Improvement in engineering properties of clay soil using waste demolished material

Gaurav Jain¹*, Prem Prakash Pandit² and Manoj Narwariya²

¹Department of Civil Engineering, IPS College of Technology & Management Gwalior, India
²Department of Mechanical Engineering, IPS College of Technology & Management Gwalior, India

E-mail: jaingaurav700@gmail.com

Abstract. Expansive soil contain the highly active clay mineral in the form of montmorillonite due to which expensive soil swell upto 7% upon adding 1% of water, which may lead to unequal settlement of subsoil. The primary characterisation of clayey soil is which possess very poor shear strength with high shrinkage & swelling. This research paper represent a complete framework to overcome this drawback of highly expansive soil by adding waste material like fly ash and brick waste to clay soil in order to improve it’s engineering properties. Fly ash can be easily obtained from coal combustion plants while brick waste is easily available at demolition area. In this research fly ash is added in different percentages 0%, 4%, 8%, 12%, 16% and brick waste is added 5%, 10%, 15%, 20%, 25% by weight of soil. The results of test shown that the addition of fly ash and brick waste reduces the liquid limit, plastic limit value, plasticity index value, optimum moisture content value, percentage free swell index value and increases the unconfined compressive strength value and California bearing ratio value.

Keywords: Fly ash (FA), brick waste (BW), Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI) California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS).

1. Introduction

The present study of characterization and stabilization of clay soil with the help of fly ash & brick waste uses clay soil [1]. Which is disposed off or dumped off in low laying area. Brick waste obtained as construction waste from brick manufacturing plant footi colony hurawali Gwalior, Madhya Pradesh. There are several material for improvement of engineering properties of clay soil like cement, sand, chemical, lime, bitumen etc. [2]. Which have shown great results in stabilization of clay soil. But these are costly in environment and limited resources. So we have an option for other material like construction waste material, industrial waste, demolished waste and other wastage [3]. These materials are available in huge amount and free of cost for stabilization purpose only transportation cost will be added [4]. Fly ash increasing the geotechnical properties of soil and brick waste increases the strength properties. In the present study, an attempt has been made to combine both materials to improve geotechnical properties as well as to increase the strength of clay soil [5][6]. Waste can be used to modify the engineering properties of expansive soil and thus economizing the construction of building structure, highways, air fields & other engineering Structures [7].
2. Literature Review

Nikhil Tiwari, Sumit Shringi, Neha Chaudhary et. al. (2018): This study tells about the utilization of brick dust & lime in the stabilization of the black cotton soil. It was concluded that the addition of 25% brick dust & 6% lime increases the UCS value. The CBR value increases upto 1000% with the use of lime and brick dust. It has been seen that differential free swelling limit and liquid limit decreases by adding lime and burnt brick dust up to 25% & 6% respectively. According to this above work the volume change in soil will be decreased.

Vakkapatla Laxmi Durga, DR. D.S.V. Prasad et. al. (2017): The brick dust waste and lime for stabilization of black cotton soil are utilized in this research work. Firstly, different % of brick dust waste with black cotton soil were mixed then different % of lime with black cotton soil were mixed. And finally the best combination of soil + lime + brick dust waste were used. The result of this experimental is lime and brick dust improving the strength of soil and reduces the water content.

Hairulla and Philipus Betaubun et. al. (2016): Brick waste is mixed to find out the UCS to stabilization of soft soil. Different percentages of brick waste like as 0%, 10%, 20%, 30% and 40% in were mixed in the soft soil and the UCS values at 3-days, 7-days, 14-days and 28-days curing period were calculated. Finally they obtained that 20% of brick waste can increase the strength of the soil.

C.Rajakumar, T.Meenaambal et. al. (2015): In this study the utilization of coal ash in the stabilization of the expansive soil is carried out. In this research work coal ash is used as an admixture. Experiments were carried out with 10%, 20%, 30%, 40%, 50% and 60% of coal ash content. On the basis of past research and experiment basis it is concluded that the properties of expansive soil effectively improved of geotechnical properties by use of different percentage of coal ash contents. It was concluded that the addition of 40% flyash or coal ash increase the UCS strength from 84.60 kn/m² to 290.748 kn/m². CBR value was reported to be increased by 6.693% to 10.193% in addition of 30% of fly ash or coal ash. Liquid limit value and plasticity index value decreases with increases the coal ash or fly ash. The results is shows that the 30% coal ash or fly ash is useful for geotechnical applications.

