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# A CBR based study evaluating subgrade strength of flexible pavements having soil flyash interfaces

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***Abstract***

*Owing to the proximity of certain locations to the thermal power stations, it has always been efforts of Engineers to enhance the flyash utilization rate in various Civil Engineering Constructions adopting suitable strategies. In the present study, a soil-flyash interface mechanism has been evolved using different soil-flyash ratios to upgrade significantly stabilization of supporting medium based on CBR tests. The study confirms soundness of approach when a particular interface arrangement gives high flyash utilization rate along with many fold increase CBR values. A study was carried out to investigate the interface effect of soil-flyash layered system in terms of CBR values so that an optimum arrangement can be achieved by using flyash in combination with soil. In this study, 18 samples of different ratios of soil and flyash (1:0.5, 1:1, 1:1.5, 1:2, 1:2.5, 1:3) with three sets of interfaces N = 2, 4 and 6 were tested to arrive at the most optimized combination of soil and flyash. The results indicate that the CBR value optimized at soil-flyash ratio 1:2.5 and number of interface N = 4. The present study reveals that soil with flyash when used in layered system with various numbers of interfaces gives considerable improvement in CBR values. In the above arrangement about 71 % of flyash and 29 % of soil thus contributing significantly in utilization of flyash in subgrade of flexible pavements. In the overall study, three equations for number of interfaces N = 2, 4 and 6 have also been developed in terms of soil-flyash ratio and CBR value, so that CBR value can directly be obtained by substituting the value of soil-flyash ratio at a particular number of interfaces.*

**Keywords:** *Construction materials, Clayey soil, Flyash.*

## 1. Introduction

The increasing demands of electrical energy and ample coal reserve in India have resulted in the construction of many coal-fired power plants. Most of the power plants which are being constructed or have been proposed are also coal-fired plants. As a result, the production of the power plant waste ash has also increased. They use pulverized coal of high ash content (45%) and produces bottom ash and flyash. The portion of the ash which is classified as flyash and constitutes about 30-60% of total ash escapes with flue gases which is collected through Electrostatic Precipitators. Since, coal is supplied from twenty-two different coal mines of Bihar, the chemical properties also vary to a great extent. With the increasing use of low-grade coal with high ash content, the annual production of flyash is about 100 million tones. Most of the ash generated from the power plant is disposed off in the vicinity of the power plant as the waste material covering several hectares of valuable land. Most developed and developing countries all over the world have huge resources of flyash. The quantity of flyash accumulated in developed and developing countries is causing disposal problems that are both financially and environmentally expensive. The bulk utilization of flyash has become very essential in view of its huge production and increasing scarcity of disposal sites. Utilization in geotechnical applications such as land reclamation, subgrade/soil improvement, structural fills etc. has the potential for bulk utilization. Though the flyash is being used as a constructional material in many civil engineering projects, but its use as a general fill has a long history. When used in embankment for the construction of highways, the design life as well as the cost of maintenance of highways may get affected. Flyash is now being put in several countries for stabilization of soil for the construction of roads and runway bases. Speedy and effective utilization of flyash has been recognized as a problem of national importance and in 1988, C.R.R.I. organized a workshop on "Utilization of

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Flyash". The detailed investigations are therefore necessary in order to understand the response of the layered system of soil and flyash with numbers of layers and interfaces.

This paper presents the results of an experimental study of CBR tests performed on the soil-flyash ratios of 1:0.5, 1:1, 1:1.5, 1:2, 1:2.5 and 1:3 in layered system with number of interfaces, N = 2, 4 and 6.

## 2. Review of Literature

Kaniraj and Havanagi (2001) conducted unconfined compression tests on cement-stabilized fibre-reinforced flyash-soil mixtures and concluded that randomly oriented polyester fibre changed the brittle behaviour to ductile behaviour. Pandian et.al. (2002) studied the effect of two types of flyashes Raichur flyash (Class F) and Neyveli flyash (Class C) on the CBR characteristics of the black cotton (BC) soil. The flyash content was increased from 0 to 100 %. The low CBR of BC soil is attributed to the inherent low strength, which is due to the dominance of clay fraction. The addition of flyash to BC soil increases the CBR of the mix upto the first optimum level due to the frictional resistance from flyash in addition to the cohesion from BC soil. Further, addition of flyash beyond the optimum level causes a decrease up to 60% and then upto the second optimum level there is an increase. Thus, the variation of CBR of flyash-BC soil mixes can be attributed to the relative contribution of frictional or cohesive resistance from flyash or BC soil, respectively. In Neyveli flyash also there is an increase of strength with the increase in the flyash content, here there will be additional puzzolonic reaction forming cementations compounds resulting in good binding between BC soil and flyash particles. Phanikumar and Sharma (2004) studied the effect of flyash on parameters like free swell index, swell potential, swelling pressure, plasticity, compaction, strength and hydraulic conductivity of expansive soil. The ash blended expansive soil with flyash contents of 0, 5, 10, 15 and 20 % on a dry weight basis and they inferred that increase in flyash content reduces plasticity characteristics and the free swell index was reduced by about 50% by the addition of 20% flyash. When the flyash content increases there is a decrease in the optimum moisture content and the maximum dry unit weight increases. The undrained shear strength of the expansive soil blended with flyash increases with the increase in the ash content. Misra et al. (2000), Senol et al. (2002) and Arora et al. (2005) used the flyash successfully for stabilizing expansive clays and the strength characteristics of flyash stabilized clays are measured by means of unconfined compressive strength (UCS) and California Bearing Ratio (CBR) values. Depending upon the soil type, the effective flyash content for improving the UCS and CBR values of the soil varies between 15 to 30%. Dutta and Sarda (2006) carried out an experimental study to investigate the CBR behaviour of waste plastic strip reinforced stone-dust/flyash overlying saturated clay. Three different sizes of waste plastic strips were used and the effect of waste plastic strip content (0.25% to 4%) and length on the CBR and secant modulus of strip reinforced stone-dust/flyash overlying saturated clay resulted in an appreciable increase in the CBR and the secant modulus.

