# INFLUENCE OF DIFFERENT WASTES ON CONSOLIDATION CHARACTERISTICS OF EXPANSIVE SOILS

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**ABSTRACT**

*Expansive Soils covers 20% area of India. Black cotton soils have expansive nature. Expansive Soils swells when water is added to it and when water evaporated from it, it shrinks. This study represents consolidation parameters ($C_c$, $C_v$, $a_v$, $m_v$, change in void ratio) of Black cotton soil stabilized with three waste materials as additive: Brick Dust, Gypsum, and Fly Ash. Soil is mixed with 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5% and 20% of Brick dust, Gypsum and Fly Ash respectively. Comparison of Change in Consolidation Parameters with virgin soil and with change in percentage was shown. Samples were prepared at Optimum Moisture Content and Maximum Dry Density by standard proctor test. After that Conventional Consolidation tests were performed by applying seating load of 0.05 kg/cm$^2$ and then load increment is doubled after 24 hours up to 6.4 kg/cm$^2$. Total 25 tests were carried out. Results shown that consolidation characteristics were decreases with increasing percentage of additive.*

**Keywords: -** *Consolidation, Expansive soil, Coefficient of Volume Change, Compression Index, Coefficient of Consolidation*

## 1. INTRODUCTION

Black cotton soils are expansive in nature. When water comes into contact with expansive soil, its volume swells means volume increases and when water evaporated from expansive soil, its volume decrease and soil shrinks. Volume changes due to change in moisture content causes settlements of foundations, damage to the pavements and other problems related with civil engineering. So to counteract these problems, soil improvement also known as soil stabilization is done by mixing soil with different additives.

Soil Stabilization or Soil Improvement is a technique to improve soil properties. Soil Improvement is done by different techniques like mechanical compaction, injection of grouts, by placing geotextiles in soil layers, preloading, by sand columns and stone columns, by using different admixtures etc. Depending upon the site conditions and other factors influencing, that type of technique is generally chosen. Soil stabilization is generally done with additives like Bitumen, lime, cement, fly ash, etc.

In this study, waste materials used are brick dust, gypsum and fly ash. Brick is generally important material in construction projects. Brick waste is generally thrown away from site after completion of construction projects.

Gypsum is material widely used in marble industries. Wastage from those industries is used as additive for this study.

Fly ash is generally material which is comes out of power generation projects like electricity generation plant which uses coal as main material for power generation.

Many research works has been carried out for fly ash as admixture with different soils for soil improvement. Other studies have focussed on fibres or other additives to improve geo technical properties of soil whereas consolidation characteristics of Clays and Expansive soils with different additive have been limited.

## 2. MATERIAL

For this study, Bricks were collected from construction site, where utilization of bricks was completed. Those half broken bricks were broken and crushed it to make a powder form. For Brick to make it in powder form, after crushing bricks it was sieved through IS 0.425 mm sieve. Particles that passed through IS 0.425 mm sieve are collected as brick dust or brick powder. Brick dust is shown in fig.1

**Fig. 1** Brick dust passing through IS 425 mm Sieve

Gypsum was collected from commercially available shop and it was in the powder form so there was no need to make it in powdered form. Gypsum was also passed through IS 425 mm sieve.

Fly Ash was collected from Sabarmati power station, Ahmedabad. Fly Ash generally is available in Class F and Class C. But for this study, Class F Fly Ash was used.

Expansive soil is collected from Dholera, Gujarat and soil was procured from 1 to 1.5 feet depth. The Index properties and Engineering Properties are shown in table 1.

