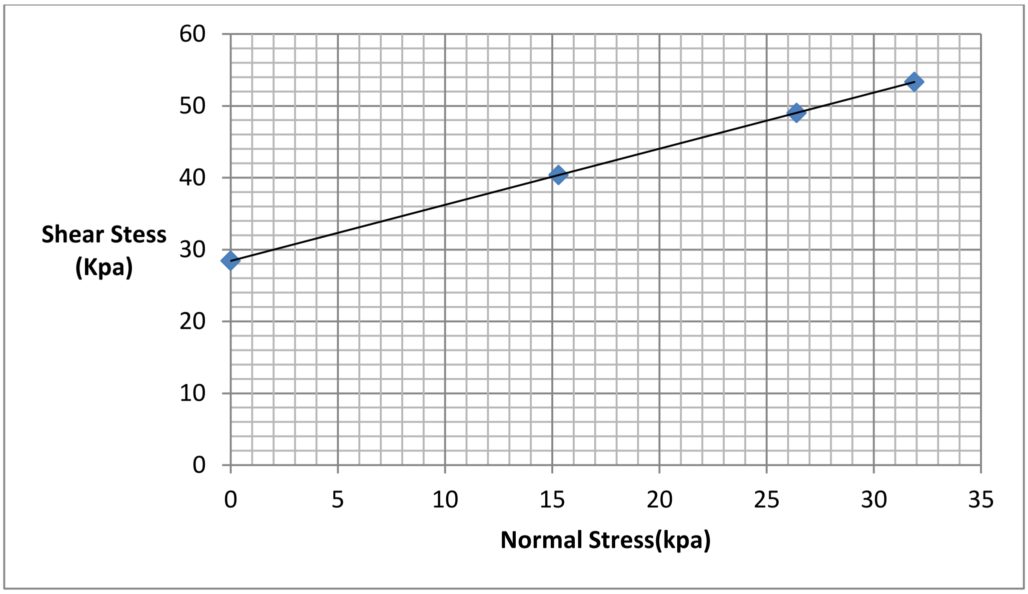


FIGURE 15 - SHEAR STRENGTH OF SOIL WITH 2% OF WASTE PAPER SLUDGE

2)Soil + 5%wps

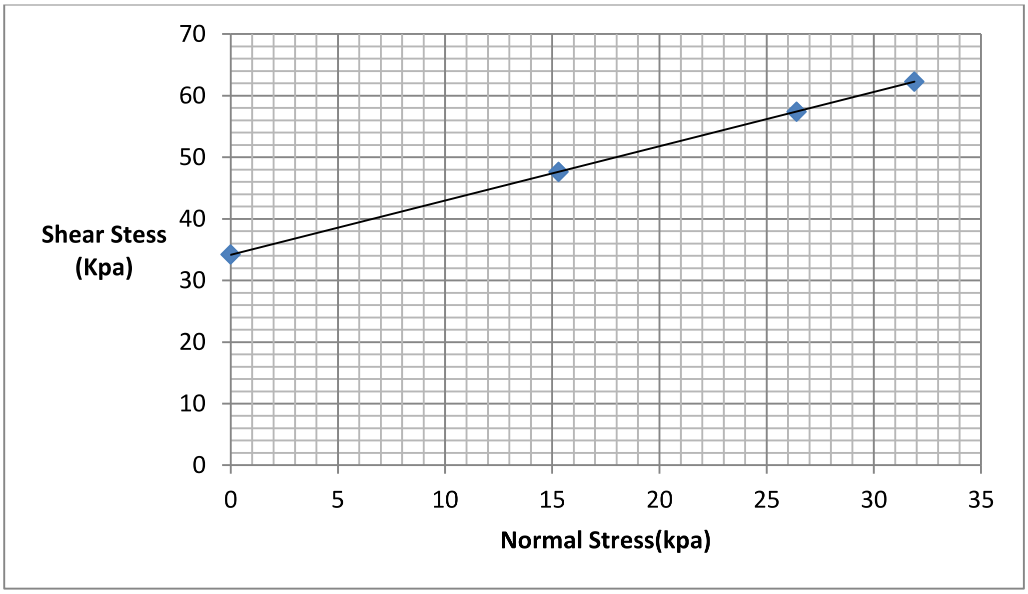


FIGURE 16 - SHEAR STRENGTH OF SOIL WITH 5% OF WASTE PAPER SLUDGE

2)Soil + 7%wps

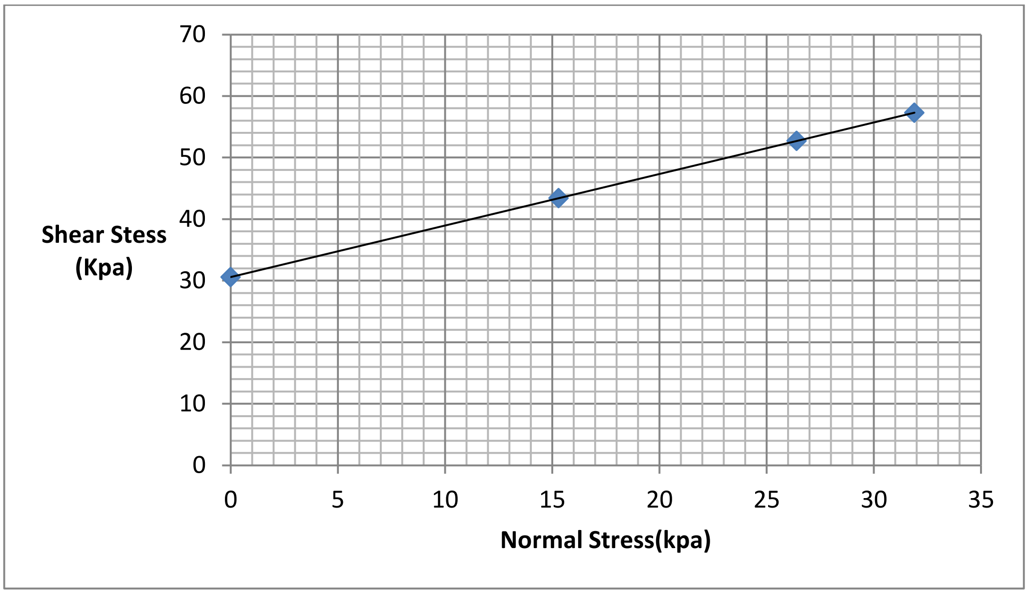


FIGURE 17 - SHEAR STRENGTH OF SOIL WITH 7% OF WASTE PAPER SLUDGE

3) **Soil + 10%wps**

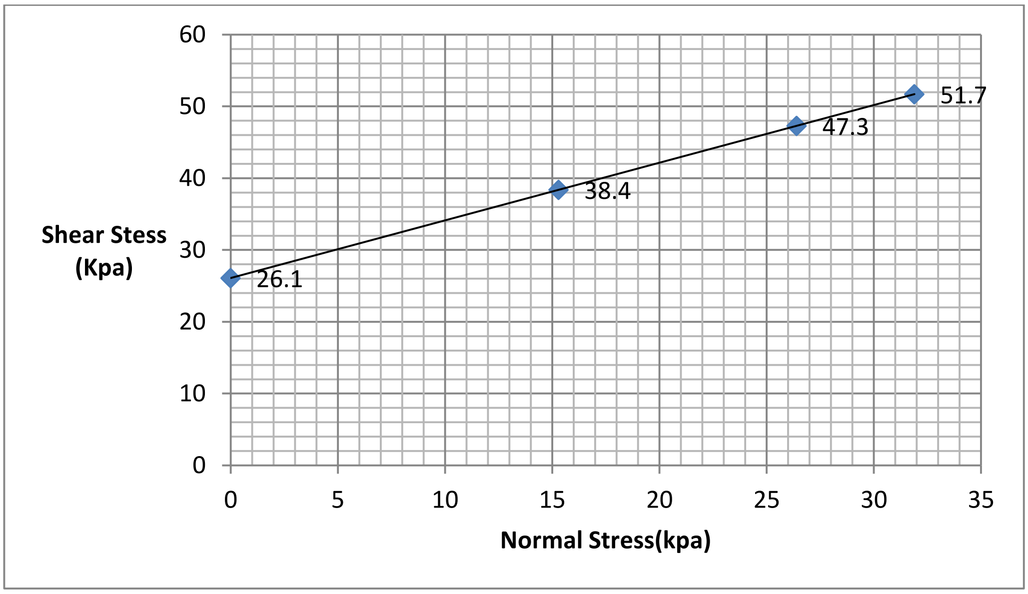


FIGURE 18 - SHEAR STRENGTH OF SOIL WITH 10% OF WASTE PAPER SLUDGE

COMPARISON OF C-ϕ CHARACTERSTICS OF SOIL ON ADDITION OF WASTE PAPER SLUDGE

S.NO	% OF WASTE PAPER SLUDGE	C (COHESION)	ϕ (ANGLE OF INTERNAL FRICTION IN DEGREE)
1	-	25.2	38.1
2	2	28.4	38.6
3	5	34.2	41.7
4	7	30.6	40.47
5	10	26.1	39.84

Waste paper sludge also enhances the shear strength properties of soil, but significantly less than actual lime.

Increase in shear strength was maximum at 5% addition of wps and then there was marginal decrease in the shear strength.

CHAPTER 4
CONCLUSION

- Lime is used as an excellent soil stabilizing materials for active soils which undergo through frequent expansion and shrinkage.
- Lime acts immediately and improves various property of soil such as carrying capacity of soil, resistance to shrinkage during moist conditions, reduction in plasticity index, and subsequent increase in the compression resistance with the increase in time.
- The reaction is very quick and stabilization of soil starts within few hours.
- The graphs presented above give a clear idea about the improvement in the properties of soil after adding lime.
- According to the above test results lime is a better soil stabilizing agent than waste paper sludge because lime by far improves soil bearing capacity and lowers compacting effort to stabilize the subgrade.

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