IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

Comparative Study of Effect of Compaction Delay on Stabilized Black Cotton Soil

N. P. Mujumdar[1], D. S. Kekan[2], S. R. Joshi[3], A. R. Joshi[4]
Sr Lecture, Guru Gobind Singh Polytechnic, Nashik, India[1]
Lecture, KVN Naik Polytechnic, Nashik, Maharashtra, India[2]
Assistant Professor, Matoshri College of Engineering and Research Centre, Nashik, India[3]
Lecture, Government Polytechnic, Samangan, India[4]

Abstract: *Urbanization and growth in the economy of India have led to the steep increase in the building construction activities and has necessitated the implementation of infrastructure projects such as highways, railways, air strips, water tanks, reclamation etc. These projects invariably require quality earth in massive quantity. In urban areas, borrow earth is not easily available which has to be hauled from a long distance. Quite often, large areas are covered with highly plastic and expansive soil, which is not suitable for such purpose. The wide spread of the black cotton soil has posed challenges and problems to the construction activities. At the same time pond ash is the most abundant of all residue and its disposal not only needs enormous land, water and power resources, but it also causes serious environmental hazards. In India there are 87 working thermal power plants producing more than 100 million tons of pond ash every year and the figure is likely to soar. Hence disposal of pond ash in ecologically in suitable manners has lately become global concern. A task was therefore undertaken to investigate and improve the engineering properties of the black cotton soils of Nashik (North West region of Maharashtra) using pond ash and pond ash-lime as a stabilizer. Some unavoidable reasons like sudden rainfall, machine failure and labour problems etc. cause delay between mixing the stabilizers and soil compaction which cause changes in soil properties. Hence effect of compaction delay on stabilized black cotton soil was investigated.*
Modified Proctor tests, UCS tests, CBR tests were conducted on the pond ash soil mixture (10%,20%,30% pond ash by weight of soil), soil- pond ash-lime mixture(10%,20%,30% pond ash and 3%,5%,8% Lime) and prepared samples were tested with time delay (time delay between mixing the contents with water and compaction) of 04 hours, 08hours, 12hours and it was observed that with increase in compaction delay MDD,UCS and CBR decreases of all mixture. However 77%Black cotton soil+ 20% pond ash+3% Lime shows better results of stabilization and has less effect of compaction delay and can be used as an admixture to improve the properties of subgrade soil.

Keywords: Cotton Soil

I. INTRODUCTION

Increased costs associated with the use of high- quality materials led to the need for local soils to be used in geotechnical and highway construction. Often however, high water content and low workability of these soils pose difficulties for construction projects. In many situations the soil present in the field, may be problematic one such as expansive soils i.e., black cotton soils. In India expansive soils cover about 20% of the total land area (Shelke and Murty 2010).

Need of study

Studies have been conducted in the past by many investigators regarding the use of pond ash alone or in conjunction with lime or cement for improving properties of black cotton soil in many regions around the world. There might be a chance of delay between mixing the stabilizers with soil and compaction of the soil stabilizers. Most of the time, delay is unavoidable because of any one reason of the following like sudden raining, delaying of compacting equipment after mining, mechanical failure, insufficient workers/equipment's, poor transportation etc. these makes the compaction

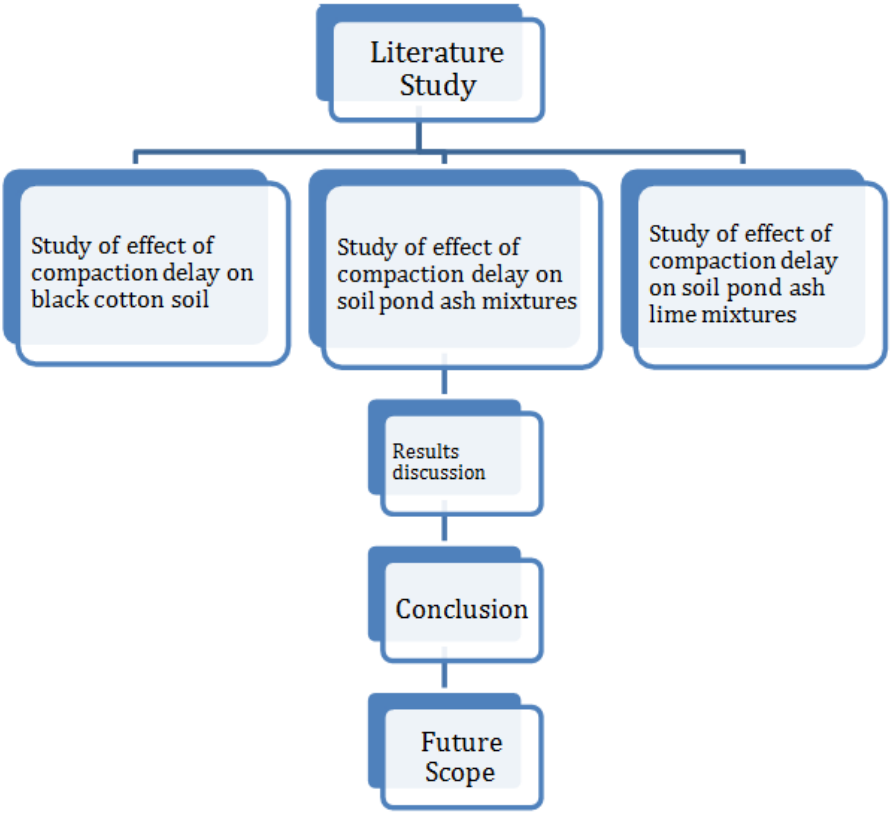
IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

process delayed one. These delaying hours considerably affects Maximum Dry Density (MDD), Optimum Moisture Content (OMC) and strength properties of soil blended with pond ash and lime in different proportions. So, there is a need to study the effect of compaction delay on properties of black cotton soil.