Yetimoglu et al. (2005) conducted CBR tests on sand fills reinforced with randomly distributed discrete fibres overlying soft clay. Their study revealed that adding fibre to sand fill resulted in an appreciable increase in the peak piston load. However, the initial stiffness of the load-penetration curves was not significantly affected by fibre reinforcement. The test results further showed that increasing fibre reinforcement content could increase the brittleness of the fibre-reinforced sand fill-soft clay system. The disagreement among the reported results is attributed to the difference in the material properties and methodology.

Choudhary and Verma (2005) conducted a series of laboratory CBR tests on flyash specimens with and without reinforcement. The effect of depth of reinforcement from the top surface of the compacted flyash specimen as well as varying number of reinforcing layers at equal vertical spacing within the specimen on the CBR characteristics of flyash were studied. The maximum strength ratio ($CBR_{reinforced}$ to $CBR_{unreinforced}$) of 2.99 was observed when the geotextile was placed at an embedment ratio of 1. The strength ratio ranges from 2.64 to 4.06 when the number of reinforcing layers varied from 2 to 4. The embedment ratio of the four geotextiles was 0.25, 0.5, 0.75 and 1.0. Edil et.al. (2006) studied that the CBR of soil–flyash mixtures generally increases with flyash content and decreases with increasing compaction water content. Adding 10 and 18% flyash to fine grained soils compacted 7% wet of optimum, the typical in situ condition resulted in increases in CBR by a factor of 4 and 8 respectively. The CBR increased by a greater factor when fly ash was added to a wetter or more plastic i.e., poorer fine grained soil. Prasad et al. (2008) carried out CBR and direct shear tests for finding the optimum percentages of waste plastics and waste tyre rubber in gravel subbase material. Based on these results, laboratory model pavement studies were conducted with optimum percentage of waste plastics and waste tyre rubber in gravel subbase, laid on expansive soil subgrade in the flexible pavement system. The load carrying capacity of the model flexible pavement system significantly increased when the gravel subbase was reinforced with waste plastics as well as waste tyre rubber compared to unreinforced subbase. Khan, M. A. et. al. (2008) studied that the cyclic load deformation behaviour of soil-flyash layered system using different intensities of failure load (I=25%, 50% and 75%) with varying number of cycles (N=10, 50 and 100). The test results reveal two types of failure mechanism that demonstrate the interface characteristics of the soil-flyash layered system under cyclic loading conditions. Data trends indicate greater stability of layered samples of soil-flyash matrix in terms of failure load (i) at higher number of loading-unloading cycles, performed at lower intensity of deviator stress and (ii) at lower number of cycles but at higher intensity of deviator stress. Brooks (2009) upgraded expansive soil as a construction material using waste materials rice husk ash (RHA) and flyash. Stress strain behavior of unconfined compressive strength showed that failure stress and strains increased by 106% and 50% respectively when the flyash content was increased from 0 to 25%. When the RHA content was increased from 0 to 12%, unconfined compressive strength increased by 97% while

CBR improved by 47 %.

The literature presented above clearly indicates that the influence of layered system of soil-flyash ratios with number of interfaces on the CBR behaviour has not been investigated so far. Therefore, the main purpose of this paper is to present the results of CBR tests with various soil-flyash ratios and number of interfaces. Effects of number of interfaces between soil-flyash layers on load-penetration behaviour and obtained an optimized arrangement of soil-flyash layered system for the construction of flexible pavements. Mollamahmutoglu et. al. (2009) carried out an experimental investigation on the stabilization of an expansive soil with flyash and determined that the 35% flyash treated expansive soil samples provide satisfactory fill material. Furthermore, the strength increases with curing time but liquid limit, plasticity index, swell pressure and thus swell percentage decrease substantially with the increase in flyash percentage.

## 3. Materials Characteristic

### *3.1. Flyash Used*

The flyash used was collected from the coal-based Harduaganj Thermal Power Plant of Uttar Pradesh located 14 km north of Aligarh City by side of upper Ganga Canal. The plant has an installed capacity of 440 MW of electricity with the maximum flyash production capacity of about 100 tons per annum. The flyash from the plant was collected in a dry form from hoppers and transported in air tight double polythene bags. The chemical composition of the flyash along with its physical and geotechnical properties were obtained in the laboratory. According to ASTM C618 standard method of testing, flyash is categorized as type F and the results obtained are presented in Table1.