**Table 1** Index Properties and Engineering Properties of virgin soil

| Test/ Parameter | IS Code referred | Result Value | Symbol |
|---|---|---|---|
| Liquid Limit | IS: 2720-part-5 | 47% | L.L. |
| Plastic Limit | IS: 2720-part-5 | 20.48% | P.L. |
| Shrinkage Limit | IS: 2720-part-6 | 17.82% | S.L. |
| Specific Gravity | IS: 2720-part-3 | 2.67 | G |
| Plasticity Index | IS: 2720-part-5 | 26.52% | P.I. |
| Free swell Index | IS: 2720-part-40 | 60% | F.S.I. |
| Optimum Moisture Content | IS: 2720-part-7 | 16% | O.M.C. |

| | | | |
|---|---|---|---|
| Maximum Dry Density | IS: 2720-part-7 | 17.9% | M.D.D. |
| Soil Classification | Indian Standard Classification system | Clay with High Plasticity | CH |

## 3. SAMPLE PREPARATION

### 3.1 Composition of Material

Samples of virgin soil and soil mixed with 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, and 20% by weight of waste material (brick dust, Gypsum, and Fly ash) passing IS 0.425 mm sieve were prepared at Optimum Moisture Content and Maximum Dry Density as per IS: 2720 (part 7). Oven Dry soil was dry mixed with different percentage of additives.

### 3.2 Compaction

On the field, to find amount of compaction and to find water content required, Compaction tests are performed in laboratory. IS: 2720 (part VII) recommends the mould of 100 mm diameter, 127.3 mm height. The rammer recommended is of 2.6 kg mass with free drop from 310 mm height. The soil is compacted in three layers. 25 blows are applied to compact each layer. The collar is of 60 mm height. For modified Proctor test, soil is compacted in five consecutive layers.

Approximately 2.5 to 3 kg of oven dried soil, passing through 4.75 mm sieve is taken. Test was started from 10% water. For virgin soil no additive was added but as additive was added, the percentage of additive was considered as reference of dry weight of soil. The additive was fine powder so it was passing through 425 micron sieve. Mass of empty mould with base plate was taken. The soil was compacted by 25 blows of rammer, with free fall of 310 mm height. The soil surface was scratched with spatula before second layer placed. The mould was filled to about two-third height with the soil and compacted again by 25 blows. Same way, third layer was placed and compacted. After that collar was removed and soil was trimmed off. The bulk density was determined from mass of compacted soil and volume of mould. To find water content, that sample was taken from bottom or middle of mould and placed in oven for 24 hours at $105^0$-110 temperature and after that its dry weight is found and water content was determined. To find dry density, value of bulk density and value of water content was taken. Equation 3.1 below gives the relation between bulk density and mass of soil.

Bulk mass density, $\rho = M/V$ ------ (3.1)

Where M= mass of soil and V= volume of mould

Equation 3.2 gives the relation between dry density and water content

Dry Density, $\rho_d = \frac{\rho}{1+w}$ --------- (3.2)

Where $\rho$ = bulk density found from above equation and w = water content.

## 4. RESULTS AND DISCUSSIONS

### 4.1. Standard Proctor Test:

Standard Proctor Test was done to find Optimum Moisture Content and Maximum Dry Density. O.M.C. and M.D.D. was also found for Brick Dust, Gypsum and Fly Ash by varying percentage from 2.5% to 20%. Values of Optimum Moisture Content and Maximum Dry Density are shown in table 2. Values shows that for virgin soil, O.M.C. was found to be 16% and M.D.D. 1.8 gm. /cc. Values for Brick dust shown that, first value of M.D.D. increases up to 10% of additive, after that value decreases for 12.5% and 15%, and after that values increases for remaining percentages. So from this it can be concluded that optimum percentage of brick dust was 10% for this black cotton soil. Same optimum percentage for Gypsum and Fly ash was 10% and 12.5% respectively.