Objectives of study

1) To determine the effect of compaction delay on characteristics of black cotton soil found in north- west region of Maharashtra.
2) To study the effect of compaction delay on characteristics of soil and pond ash mixtures.
3) To study the effect of compaction delay on properties of soil, pond ash and lime mixtures.

II. METHODOLOGY



III. EXPERIMENTAL METHODOLOGY

The purpose of this chapter is to give detail information about materials used in present work and experimental methodology used for the same.

Materials used

Table 3.1 Properties of soil

Sr. No.	Parameter	Symbol or Percentage	Values obtained	Range for Black cotton soil
1.	Specific gravity	Gs	2.60	-
2.	Natural water content	%	12	
3.	Liquid limit	%	65	50-100%
4.	Plastic limit	%	43.58	20-65%
5.	Shrinkage limit	%	12.35	9-14%

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

6.	Plasticity index	Ip	21.42	-
7.	MDD	g/cc	1.627	-
8.	OMC	%	19.20	-
9.	Swelling Index	%	37	35-50%
10.	C.B.R (unsoaked)	%	5%	-
11.	C.B.R(soaked)	%	2.02%	
12	Colour		Black	

Table 3.2 Chemical properties of pond ash

Sr. No.	Chemical Properties	Unit	% by mass
1.	SiO2	%	58.66
2.	MgO	%	1.82
3.	SO3	%	0.76
4.	Na2O	%	0.62
5.	SiO2+AL2O3+Fe2O3	%	92.56
6.	Total chloride	%	0.027
7.	Loss on Ignition	%	1.94
8.	Moisture content	%	0.25
9.	Specific gravity	-	2.23

Table 3.3 Oxide Composition of Hydrated lime

Sr no.	Oxide	Concentration (% by weight)
1.	Cao	67.16
2.	Sio2	1.58
3.	P2O5	1.1
4.	Fe2o3	0.64
5.	AL2O3	0.50
6.	MNO2	0.05
7.	Loss on Ignition	26.87

Experimental investigation and testing program

The investigation was aimed at studying the effect of compaction delay on relationship between moisture and density of a black cotton soil mixed with different proportion of pond ash and then examining the enhanced effect of lime on above characteristics.

Table 3.4 Schedule of stage 1

Designation of mix	Delayed in compaction (Hours)
Black cotton soil	Immidiately,4,8,12

Table 3.5 Schedule of stage 2

Designation of mix	Mixture	Delayed in compaction
10 P.A.	90% BCS + 10% P.A.	Immidiately,4,8,12 hours
20 P.A.	80% BCS + 20% P.A.	Immidiately,4,8,12 hours
30 P.A.	70% BCS + 30% P.A.	Immidiately,4,8,12 hours

Table 3.6 Schedule of stage 3

Designation of mix	Mixture	% Lime used	Delayed in compaction
10 P.A.	90% BCS + 10% P.A.	3	Immidiately,4,8,12 hours
20 P.A.	77% BCS + 20% P.A.	5	Immidiately,4,8,12 hours
30 P.A.	65% BCS + 30% P.A.	8	Immidiately,4,8,12 hours

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

Tests Performed

Preliminary tests were performed on soil samples to determine its engineering property as well index properties. Also along with preliminary tests Modified Proctor Tests, Unconfined compression tests, California Bearing Ratio tests were performed to determine density and strength properties of soil in its natural condition.

IV. RESULT AND DISCUSSION

Background

This chapter deals with results obtained of all tests performed during the entire work and discussion about those results. The effect of compaction delay on Specific Gravity, Atterberg's limit, Free swell index, MDD, CBR (soaked and unsoaked) and UCS of black cotton soil is discussed in detail.

Effect on Specific Gravity (G) after addition of Stabilizers in different percentage

Specific Gravity was conducted using pycnometer according to IS 2720 (Part 2) 1964. Specific gravity was calculated with help of formula

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

Where,

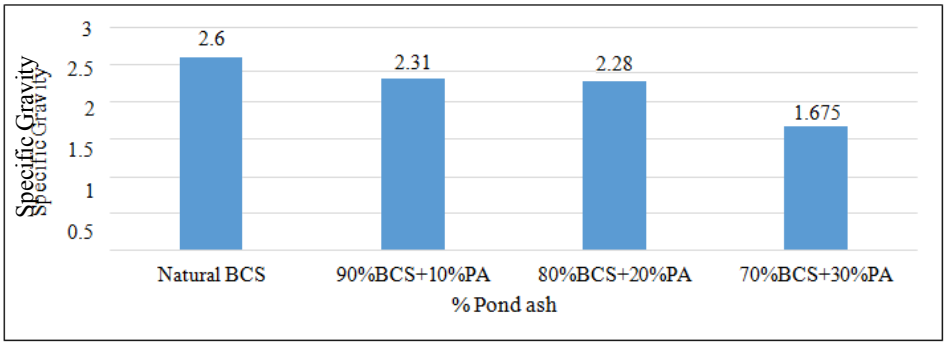
M1 = Empty weight of Pycnometer

M2 = Weight of pycnometer + Weight of sand

M3 = Weight of pycnometer + Weight of sand + Water M4 = Weight of pycnometer + Water