**Table 1** Chemical Composition and Properties of Flyash

| Properties | Value |
|---|---|
| **Chemical Composition** | |
| Silica ($SiO_2$) | 50-60 % |
| Alumina ($Al_2O_3$) | 15-28 % |
| Iron oxide ($Fe_2O_3$) | 5-10 % |
| Lime (CaO) | 3-6 % |
| Magnesia (MgO) | 1-2 % |
| Soda ($Na_2O$) | -- |
| Potash ($K_2O$) | -- |
| Manganese oxide (MnO) | 1-2 % |
| **Physical Properties** | |
| Specific gravity | 2.06 |
| Loss on ignition | 5-6 % |
| **Geotechnical Properties** | |
| Maximum dry density (MDD) | 11.8 $kN/m^3$ |
| Optimum moisture content (OMC) | 37.5 % |
| Percentage finer than75 micron | 92 % |
| Compression index | 0.07 |
| Coefficient of consolidation at 200 $kN/m^2$ pressure | $2.985\times10^{-8}$ $m^2/sec$ |
| Permeability at MDD of 11.8 $kN/m^3$ | $4.88\times10^{-7}$ m/sec |
| Unconfined compressive strength at MDD | 110 $kN/m^2$ |
| Swelling pressure | 0.00 $kN/m^2$ |
| Cohesion | 6.8 $kN/m^2$ |
| Angle of shearing resistance | 32° |
| CBR at MDD of 11.8 $kN/m^3$ | 5.77 |

### *3.2. Soil Investigated*

The soil for the present investigation was sampled from the campus of the Aligarh Muslim University, Aligarh. As per IS classification system, the soil is classified as clay of low compressibility (CL). The index and other geotechnical properties of soil are reported in Table 2. The grain size distribution of both the experimental soil and flyash are shown in Fig. 9.

## 4. Laboratory Experimental Programme

A detailed experimental work has been taken-up covering various properties of soil and flyash viz., liquid limit, plastic limit, compaction, specific gravity, shear strength parameters, compression index, permeability and swelling pressure. The flyash used in this investigation is obtained from Harduaganj Thermal Power Plant of Uttar Pradesh near Aligarh. The flyash collected is dried, sieved through 425 microns and stored in airtight containers in the laboratory. The particle size distribution curve of flyash shows that about 73% of the flyash consists of particles with diameter 2-60 μm (silt size), about 22% of the flyash consists of particles with diameter 60-200 μm (fine sand size) and the rest of the particles size lies within medium sand size (200-600 μm). The soil used in this investigation is air dried, pulverized and sieved through 4.75mm IS sieve. The samples thus obtained are stored in airtight containers in the laboratory. The optimum moisture content (OMC) and maximum dry density (MDD) of plain soil and flyash are determined by Standard Proctor Compaction Test and then specimens of CBR mould of soil, flyash and layers of soil and flyash are prepared in laboratory at standard proctor density. Different samples were prepared in the similar lines for CBR tests using soil and flyash materials in various ratios and number of interfaces. After soaking test, the CBR mould is placed on the CBR testing machine with minimum surcharge weight of 4.5 kg. A rigid plunger of 50 mm diameter is allowed to penetrate into the specimen and the

**Table 2** Physical and Geotechnical Properties of soil

| Properties | Value |
|---|---|
| IS Classification | CL |
| Liquid limit | 28 % |
| Plastic limit | 18 % |
| Plasticity index | 10 % |
| Specific gravity | 2.70 |
| **Grain size distribution** | |
| Gravel | 0.0 % |
| Sand | 24 % |
| Silt | 66 % |
| Clay | 10 % |
| Maximum dry density (MDD) | 18.3 $kN/m^3$ |
| Optimum moisture content (OMC) | 16.0 % |
| Unconfined compressive strength at MDD | 175 $kN/m^2$ |
| Swelling pressure | 84.53 $kN/m^2$ |
| Cohesion | 25 $kN/m^2$ |
| Angle of shearing resistance | 13° |
| CBR value at MDD of 11.8 $kN/m^3$ | 3.62 |

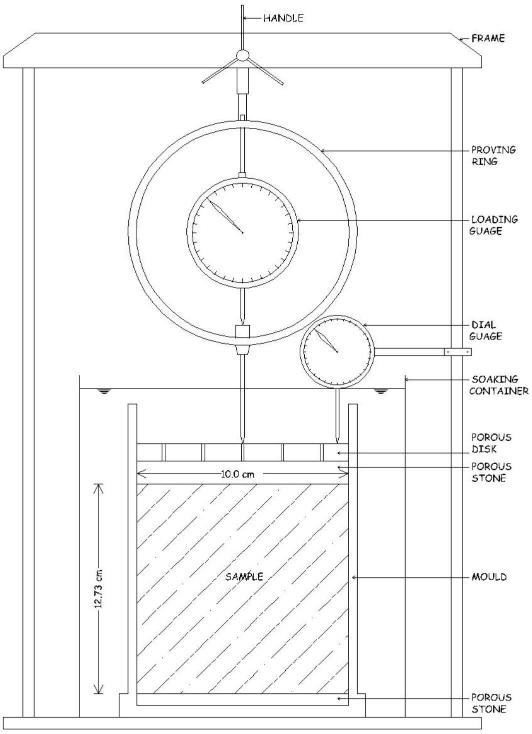
penetration of the plunger is recorded by the dial gauge and resistance to penetration is recorded by the calibrated proving ring. A typical arrangement of samples of plain soil and plain flyash and various ratios of soil-flyash (S:F) 1:0.5, 1:1, 1:1.5, 1:2, 1:2.5 and 1:3 which were prepared in layered system keeping number of interfaces N = 2, 4 and 6 as shown in Figs. 1 to 7. The CBR tests were conducted in the laboratory for all the samples as per IS: 2720 (Part-16)-1979. The CBR value is calculated by the relation,