Brajesh Mishra et. al. (2015): In this study different percentage of lime (3% & 5%) was utilized to stabilize the clayey soil. Maximum dry density was expanded relatively by 6.29% and 5.59% at 3% and 5% lime respectively. 3% of lime reduces the liquid limit value by 2.70% while with 5% addition of lime shown a decrease 15.27%. Reduction in optimum moisture content of 3.4% and 10.7% at 3% and at 5% lime individually. The C.B.R. value of clayey soil increasing and the swelling pressure is decreasing.

3. Material and Methodology

The object of this experimental program is to observe the enhancement in the properties of clay soil with the addition of the fly ash and brick waste individually as well as together. In this paper the basic tests carried out on the materials used for this stabilization of expansive soil. Which is followed by the brief description about the preparation of the samples and test procedure for determining the engineering properties of the expansive soil with and without the fly ash and brick waste and both together. In the end of various test conducted on the soil are discussed below.
3.1 Clay Soil

The soil for this research was collected from Dabra, Gwalior (M.P.). Clay are soil which expands directly propositional to moisture content due to presence of montmorillonite, can also be known as expansive soil or black cotton soil. It is produce by chemical decomposition of basalt and trap. In this type of soil swelling and shrinkage is often occurred. In some part of the soil excepting rest formed active and passive zone. This is highly unacceptable for pavement construction work.

| Sr. No | Test Results |
|--------|--------------|
| 1      | Grain Size   |
| Sand Particles [%] | 0% |
| Silt Particles [%] | 9% |
| Clay Particles [%] | 91% |
| 2      | Liquid Limit Value [%] | 56.28% |
| 3      | Plastic Limit Value [%] | 28% |
| 4      | Plasticity Index Value [%] | 28.28% |
| 5      | Specific Gravity Value | 2.28 |
| 6      | Optimum Moisture Content Value [%] | 17% |
| 7      | Maximum Dry Density Value [gm/cm³] | 1.62 gm/cm³ |
| 8      | Differential Free Swell Value [%] | 45% |
| 9      | California Bearing Ratio value (CBR) [%] | 0.801% |
| 10     | Unconfined Compressive Strength Value [UCS] [kn/m²] | 70.78 kn/m² |

3.2 Fly Ash

Fly ash generates in combustion process of coal and it is composed of particulates (particle of burned fuels). It is also known as fuel ash. It can be used as a soil stabilization and soil solidification material. Because of its pozzolanic properties, it can be used as Portland cement partner in concrete and soil solidification.

| Sr. No | Chemical Composition | Percentage |
|--------|----------------------|------------|
| 1      | Sio₂                 | 60.20%     |
| 2      | Al₂O₃                | 18.45%     |
| 3      | Fe₂O₃                | 16.34%     |
| 4      | Sio₂ + Al₂O₃ + Fe₂O₃ | 94.99%     |
| 5      | Mgo                  | 1.32%      |
| 6      | Cao                  | 2.00%      |
| 7      | So₃                  | 1.50%      |
| 8      | Na₂O                 | 1.50%      |
| 9      | Soluble Salts        | 0.58%      |
| 10     | Loss of Ignition     | 1.07%      |
3.3 **Brick Waste**

Brick waste one of the construction waste produce by demolition and remodelling of construction project. It’s cost is negligible in ahead of soil and it has better engineering properties then clay soil. So, it can be used as supplement material to improve properties of clay soil as shown in this research.

3.4 **Testing Methodology**

Lab tests were done on clay soil blended in with Fly Ash at different % for example [4%, 8%, 12%, 16%] by weight of dry soil. The following tests were performed on soil with Demolished Waste according to important IS Code.