**Table 2** Standard proctor values for different percentage of additives

| Standard Proctor Test | Optimum Moisture Content (%) | Maximum Dry Density (gm./cc) |
|---|---|---|
| 1. Virgin Soil | 16.00 | 1.800 |
| 2. Soil + 2.5% Brick dust | 15.90 | 1.664 |
| 3. Soil + 5% Brick Dust | 17.64 | 1.647 |
| 4. Soil + 7.5% Brick Dust | 19.04 | 1.768 |
| 5. Soil + 10% Brick Dust | 20.93 | 1.782 |
| 6. Soil + 12.5% Brick Dust | 21.95 | 1.639 |
| 7. Soil + 15% Brick Dust | 24.39 | 1.586 |
| 8. Soil + 17.5% Brick Dust | 26.19 | 1.644 |
| 9. Soil + 20% Brick Dust | 27.50 | 1.656 |
| 10. Soil + 2.5% Gypsum | 17.77 | 1.647 |
| 11. Soil + 5% Gypsum | 19.04 | 1.641 |
| 12. Soil + 7.5% Gypsum | 21.42 | 1.605 |
| 13. Soil + 10% Gypsum | 23.80 | 1.620 |
| 14. Soil + 12.5% Gypsum | 24.39 | 1.638 |
| 15. Soil + 15% Gypsum | 26.82 | 1.630 |
| 16. Soil + 17.5% Gypsum | 28.20 | 1.646 |
| 17. Soil + 20% Gypsum | 30.76 | 1.620 |
| 18. Soil + 2.5% Fly Ash | 16.27 | 1.542 |
| 19. Soil + 5% Fly Ash | 19.04 | 1.613 |
| 20. Soil + 7.5% Fly Ash | 20.93 | 1.704 |
| 21. Soil + 10% Fly Ash | 21.42 | 1.696 |
| 22. Soil + 12.5% Fly Ash | 23.80 | 1.703 |
| 23. Soil + 15% Fly Ash | 25 | 1.696 |
| 24. Soil + 17.5% Fly Ash | 27.5 | 1.707 |
| 25. Soil + 20% Fly Ash | 28.20 | 1.694 |

**4.2. Change in Void ratio:**

Change in Void ratio for different percentages is shown as below in table 3. As from the table 3, value of change in void ratio for virgin soil was found to be decreasing from 0.750 to 0.573. Value of void ratio was found from the graph which is plotted between void ratios versus log σ. As effective pressure was increased change in void ratio decreases. For Brick dust maximum void ratio changes from 0.9040 to 0.6605 which was found for 7.5% of Brick dust and the difference was approximately 0.24%. For Gypsum, Value decreases from 0.9092 to 0.6264 for 12.5% of Gypsum and the difference was 0.28% approximately. For Fly Ash, value decreases from 0.9103 to 0.6477 for 10% of Fly Ash and the difference was found to be 0.27% approximately. On the basis of these values we can say that Change in void ratio for gypsum found to be more than Brick dust and Fly ash.

**Table 3** Change in void ratio for different percentage of additive

| Test | Initial Void Ratio | Final Void Ratio |
|---|---|---|
| Virgin Soil | 0.750 | 0.573 |
| Soil+ 2.5% Brick Dust | 0.8599 | 0.7536 |
| Soil + 5% Brick Dust | 0.9354 | 0.6951 |
| Soil + 7.5% Brick Dust | 0.9040 | 0.6605 |
| Soil + 10% Brick Dust | 0.8364 | 0.6213 |
| Soil + 12.5% Brick Dust | 0.7977 | 0.6034 |
| Soil + 15% Brick Dust | 0.7517 | 0.5750 |
| Soil + 2.5% Gypsum | 0.9616 | 0.8292 |
| Soil + 5% Gypsum | 0.8927 | 0.7313 |
| Soil + 7.5% Gypsum | 0.8834 | 0.6810 |
| Soil + 10% Gypsum | 0.9390 | 0.6400 |
| Soil + 12.5% Gypsum | 0.9092 | 0.6264 |
| Soil + 15% Gypsum | 0.8368 | 0.5858 |
| Soil + 2.5% Fly Ash | 0.9436 | 0.7601 |
| Soil + 5% Fly Ash | 0.8579 | 0.6719 |
| Soil + 7.5% Fly Ash | 0.9014 | 0.6706 |
| Soil + 10% Fly Ash | 0.9103 | 0.6477 |
| Soil + 12.5% Fly Ash | 0.8641 | 0.6560 |
| Soil + 15% Fly Ash | 0.8232 | 0.6375 |

**4.3. Compression Index:**

For Brick dust, compression index decreases from 0.2087 to 0.1227. it is shown in fig.2