Table 4.1 Effect on specific gravity of Black cotton soil

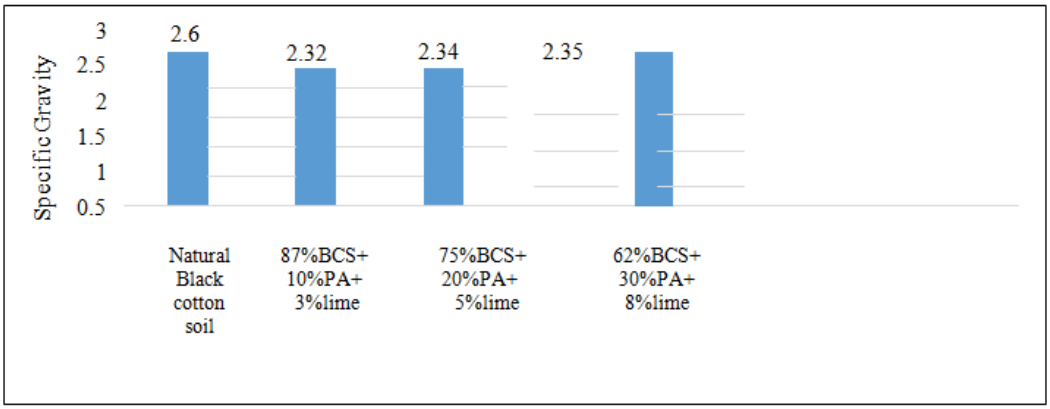
Sr. No.	Designation	Specific Gravity
1.	Black cotton soil	2.60
2.	90% BCS + 10% PA	2.31
3.	80% BCS + 20% PA	2.28
4.	70% BCS + 30% PA	1.675



Graph 4.1 Specific gravity of BCS stabilized with different percentage of pond ash

Graph 4.1 shows the effect on specific gravity of black cotton soil on addition of pond ash. From the graph it can be observed that specific gravity of soil pond ash mixture decreases with increase in percentage of pond ash.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025



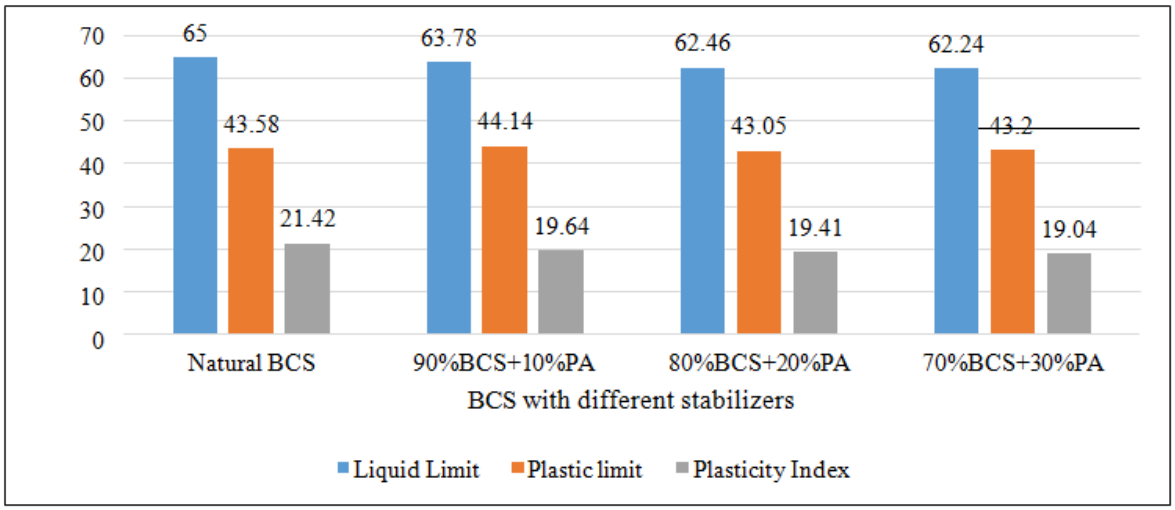
Graph 4.2 Specific Gravity of soil- pond ash mixture after addition of lime Graph 4.2 shows the effect on soil-pond ash mixture after addition of 3%, 5% and 8% lime. Graph shows that addition of lime further reduces the specific gravity of soil pond ash mixture. With addition of lime to 80%BCS+20%PA mixture specific gravity increases by 0.01, 0.02 and 0.03 with addition of 3%, 5% and 8% lime respectively.

4.2 Effect on Atterberg's limit of Black cotton soil on addition of stabilizers.

Liquid limit, Plastic limit, Plasticity index was found out of Black cotton soil on addition of pond ash, pond ash–lime.