4. **Results and Declaration**

In this research work experiments are performed to determinethe mechanical and physical properties of soil. According to (ISCS), the sample soil is classified as highly compressible clay (CH). Firstly fly ash was mixed with clay soil in different proportion as shown in table: 3. which results that, the proportion of (soil + 8% fly ash) was found best soil-fly ash proportion on the basis of tests performed. Then this proportion (soil + 8% fly ash) was mixed with brick waste in different-different proportion to found best combination of soil, fly ash and brick waste. Results show that soil + 8% fly ash + 15% brick waste is best proportion.

|Sr. No.| Particulars of Test| Soil| Soil +4% (FA)| Soil+8% (FA)| Soil+12% (FA)| Soil+16% (FA) |
|-------|-------------------|-----|--------------|------------|--------------|--------------|
|1| Soil Classification| CH | 56.28 | 52.67 | 49.52 | 50.88 | 52.45 |
|2| Liquid Limit (%)| 28 | 27 | 25.5 | 26.5 | 27.5 |
|3| Plasticity Index (%)| 28.28 | 25.67 | 24.02 | 24.38 | 24.95 |
|4| Specific Gravity| 2.69 | 2.67 | 2.65 | 2.63 | 2.61 |
|5| Optimum Moisture Content (%)| 17 | 20 | 16 | 19 | 19.75 |
|6| Maximum Dry Density (gm/cm³)| 1.62 | 1.40 | 1.506 | 1.542 | 1.508 |
|7| Differential Free Swell (%)| 48 | 41.18 | 38.10 | 27.27 | 22.73 |

4.1 **Primary Discussion on Soil and Fly Ash Mix Results**

The variation of LL, PL and PI of the mixes which the different % of fly ash added to the clay soil. it is observed that the LL & PL of the soil fly ash mix decreases first. When 4% fly ash added then % of decreases in LL is 6.41% and % of decreases in PL is 3.57%. When 8% addition of fly ash the LL decrease is 12.02% and PL decrease is 8.76%. Beyond 8% addition of fly ash the LL and PL began to increases. Increment in LL are 9.46% , 6.82% ,4.61% & increment in PL are 5.6% ,0.35% ,1.38% respectively by addition of 12%,16% & 20% fly ash in the soil.

Finally, it is concluded that 8% addition of fly ash to soil LL decreases by 12.02% and PL decreases by 8.76%. our aim is reduces to liquid limit & plastic limit. On the basis of Atterberg Limits 8% addition of fly ash to the soil is best combination.
### Table 4. Free Swell Index Results

| Sr. No. | Soil Mix Proportion                        | Soil volume in distilled water (ml) | Soil volume in kerosene (ml) | Differential Free swell Value (%) |
|---------|--------------------------------------------|-------------------------------------|-------------------------------|----------------------------------|
| 1       | Natural Soil                               | 14.8                                | 10                            | 48                               |
| 2       | Soil + 4% Fly Ash                          | 14.4                                | 10.2                          | 41.18                            |
| 3       | Soil + 8% Fly Ash                          | 14.5                                | 10.5                          | 38.10                            |
| 4       | Soil + 12% Fly Ash                         | 14                                  | 11                            | 27.27                            |
| 5       | Soil + 16% Fly Ash                         | 13.5                                | 11                            | 22.73                            |
| 6       | Soil + 20% Fly Ash                         | 13.5                                | 11.5                          | 17.39                            |
| 7       | Soil + 8% Fly Ash + 5% Brick Waste         | 12.5                                | 11                            | 13.64                            |
| 8       | Soil + 8% Fly Ash + 10% Brick Waste        | 12                                  | 11                            | 9.09                             |
| 9       | Soil + 8% Fly Ash + 15% Brick Waste        | 11.7                                | 11.2                          | 4.46                             |
| 10      | Soil + 8% Fly Ash + 20% Brick Waste        | 11.9                                | 11.6                          | 2.59                             |
| 11      | Soil + 8% Fly Ash + 25% Brick Waste        | 12                                  | 11.8                          | 1.69                             |

### Table 5. Liquid Limit Samples and Results

| Sr. No. | Liquid Limit Sample                        | Test Results (%) |
|---------|--------------------------------------------|------------------|
| 1       | Soil                                       | 56.28            |
| 2       | Soil + 8%FA + 5%BW                        | 51.48            |
| 3       | Soil + 8%FA + 10%BW                       | 45.65            |
| 4       | Soil + 8%FA + 15%BW                       | 43.43            |
| 5       | Soil + 8%FA + 20%BW                       | 47.85            |
| 6       | Soil + 8%FA + 25%BW                       | 49.90            |