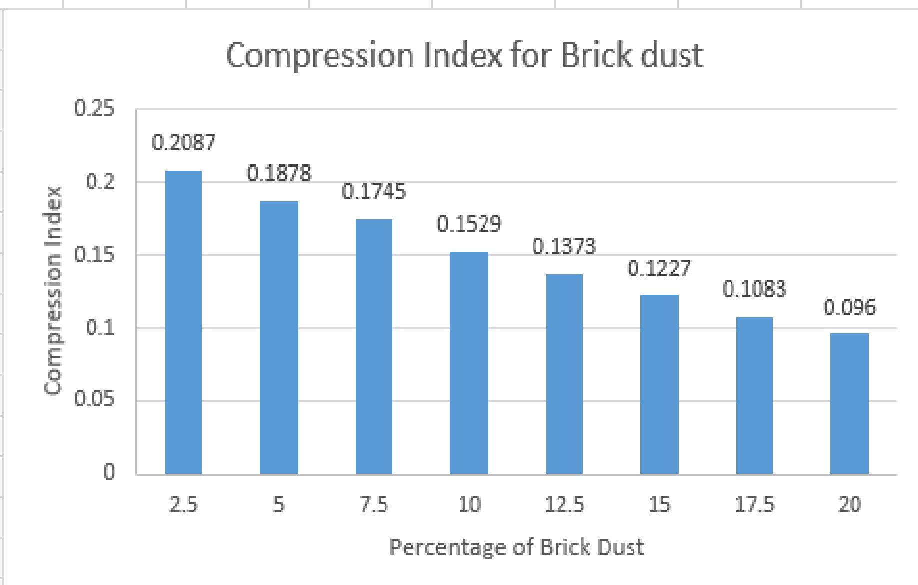


**Fig. 2** Compression Index for Brick dust

For Gypsum, Compression Index values are shown in figure 3. Values of Compression Index were decreases for Gypsum from 0.1814 to 0.1083. Compression Index was calculated from the graph of void ratio versus effective stress.

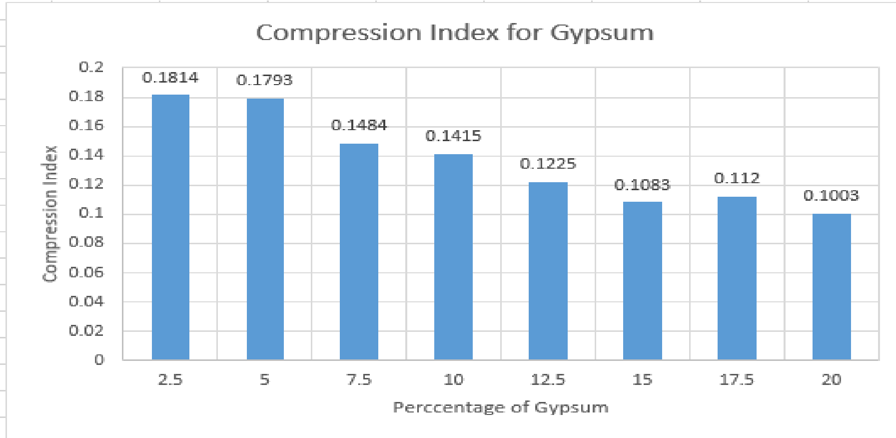


**Fig. 3** Compression Index for Gypsum

Value for Compression Index was decreased from 0.2148 to 0.1208. It is shown in figure 4.

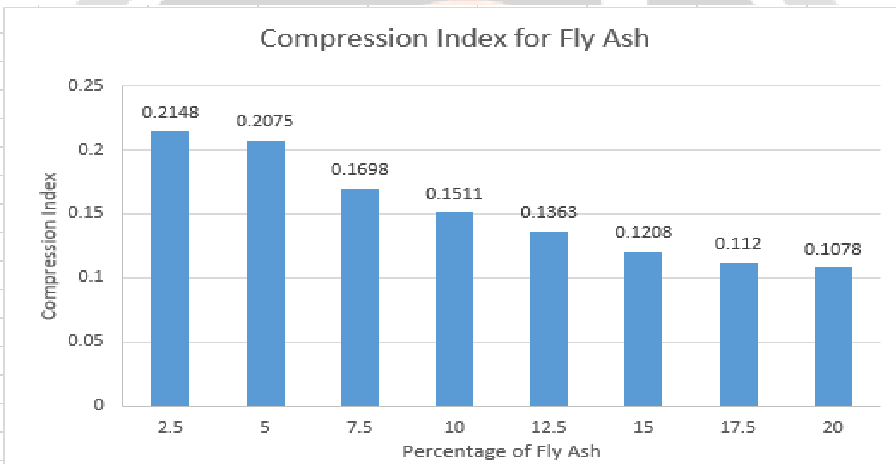


**Fig. 4** Compression Index for Fly Ash

**4.4. Coefficient of volume change:**

Coefficient of volume change for Brick dust decreases from 0.015cm$^2$/kg to 0.0108cm$^2$/kg. It is shown in figure 5.