Sr. No	Designation	Liquid limit	Plastic limit	Plasticity index
1.	Black cotton soil	65.00	43.58	21.42
2.	90%BCS+10%PA	63.78	44.14	19.64
3.	80%BCS+20%PA	62.46	43.05	19.41
4	70%BCS+30%PA	62.24	43.20	19.04
5.	87%BCS+10%PA+3%LIME	63.42	44.10	19.32
6.	75%BCS+20%PA+5%LIME	62.95	43.94	19.01
7.	62%BCS+30%PA+8%LIME	62.10	42.86	19.24

Table 4.2 Effect on Atterberg's limit of Black cotton soil



Graph 4.3 Relation set for the Black cotton soil and different percentage of pond

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

Graph 4.3 shows the relationship between liquid limit, plastic limit, and plasticity index for black cotton soil and soil-pond ash mixture. From the graph it was observed that liquid limit decreases from 65% to 63.78%, 62.46%,62.24% with increase in % of pond ash from 20%, 30%, 50% respectively.

4.3 Effect on free swell index of black cotton soil using different percentage of stabilizers

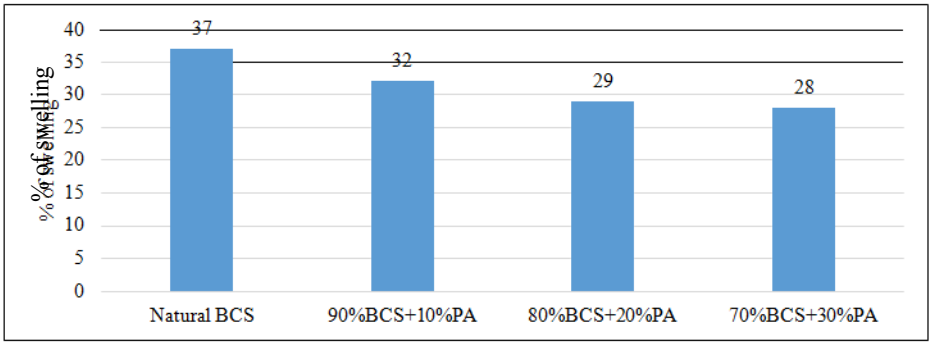
Free Swell Index (%) = (V2-V1)/ V1* 100

V1 = Volume of soil specimen in the graduated cylinder containing kerosene oil.

V2 = Volume of soil specimen in the graduated cylinder containing distilled water.

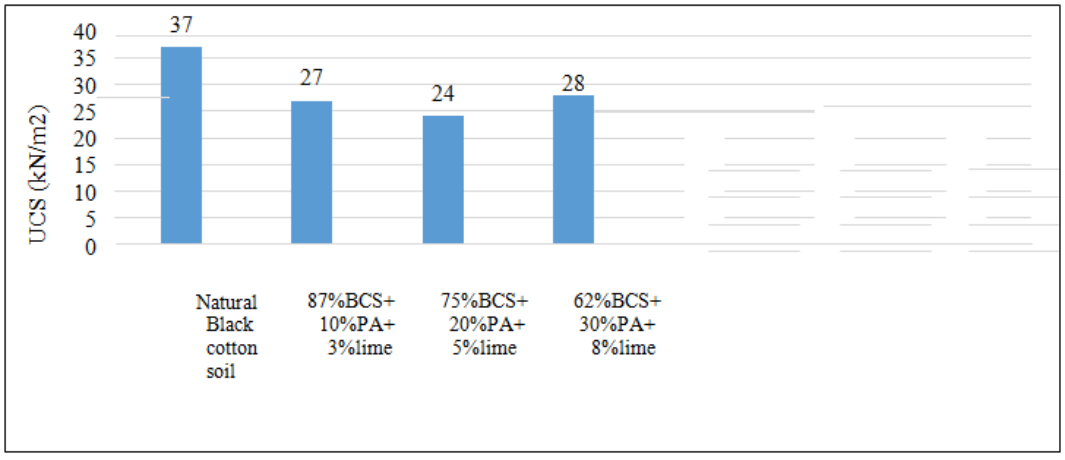
Table 4.3 Effect on Free Swell Index of Black cotton soil

Sr. No.	Designation	Free Swell Index (%)
1.	Black cotton soil	37
2.	90%BCS+10%PA	32
3.	80%BCS+20%PA	29
4.	70%BCS+30%PA	26
5.	87%BCS+10%PA+3%LIME	27
6.	75%BCS+20%PA+5%LIME	24
7.	62%BCS+30%PA+8%LIME	26



Graph 4.4 Effect on free swell index of BCS after addition of pond ash

Graph 4.4 shows the effect on free swell index on black cotton soil after addition of pond ash in different percentage. Graph shows that free swell index swelling characteristics decreases with increase in percentage of pond ash



Graph 4.5 Effect on free swell index of soil-pond ash mixture after addition of lime.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

Graph 4.5 shows the effect on free swell index of soil-pond ash mixture after addition of lime in 3%, 5% and 8%. Addition of lime 8% lime to 62%BCS+30%PA shows great improvement in avoiding swelling characteristics of the soil.