### Table 6. Plastic Limit Samples and Results

| Sr. No. | Plastic Limit Sample                        | Test Results (%) |
|---------|--------------------------------------------|------------------|
| 1       | Soil                                       | 28.09            |
| 2       | Soil + 8%FA + 5%BW                        | 26.20            |
| 3       | Soil + 8%FA + 10%BW                       | 25.25            |
| 4       | Soil + 8%FA + 15%BW                       | 24.05            |
| 5       | Soil + 8%FA + 20%BW                       | 24.31            |
| 6       | Soil + 8%FA + 25%BW                       | 24.74            |

### Table 7. Plasticity Index Samples and Results

| Sr. No. | Soil Sample                             | Plasticity Index (%) |
|---------|----------------------------------------|----------------------|
| 1       | Natural Soil                            | 28.19                |
| 2       | Soil + 8% Fly Ash + 5% Brick Waste     | 25.28                |
| 3       | Soil + 8% Fly Ash + 10% Brick Waste    | 20.4                 |
| 4       | Soil + 8% Fly Ash + 15% Brick Waste    | 19.38                |
| 5       | Soil + 8% Fly Ash + 20% Brick Waste    | 23.54                |
| 6       | Soil + 8% Fly Ash + 25% Brick Waste    | 25.16                |
Table: 8. Specific Gravity Sample and Results

| Sr. No. | Soil sample                                      | Specific Gravity Avg. of two sample |
|---------|--------------------------------------------------|-------------------------------------|
| 1       | Natural Soil                                     | 2.60                                |
| 2       | Soil + 8% Fly Ash + 5% Brick Waste               | 2.67                                |
| 3       | Soil + 8% Fly Ash + 10% Brick Waste              | 2.69                                |
| 4       | Soil + 8% Fly Ash + 15% Brick Waste              | 2.71                                |
| 5       | Soil + 8% Fly Ash + 20% Brick Waste              | 2.78                                |
| 6       | Soil + 8% Fly Ash + 25% Brick Waste              | 2.80                                |

Table: 9. OMC & MDD results of soil Mixed with different percentage of Fly Ash and Brick Waste

| Sr. No. | Description of Mix                  | (OMC) % | (MDD) gm/cc |
|---------|-------------------------------------|---------|-------------|
| 1       | Natural Soil                        | 17      | 1.62        |
| 2       | Soil + 4% Fly Ash                   | 20      | 1.40        |
| 3       | Soil + 8% Fly Ash                   | 16      | 1.506       |
| 4       | Soil + 12% Fly Ash                  | 19      | 1.542       |
| 5       | Soil + 16% Fly Ash                  | 19.75   | 1.508       |
| 6       | Soil + 20% Fly Ash                  | 20      | 1.50        |
| 7       | Soil + 8% Fly Ash + 5% Brick Waste  | 17      | 1.62        |
| 8       | Soil + 8% Fly Ash + 10% Brick Waste | 16.5    | 1.63        |
| 9       | Soil + 8% Fly Ash + 15% Brick Waste | 16      | 1.66        |
| 10      | Soil + 8% Fly Ash + 20% Brick Waste | 18      | 1.59        |
| 11      | Soil + 8% Fly Ash + 25% Brick Waste | 18.5    | 1.55        |

Table: 10. CBR results of soil Mixed with different percentage of Fly Ash and Brick Waste

| Sr. No. | CBR Sample                                      | CBR % at 2.5 mm penetration | CBR % at 5.0 mm penetration |
|---------|-------------------------------------------------|----------------------------|----------------------------|
| 1       | Soil                                            | 0.81                       | 0.67                       |
| 2       | Soil + 8%FA + 5%BW                              | 4.67                       | 4.31                       |
| 3       | Soil + 8%FA + 10%BW                             | 8.75                       | 8.42                       |
| 4       | Soil + 8%FA + 15%BW                             | 12.07                      | 12.76                      |
| 5       | Soil + 8%FA + 20%BW                             | 11.01                      | 11.54                      |
| 6       | Soil + 8%FA + 25%BW                             | 10.41                      | 10.94                      |