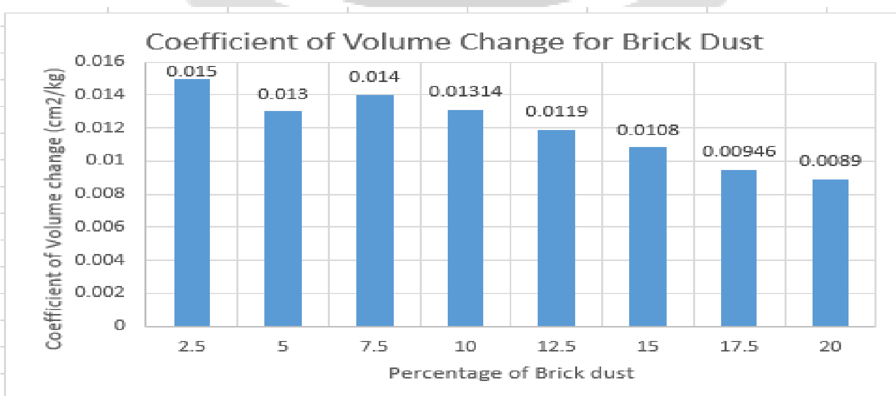


**Fig. 5** Coefficient of Volume Change for Brick dust

Co-efficient of Volume Change for Gypsum decreases from 0.015cm$^2$/kg to 0.0113cm$^2$/kg. It is shown in figure 6.

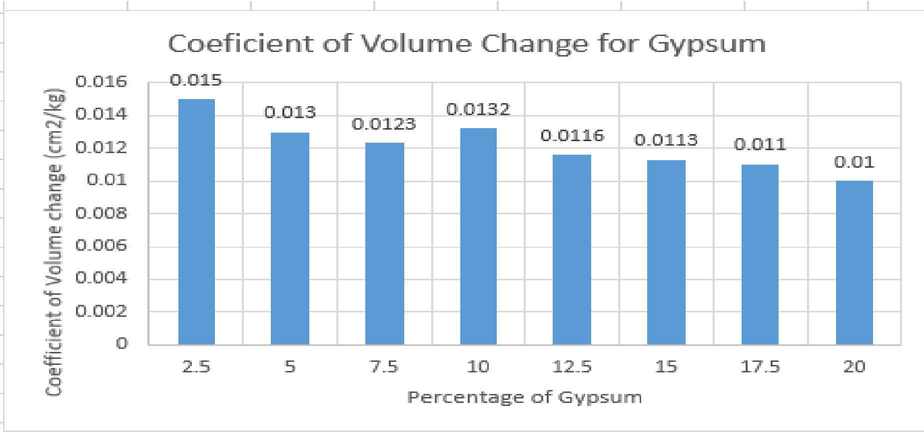


**Fig. 6** Coefficient of Volume Change for Gypsum

Co-efficient of Volume Change for Fly ash decreases from 0.019cm$^2$/kg to 0.010cm$^2$/kg. It is shown in figure 7.