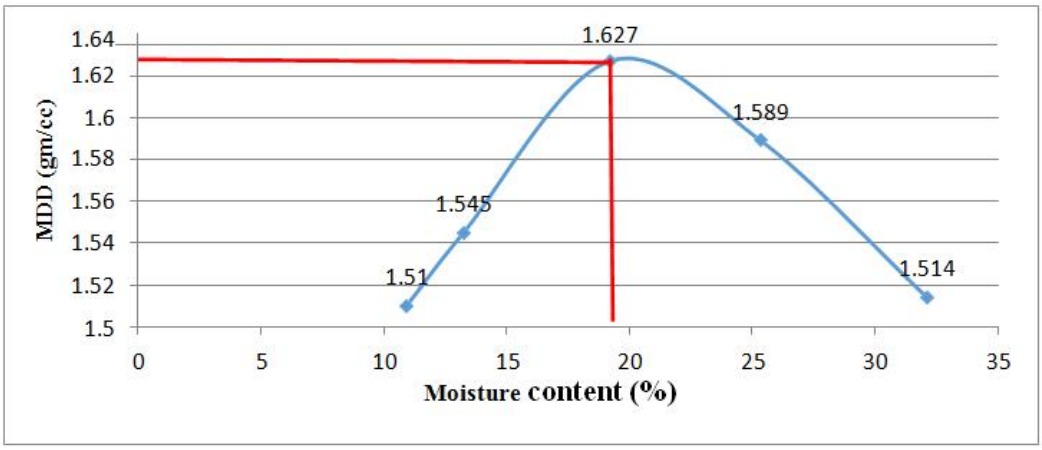
Effect of compaction delay on Plane Black cotton soil

Table 4.4: Sample calculation for MDD and OMC

Sr no.	Mass of empty mould +Test sample	Mass of sample	Bulk density Pb	Water content W%	Dry density Pd
1	7118	1632	1.675	10.93	1.51
2	7190	1704	1.749	13.25	1.545
3	7374	1888	1.938	19.20	1.627
4	7462	1976	2.028	25.33	1.589
5	7434	1948	2.002	32.11	1.514

Table 4.5: Results of MDD and OMC for Black Cotton Soil

MDD(gm/cc)	1.51	1.545	1.627	1.589	1.514
Water content%	10.93	13.25	19.20	25.33	32.11

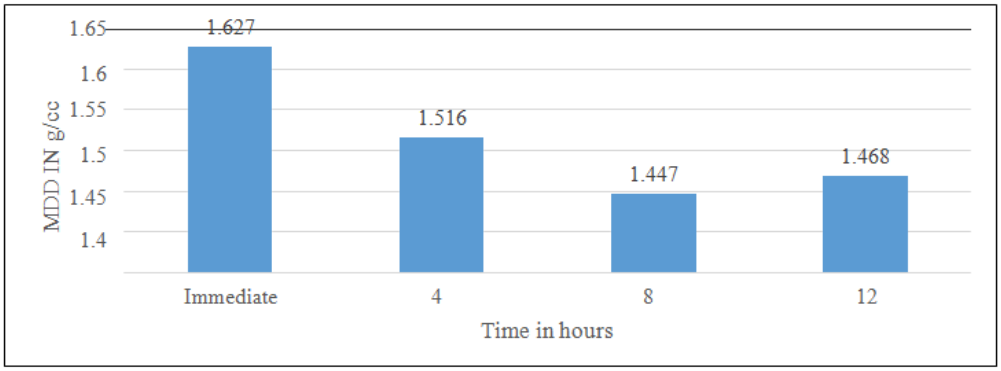


Graph 4.6 Relationship between MDD and moisture content for Black cotton soil

Following results were obtained for delay in compaction.

Table 4.6: Results of MDD of black cotton soil

Delay in hours	0	4	8	12
MDD(gm/cc)	1.627	1.516	1.447	1.468



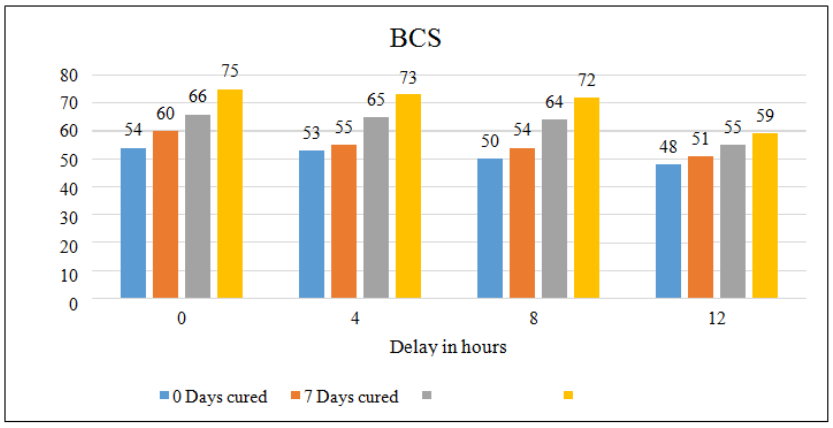
Graph 4.7 Variation of MDD of black cotton soil due to delay in compaction

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

Graph 4.7 shows the effect of compaction delay on black cotton soil. From the graph it can be observed that maximum dry density decreases with increase in compaction delay up to 8 hours, but it increases after 8 hours.