CBR (%) = (Test load / Standard load) × 100.

Normally, CBR value at 2.5 mm penetration is higher than that of at 5.0 mm penetration and is reported as CBR value. If the CBR value at 5.0 mm penetration is consistently higher than that of at 2.5 mm penetration then CBR at 5.0 mm penetration is reported. Load-penetration curves were plotted for plain soil, plain flyash and layered system of soil-flyash ratios (S:F) with numbers of interfaces (N) and CBR values are calculated which are presented in Table 3. In the present investigation, a limited effort is devoted to understand the possible mechanisms governing the behaviour of layered system of soil and flyash in relation to CBR values.

### 4.1. Method of Swelling Test

Proving ring method was used for measurement of swelling pressures of plain soil, plain flyash and layered system of soil-flyash ratios (S:F) with number of interfaces (N). The



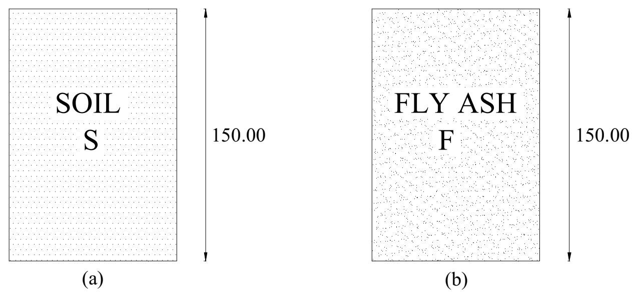




**Fig. 1** Schematic Diagram of Swelling pressure measurement set-up - Plain soil and flyash

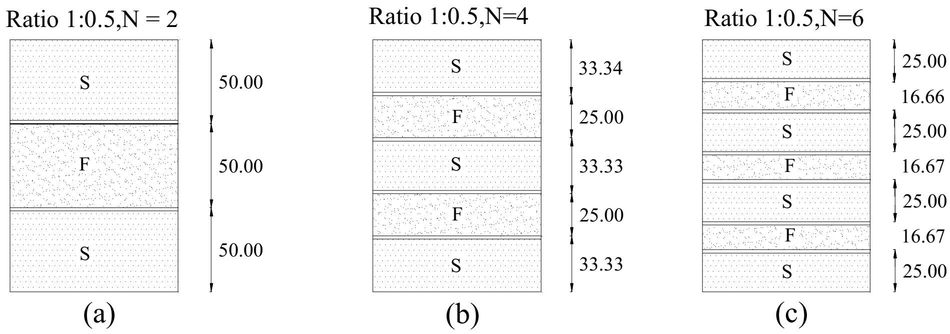



**Fig. 2** Layered system of soil and flyash having ratio 1:0.5 and number of interfaces, N=2,4 and 6

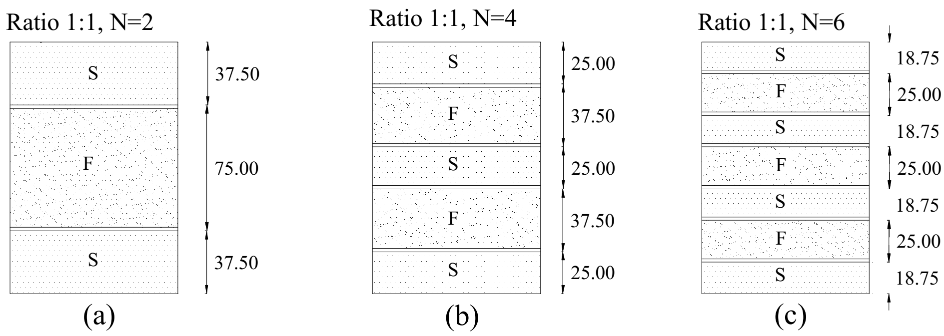



**Fig. 3** Layered system of soil and flyash having ratio 1:1 and number of interfaces, N=2,4 and 6

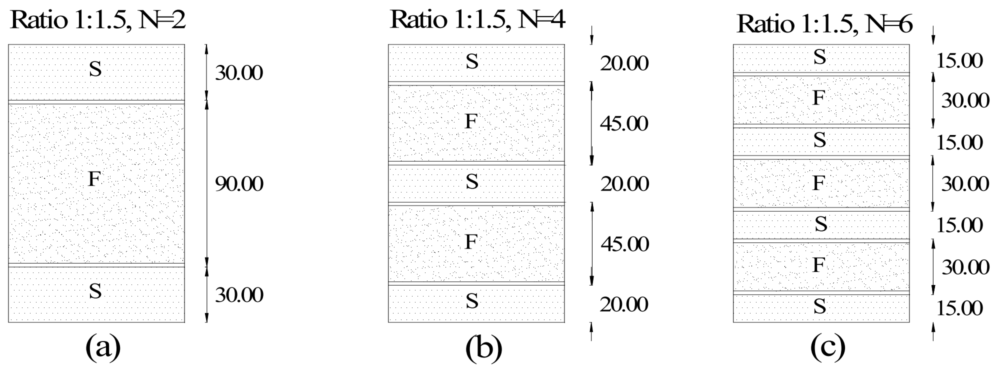



**Fig. 4** Layered system of soil and flyash having ratio 1:1.5 and number of interfaces, N=2,4 and 6

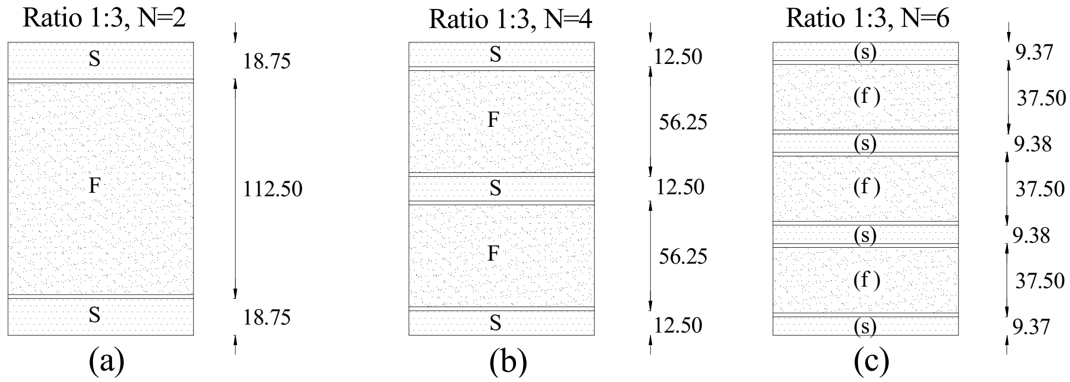



**Fig. 5** Layered system of soil and flyash having ratio 1:2 and number of interfaces, N=2,4 and 6

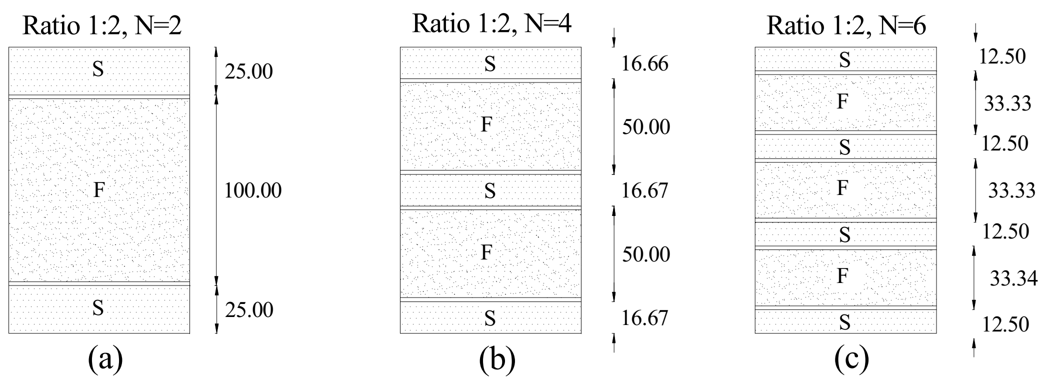