Table: 11. UCS results of soil Mixed with 8% of Fly Ash & Different Percentage of Brick Waste

| Sr. No. | Description of Mix | (UCS) Value (kn/m²) |
|---------|--------------------|---------------------|
| 1       | Natural Soil       | 70.78               |
| 2       | Soil + 8% FA + 5% BW | 76.03               |
| 3       | Soil + 8% FA + 10% BW | 83.11               |
| 4       | Soil + 8% FA + 15% BW | 90.14               |
| 5       | Soil + 8% FA + 20% BW | 99                  |
| 6       | Soil + 8% FA + 25% BW | 111                 |
Figure 1. Graphical representation of stress-strain curve for unconfined compressive strength

Figure 2. Shown Preparation of mould in CSIR-CBRI

Figure 3. Shown UCS machine in CSIR-CBRI

Figure 4. Shown Place sample in UCS machine in CSIR-CBRI

Figure 5. Shown Failure of sample in CSIR-CBRI
5. Conclusion
From this study following significant observation have been made. The effect of addition of fly ash and brick waste to soil

- According to above results the combination of 8% fly ash reduce the liquid limit, plastic limit and plasticity index of clay soil.
- Optimum moisture content decreased from 17% to 16% at 8% replacement of fly ash with soil. A slight increase is noted in maximum dry density and high amount of decrement in differential free swell is observed.
- According to above result the 8% fly ash is found the best combination for mixed it with brick waste.
- Liquid limit decreased from 56.28% to 43.43% at combination of 8% replacement of fly ash and 15% replacement of brick waste with soil.
- Plastic limit decreased from 28.09% to 24.05% at combination of 8% replacement of fly ash and 15% replacement of brick waste with soil.
- Plasticity index value decreased from 28.19% to 19.38% at combination of 8% replacement of fly ash and 15% replacement of brick waste with soil.
- CBR value is increased from 0.81 to 12.07 at combination of 8% replacement of fly ash and 15% replacement of brick waste with soil.
- UCS value is increased from 70.78 kn/m² to 90.14 kn/m² at combination of 8% replacement of fly ash and 15% replacement of brick waste with soil.
- It has been observed that the optimum requirement for stabilization for different proportion are different, but the optimum content is soil +8% fly ash +15% brick waste. Depending on the requirement of particular project, suitable proportion of fly ash and brick waste can be chosen to improve the characteristic of clay soil.

Acknowledgment
I would like to express my special thanks of gratitude to all respected faculty members of MITS Gwalior for their able guidance and support. This work would not have been complete without his direction, encouragement and support. All the tests were performed in the Geotechnical lab of CSIR-CBRI ROORKEE (IIT-ROORKEE) Research institute.

6. References
[1] A. Arulrajah, J. Piratheepan, M. M. Disfani and M.W. Bo 2013 Geotechnical and geo-environmental properties of recycled construction and demolition materials in pavement subbase applications Journal of Materials In Civil Engineering ASCE 25 1077-1088
[2] Alireza Mohammadinia, Arul Arulrajah, Jay Sanjayan, Mahdi M. Disfani, Myint Win Bo and Stephen Darmawan 2016 Stabilization of demolition materials for pavement base/sub base applications using fly ash and slag geopolymers: laboratory investigationJournal of Materials In Civil Engineering ASCE04016033 1-9
[3] Brajesh Mishra 2014 A study on engineering behavior of black cotton soil and its stabilization by use of limeInternational Journal of Science and Research 4 290-294
[4] Vikas Shukla & M. K. Trivedi 2020 Improvement of pavement soil sub-grade using industrial waste: cement kiln dust &brick kiln dustSpringer Nature Switzerland13 1-10
[5] S. Srikanth Reddy, A. C. S. V. Prasad, and N. Vamsi Krishna 2018 Lime-stabilized black cotton soil and brick powder mixture as subbase materialHindawi Advances in Civil Engineering 2018 1-5
[6] C.John Suresh Kumar, Dr.M.Sahul Hameed 2018 A review on stabilization of black cotton soilbyusing fly ash, marble sludge and brickdust wasteInternational Journal of Engineering Development and Research6 695-700
[7] Z.A. Baghdadi, M.N. Fatani and N.A. Sabban 1995 Soil modification by cement kiln dustJournal of Materials In Civil Engineering ASCE 7 218-222