Table 4.7: Results of UCS due to compaction delay of black cotton soil

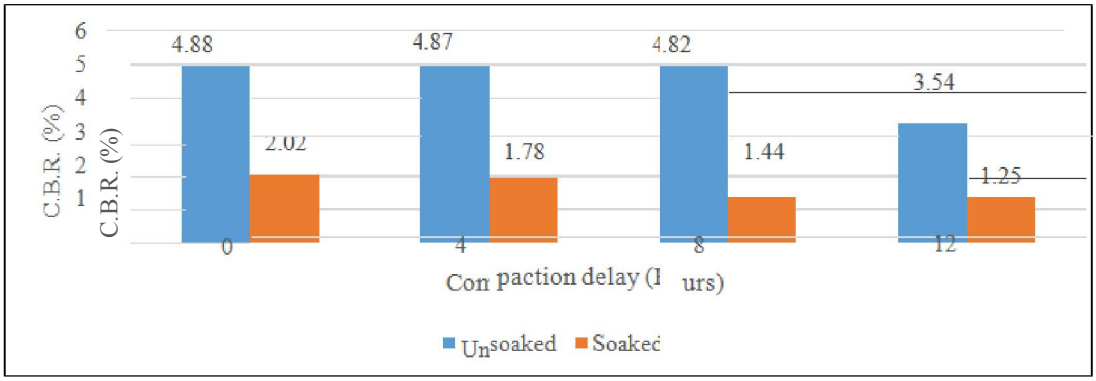
Days cured/Delay in hours	0	7	14	28
0	54	60	66	75
4	53	55	65	73
8	50	54	64	72
12	48	51	55	59



Graph 4.8 Variation of UCS of black cotton soil due to delay in compaction

Table 4.8: Results of CBR due to compaction delay of black cotton soil

Delay in hours	0	4	8	12
C.B.R %(unsoaked)	4.88	4.87	4.82	3.54
C.B.R %(soaked)	2.02	1.78	1.44	1.25



Graph 4.9 Variation of CBR (soaked and unsoaked condition) of black cotton soil due to delay in compaction

Graph 4.13 shows the variation of CBR of black cotton soil in unsoaked condition. CBR value of black cotton soil was observed to be 4.88% at no compaction delay. As the compaction delay increases CBR of soil decreases.

Effect on black cotton soil-pond ash mixture (70%BCS+30%PA)

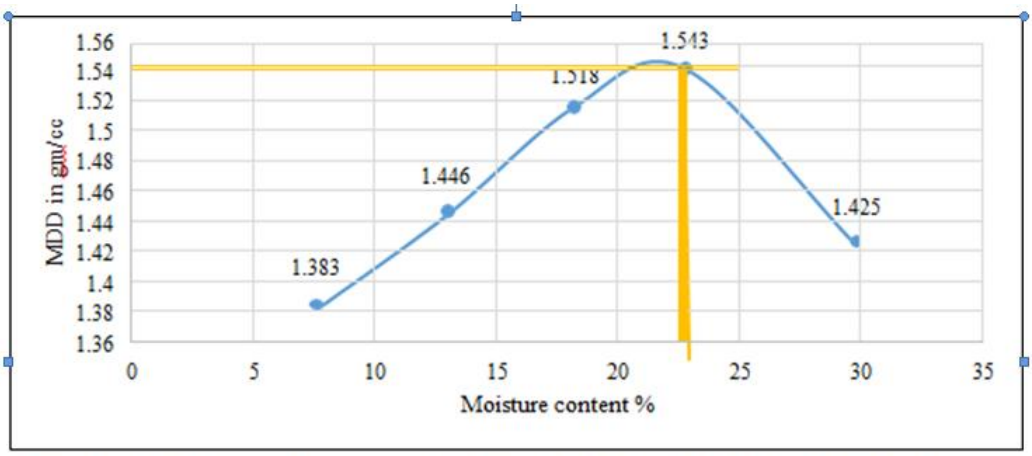
In this programme 70% black cotton soil is replace with 30% pond ash by weight of soil and effect of compaction delay was observed.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

Table 4.9: Results of MDD of 70%BCS+30%PA mixture

MDD(gm/cc)	1.383	1.446	1.518	1.543	1.425
Water content%	7.544	12.93	18.18	22.71	29.79

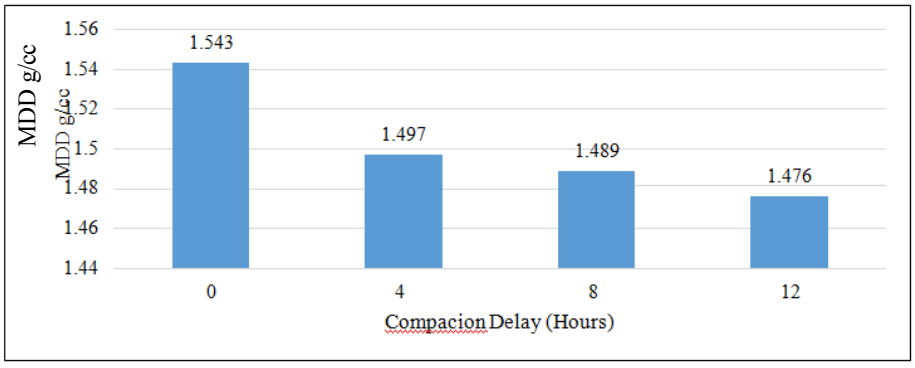
From the above Table it can be observed that Maximum Dry density decreases as compared to 90%BCS+10%PA and 80%BCS+20%PA. But there was increase in optimum moisture content of the mixture. Increases in percentage of pond ash reduce the density of the soil-pond ash mixture