**Fig. 6** Layered system of soil and flyash having ratio 1:2.5 and number of interfaces, N=2,4 and 6

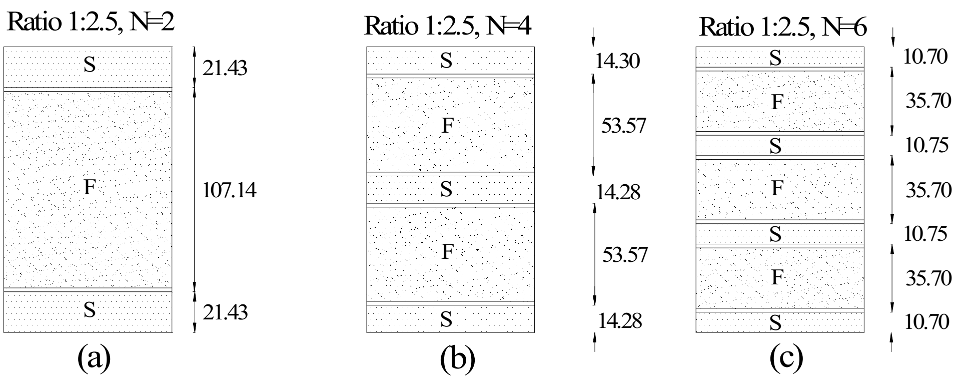



**Fig. 7** Layered system of soil and flyash having ratio 1:3 and number of interfaces, N=2,4 and 6

**Table 3** CBR and swelling pressure of different samples of soil and flyash

| Samples | | CBR Values At Penetration 2.5 mm | CBR Values At Penetration 5.0 mm | Swelling Pressure (kN/m²) |
|---|---|---|---|---|
| Plain Soil | | 2.7 | 3.62 | 84.53 |
| Plain Flyash | | 4.1 | 5.77 | 0.00 |
| Soil-Flyash Ratio (S:F) | Number of Interfaces (N) | - | - | - |
| 1:0.5 | N = 2 | 3.36 | 3.92 | 61.34 |
| | N = 4 | 4.21 | 4.29 | 57.61 |
| | N = 6 | 3.64 | 4.11 | 58.32 |
| 1:1 | N = 2 | 3.92 | 4.13 | 52.80 |
| | N = 4 | 4.37 | 4.62 | 49.21 |
| | N = 6 | 4.04 | 4.37 | 51.45 |
| 1:1.5 | N = 2 | 3.64 | 4.41 | 41.50 |
| | N = 4 | 5.47 | 6.10 | 35.35 |
| | N = 6 | 5.10 | 5.21 | 38.20 |
| 1:2 | N = 2 | 3.92 | 4.80 | 28.76 |
| | N = 4 | 5.93 | 6.88 | 26.50 |
| | N = 6 | 4.77 | 5.65 | 27.15 |
| 1:2.5 | N = 2 | 4.74 | 5.40 | 23.65 |
| | N = 4 | 8.75 | 10.70 | 20.80 |
| | N = 6 | 7.90 | 8.50 | 21.30 |
| 1:3 | N = 2 | 4.74 | 4.80 | 12.50 |
| | N = 4 | 8.51 | 9.73 | 10.35 |
| | N = 6 | 5.73 | 7.64 | 11.50 |

schematic diagram of the set up used is given in Fig. A. During the ingress of moisture, change in height and resistance due to swelling of specimens were recorded by dial gauge with time and proving ring respectively. For swelling potential, surcharge equivalent to 6.9 kPa, was used. The values of swelling pressures obtained are shown in Table 3.