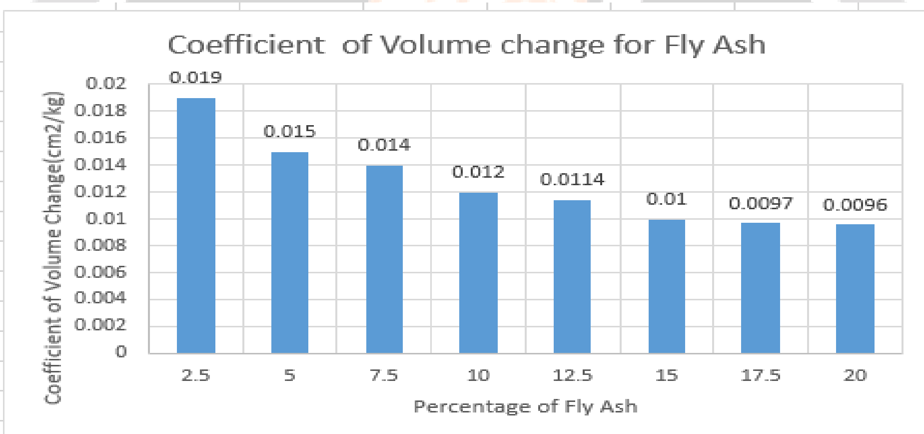


**Fig. 7** Coefficient of volume change for Fly Ash

**4.5. Coefficient of Compressibility:**

Coefficient of Compressibility for Brick dust was decreases from 0.0278 cm$^2$/kg to 0.017 cm$^2$/kg. It is shown in figure 8.

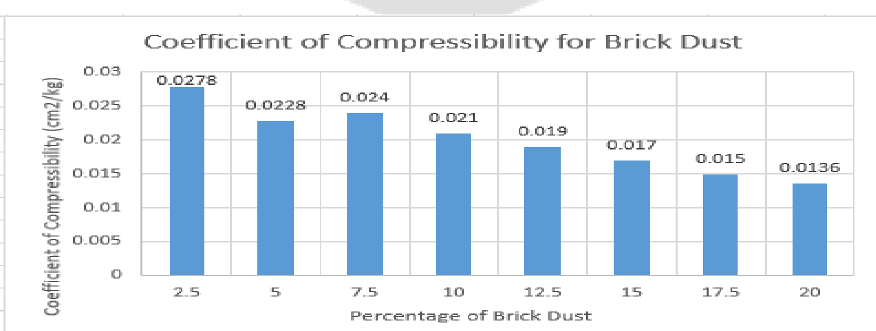


**Fig. 8** Coefficient of Compressibility for Brick dust

Coefficient of Compressibility for Gypsum decreases from 0.028 $cm^2/kg$ to 0.018 $cm^2/kg$. It is shown in figure 9 and for Fly ash it is shown in figure 10.