Graph 4.22 Relationship between MDD and OMC for 70%BCS+30%PA mixture

Table 4.19: Results of MDD due to delay in compaction of 70%BCS+30%PA mixture

Delay in hours	0	4	8	12
MDD in gm/cc	1.543	1.497	1.489	1.476



Graph 4.11 Variation of MDD due to delay in compaction of 70%BCS+30%PA mixture

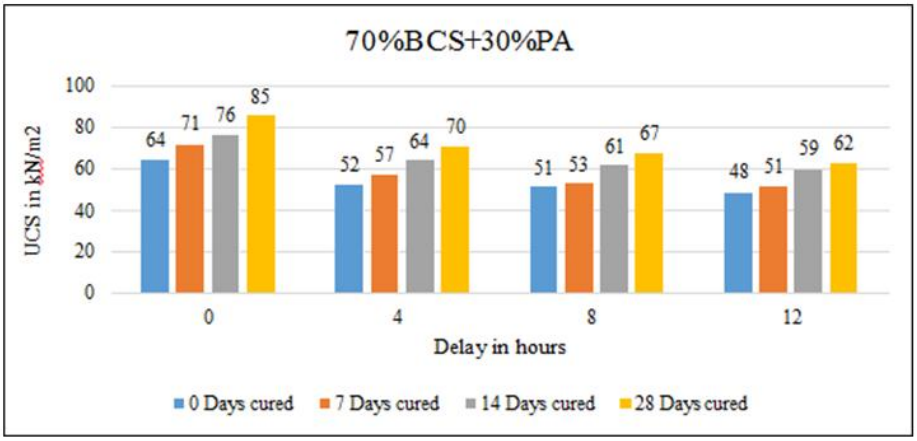
Graph 4.23 shows the variation of MDD due to delay in compaction of black cotton soil treated with 30 % of pond ash. With increase in % of pond ash there is decrease in MDD to 1.543gm/cc at no compaction delay and moisture content increase to 22.71%. With increase in % of pond ash there is reduction in cohesion of black cotton soil and due to which soil gets compacted to lower densities.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

Table 4.10: Results of UCS due to delay in compaction of 70%BCS+30%PA mixture

Days cured/Delay in hours	0	7	14	28
0	64	71	76	85
4	52	57	64	70
8	51	53	61	67
12	48	51	59	62

Graph 4.12 shows the variation of unconfined compressive strength of 70% BCS+30% PA mixture due to delay in compaction. The strength was increase by 13% with addition 30% of pond ash to Black Cotton soil. There was decrease in strength from 64kN/m ^{2} to 52kN/m^2 with compaction delay of 8 hours, with further delay in compaction there was not too much decrease in compressive strength.

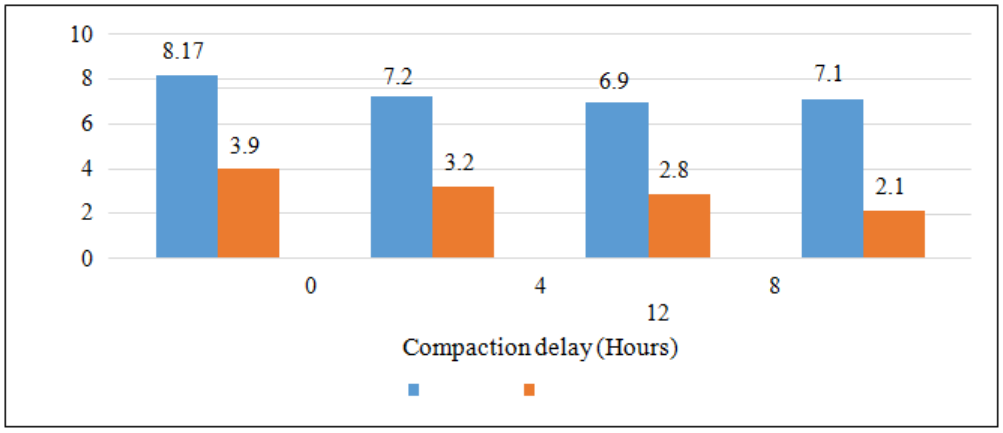


Graph 4.12 Variation of UCS due to delay in compaction of soil 70%BCS+30% PA mixture

Table 4.11: Results of CBR due to delay in compaction of 70%BCS+30%PA mixture

Delay in hours	0	4	8	12
C.B.R %(Unsoaked)	8.175	7.21	6.99	7.12
C.B.R%(Soaked)	3.98	3.21	2.86	2.15

Graph 4.13 shows the variation of CBR due to delay in compaction of soil treated with addition of 30% of pond ash in unsoaked condition. With increase in percentage of pond ash to 30% there was increase in CBR by 67% in unsoaked condition while there was an increase by 97% in soaked condition as compared to black cotton soil.