## 5. Results and Discussions

The specific gravity of soil and flyash are obtained by density bottle method as 2.7 and 2.0 respectively. The liquid limit, plastic limit and plasticity index of soil are obtained by using Cassagrande's apparatus as 28%, 18% and 10% respectively. Standard Proctor Compaction Tests were carried out on soil and flyash for the determination of optimum moisture content (OMC) and maximum dry density (MDD). The OMC and MDD for soil are obtained as 16% and 18.3 kN/m³ and for flyash as 37.5% and 11.8 kN/m3 respectively (Table 1 and 2). The variation of dry density with moisture content of plain soil was rapid pattern but for plain flyash was slow pattern as shown in Fig. 8.

The experimental results established a basis for investigating the relationship between CBR of soil, flyash and layered system of soil-flyash ratios with different number of interfaces. The CBR tests were conducted on each sample as close to the OMC as possible. The CBR values of soaked samples of plain soil, flyash and layered system of soil-flyash ratio (S:F) with number of interfaces (N) were obtained by plotting curves of penetration resistance vs. penetration as shown in Figs. 10 to 16. The penetration resistance of a rigid plunger is measured and the loads at penetrations of 2.5 mm and 5.0 mm are expressed as percentage of two standard loads. The desired CBR value was chosen as the greater of the computed values at 2.5 mm and 5.0 mm penetration. The CBR tests were first performed on plain soil and flyash samples and then on the various ratios of soil and flyash (1:0.5, 1:1, 1:1.5,