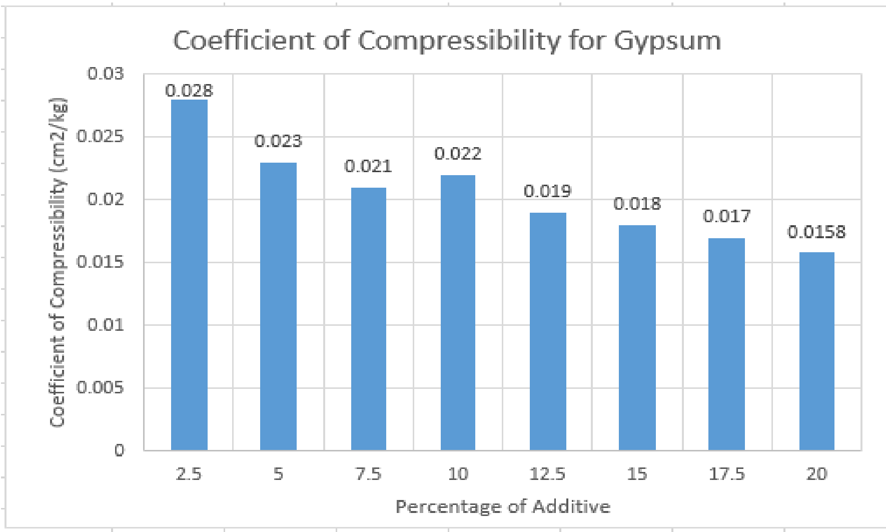


**Fig. 9** Coefficient of Compressibility for Gypsum

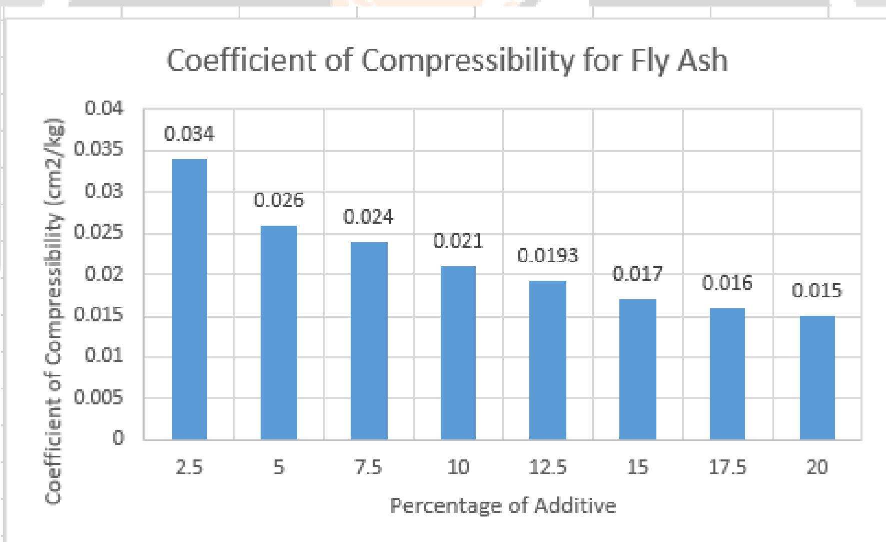


**Fig. 10** Coefficient of Compressibility for Fly Ash

**4.6. Coefficient of Consolidation:**

Coefficient of consolidation values were shown in table 4. As table shows for virgin soil value was found to be $10.85\times10^{-3}$ $cm^2/min$ and it was decreases for all three additives. However values were not drastically decreases for all three additives.

**Table 4** Coefficient of consolidation

| Test | Coefficient of Consolidation ($cm^2$/min.) |
|---|---|
| 1. Virgin soil | $10.85 \times 10^{-3}$ |
| 2. Soil+ 2.5% of Brick dust | $10.7 \times 10^{-3}$ |
| 3. Soil+ 5% of Brick dust | $5.4 \times 10^{-3}$ |
| 4. Soil+ 7.5% of Brick dust | $6.31 \times 10^{-3}$ |
| 5. Soil+ 10% of Brick dust | $6.92 \times 10^{-3}$ |
| 6. Soil+ 12.5% of Brick dust | $6.76 \times 10^{-3}$ |
| 7. Soil+ 15% of Brick dust | $3.98 \times 10^{-3}$ |
| 8. Soil+ 2.5% of Gypsum | $3.98 \times 10^{-3}$ |
| 9. Soil+ 5% of Gypsum | $9.71 \times 10^{-3}$ |
| 10. Soil+ 7.5% of Gypsum | $5.17 \times 10^{-3}$ |
| 11. Soil+ 10% of Gypsum | $6.68 \times 10^{-3}$ |
| 12. Soil+ 12.5% of Gypsum | $8.25 \times 10^{-3}$ |
| 13. Soil+ 15% of Gypsum | $6.45 \times 10^{-3}$ |
| 14. Soil+ 2.5% of Fly ash | $5.25 \times 10^{-3}$ |
| 15. Soil+ 5% of Fly ash | $3.85 \times 10^{-3}$ |
| 16. Soil+ 7.5% of Fly ash | $6.55 \times 10^{-3}$ |
| 17. Soil+ 10% of Fly ash | $9.92 \times 10^{-3}$ |
| 18. Soil+ 12.5% of Fly ash | $5.79 \times 10^{-3}$ |
| 19. Soil+ 15% of Fly ash | $4.45 \times 10^{-3}$ |

## 5. CONCLUSIONS

1. From standard proctor test on soil with different wastes increases O.M.C. for all three wastes, but among these three wastes, values of O.M.C. were higher for Gypsum.
2. Compression Index decreases for all three additives, but for fly ash compression index decreases more as compared to other two waste materials. Which shows that fly ash improves consolidation as compared with other additives.
3. Coefficient of Compressibility decreases with increase in percentage of all three additives. But for fly ash values are decreases more as compared to other two additives.

## 6. REFERENCES


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