Graph 4.13 Variation of CBR due to delay in compaction of 70%BCS+30%PA

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

V. CONCLUSION

Pond ash resembles to soil in its chemical compositions as they have the same major compounds (N, P, K, S, Al) and Trace elements (Mn, Zn, Cu, B, As, Cd).It is also similar to soil in its physical composition (Gravel, Sand & Silt and clay content). So it can be used as an additive to soil in its predetermined fractions to improve engineering and index properties of soil. The values of almost all the index properties of the soil undulate on the addition of pond ash. Sometimes along with pond ash lime use as an additive to improve the properties of soil. Pond ash in the proportion of 10%, 20% and 30%

along with Lime in 3%, 5% and 8% was added to the sample of soil collected from the site near Pimpalgaon baswant (North West region of Maharashtra) and experiments were conducted on these soil composites of soil samples. Following Following Conclusions are drawn from the tests.

1. After addition of pond ash to black cotton soil specific gravity decreases due to less specific gravity of pond ash as compared to black cotton soil.
2. Dry density, CBR, UCS of black cotton soil decreases as the compaction delay increases, however moisture content increases. Peak values of MDD, CBR, and UCS of black cotton soil only were obtained at no compaction delay.
3. 20% addition of pond ash to black cotton soil gives best results of soil stabilization and also have less effect of compaction delay as compared to other proportions.
4. 3% addition of lime to 90BCS+10PA mixture attain its highest value of CBR 22.18% from 12.01% for an addition of 20% pond ash. Similarly for UCS it was 105kN/m2 from 87kN/m2 after addition of 20% pond ash.
5. Soil-pond ash-lime shows that addition lime to soil- pond mixture gives better results of stabilization and shows less effect of compaction delay.
6. 30% addition of pond ash to any mixture gives poor result and effect of compaction delay was more as compared to any other mixture.

Future Scope

1) Effect of compaction delay can be studied for cement stabilized black cotton soil.
2) Effect of compaction delay can be studied for fly ash stabilized black cotton soil.

REFERENCES

[1]. Karthik. S (2014) – " Soil stabilization by using pond ash" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p- ISSN: 2320-334X, Volume 10, Issue 6 (Jan. 2014), PP 20-26

[2]. Prof.J.M. Raut, Dr. S.P.Bajad, Dr. S.R.Khadeshwar (2014) - "Stabilization of expansive soil using pond ash and murrum" International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 7, July 2014

[3]. Ankit Singh Negi (2013) – "Soil stabilization using Lime" International Journal Of Innovative Research in Science, Engineering and Technology. Volume.2, Issue 2

[4]. Pengpeng Wu (2013) – "International journal of pavement conference", Sao Paulo, Brazil PP 227-1

[5]. Gyanen. Takhelmayum, Savita A.L. Krishna Gaudi (2013) – "Laboratory study on the soil stabilization using pond ash mixtures". ISOR journal of Mechanical and Civil engineering Volume 2, Issue 1, January 2013

[6]. Kunal Anandet (2013)- " A comparative study of black cotton soil and alluvial soilfor economical design by lime and pond ash stabilization" ISOR journal of Mechanical and Civil engineering Volume 3, Issue 6, January 2013

[7]. Bairwa Ramalakhan, Saxena Anil Kumar, Arora T.R. (2013)- "Effect of Lime and pond ash on engineering properties of black cotton soil" ISOR journal of Emerging Technology and Advanced engineering. ISSN 2250- 2459 Volume 3, Issue 11, PP 09-15.

[8]. Olugbenga oludolupo amu (2011) – "The suitability and lime stabilization requirement of some lateritic soil samples as pavement." International Journal of Pure and Applied Science and Technology. ISSN 2269-6107. PP 29-46

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

[9]. S. Bhuvaneshwari, R. G. Robinson ,S. R. Gandhi (2005)-"Stabilization of Expansive soils using pond ash" Pond Ash Utilization Programme(FAUP)

[10]. Dr. Robert M. Brooks (2009)–"Soil stabilization with pond ash and rice husk ash" International Journal of Research and Reviews in Applied Sciences, Philadelphia,Volume 1, Issue 3

[11]. S. Boobathiraja et al (2014) – "Study on Strength of Peat soil stabilized With Cement and Other Pozzolanic Maternials. International journal of Civil Engineering Research. Volume 5 Issue 4, PP431-438 February 2014

[12]. Jyoti S Trivedi (2013)- "Optimum Utilization of pond ash For stabilization of subgrade soil using genetic algoritham." Procedia Engineering, PP 250-258 (2013)

[13]. HabeebAdedjiQuadni (2013) – "Impact of compaction delay on the Engineering properties of Cement-Treated soil."

[14]. Bello AfeezAdefemi (2013) – "Regression analysis of compaction delay on CBR and UCS of Lime stabilized Yellowish Brown Lateritic soil."

[15]. Kolawole J. Osinubi (2013) – "Influence of compactive efforts and compaction delays on Lime-Treated soil."Journal of transportation engineering.124:124- 155

[16]. S. SahayaVincy and M. Muttharam (2009) – "Delayed compaction effects on the behaviour of stabilized soil." IGC 2009,Guntur

[17]. U. N. Okonkwo – "Effects of compaction delay on the properties of Cement–Boundlateritic soil."Nigerian journal of technology, Volume 28 No.2