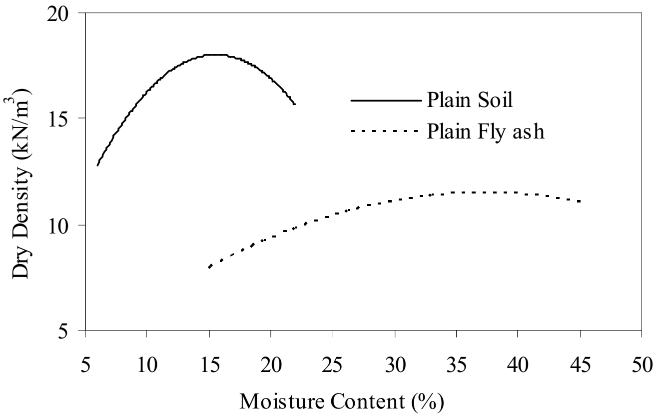



**Fig. 8** Moisture density relationship of soil and flyash

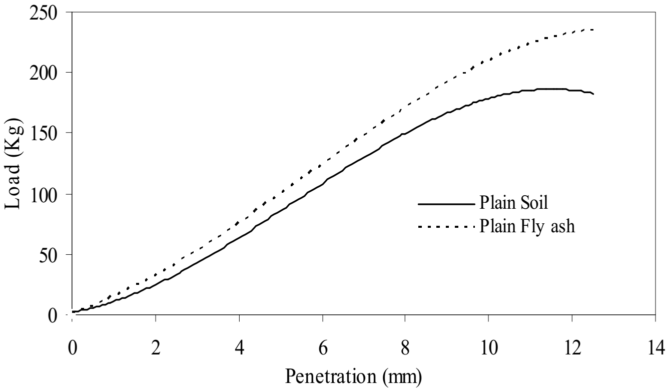



**Fig. 10** Load penetration curves for CBR values of plain soil and flyash

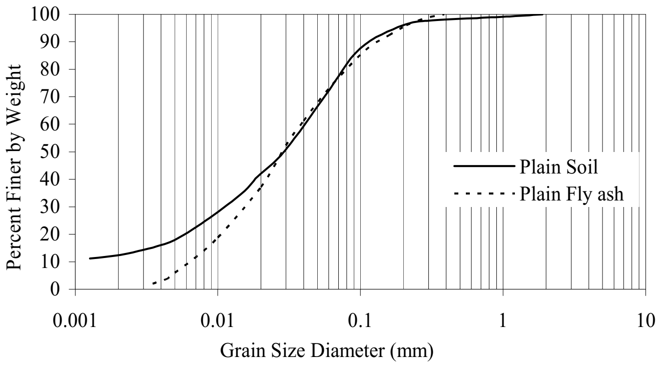



**Fig. 9** Grain size distribution curve for soil and flyash

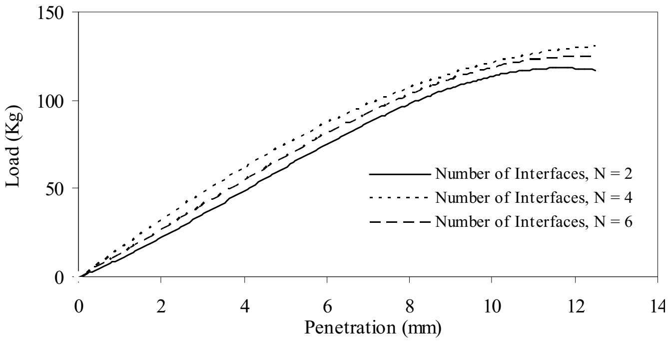



**Fig. 11** Load penetration curves for soil flyash ratio 1:05 with number of interfaces, N=2,4 and 6

1:2.0, 1:2.5 and 1:3.0) in layered system with number of interfaces, N = 2, 4 and 6.

The CBR values for plain soil and plain flyash were found to be 3.62 % and 5.77 % respectively. The low CBR of plain soil is attributed to the inherent low strength, which is due to the dominance of clay fraction and high CBR of flyash, which consists predominantly of coarser particles, is contributed by its frictional component. In over all study, it was observed that at any soil-flyash ratio (S:F), the CBR value is optimized at number of interfaces, N = 4. The CBR showed an upward trend throughout in the layered system having various interfaces, however the maximum value of CBR was found to be 10.7% at soil-flyash ratio (S:F) 1:2.5 and number of interfaces N = 4, which is a significant achievement in the present experimental study.

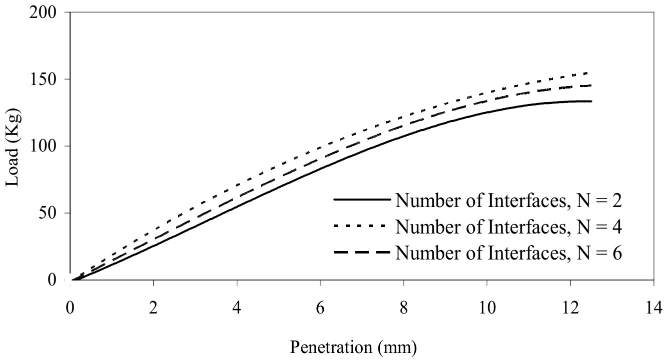



**Fig. 12** Load penetration curves for soil flyash ratio 1:1 with number of interfaces, N=2,4 and 6

The maximum improvement in the CBR values of plain soil and plain flyash with respect to layered system of soil-flyash having ratio, S:F = 1:2.5 and number of interfaces, N = 4 are 195% and 85% respectively. The least value of swelling pressures for any soil-flyash ratio (S:F) was obtained at number of interfaces, N = 4 (Table 3).

As the thickness of soil layers in between the layers of flyash decreases along with the increase in number of interfaces, N and ratios (S:F), the system could resist the shearing load due to dominance of frictional component and increase in shear strength by interlocking between finer and coarser particles at soil-flyash interfaces up to the optimum level. The number of interfaces increased more than N = 4 and ratio (S:F) 1:2.5, beyond the optimum level, the specimen sustains lesser load for the same penetration and giving lower CBR values due to decrease in frictional and cohesion resistance at the interfaces of soil-flyash. Thus the variation in CBR values of soil-flyash layered system having ratio (S:F) and number of interfaces, N can be attributed to the relative contribution of frictional and cohesive resistance from flyash and soil, respectively.

Three equations in terms of CBR values for various soil-flyash ratios (S:F) with number of interfaces, N = 2, 4 and 6 are obtained as shown in Fig. 17. An equation for CBR values has been derived in terms of soil and flyash ratios (S:F) and number of interfaces (N) as given below.

$$y = C_1 x^3 + C_2 x^2 + C_3 x + C_4 \quad (1)$$

where,

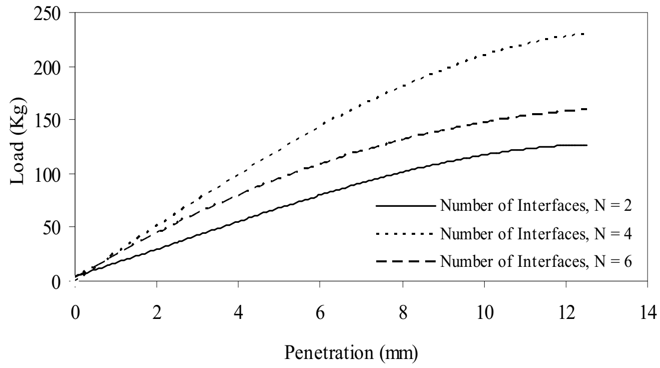



**Fig. 13** Load penetration curves for soil flyash ratio 1:1.5 with number of interfaces, N=2,4 and 6

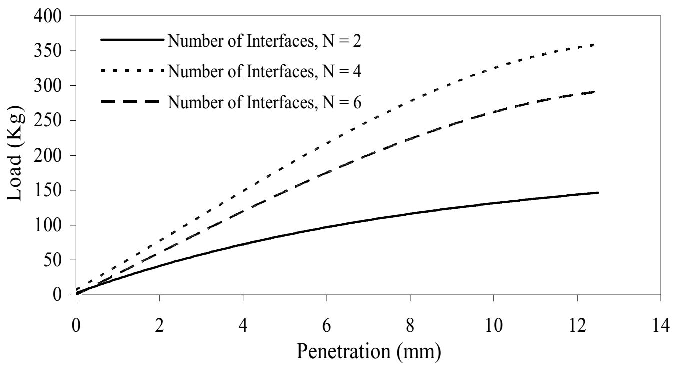



**Fig. 15** Load penetration curves for soil flyash ratio 1:2.5 with number of interfaces, N=2,4 and 6

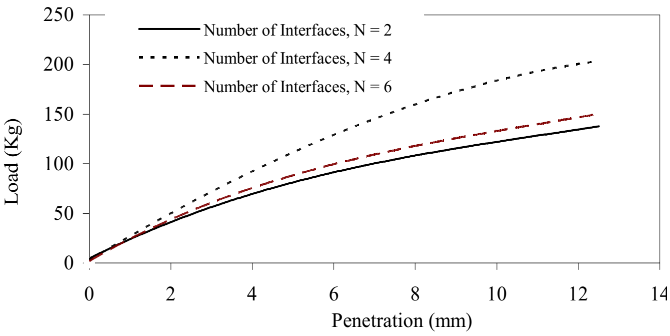



**Fig. 14** Load penetration curves for soil flyash ratio 1:2 with number of interfaces, N=2,4 and 6

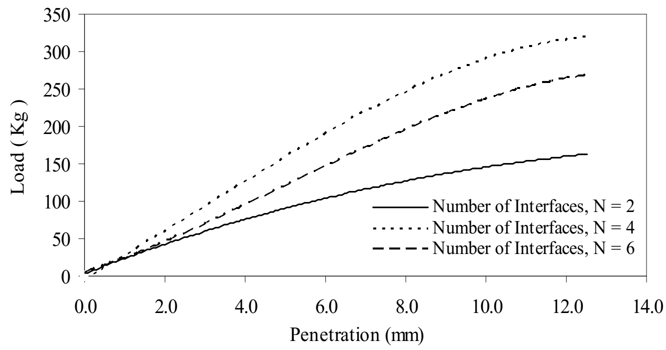



**Fig. 16** Load penetration curves for soil flyash ratio 1:3 with number of interfaces, N=2,4 and 6

y = CBR value (%), x = Soil-flyash ratio and $C_1$, $C_2$, $C_3$ and $C_4$ are correlation coefficients

For $N = 2$, $C_1 = -0.57$, $C_2 = 2.91$, $C_3 = -3.50$, $C_4 = 5.10$ and R2 = 0.8914

For $N = 4$, C1 = -1.59, $C_2 = 8.50$, $C_3 = -10.4$, $C_3 = 7.77$ and R2 = 0.9482

For $N = 6$, $C_1 = -1.11$, $C_2 = 5.97$, $C_3 = -7.46$, $C_3 = 6.61$ and R2 = 0.9371

From the above Eq. (1), the CBR values can be obtained for any soil-flyash ratio (S:F) corresponding to number of interfaces, $N = 2$, 4 and 6.

In present study, the pavement thickness vs CBR values curves of soil-flyash ratios with number of interfaces have been plotted as shown in Fig. 18. From these curves, the optimized thickness of pavement can be obtained corresponding to soil-flyash ratio and number of interfaces.

### *5.1 Economic Analysis*

The CBR values of conventional stabilization of plain soil and optimized soil-flyash layered technique are reported as 3.62 % and 10.70 % respectively. The corresponding total pavement thicknesses for 10 msa (million standard axles) as per IRC: 37-2001 are obtained as 755 mm and 540 mm. The total construction cost of flexible pavement for optimized soil-flyash layered technique reduces up to 24.5%.

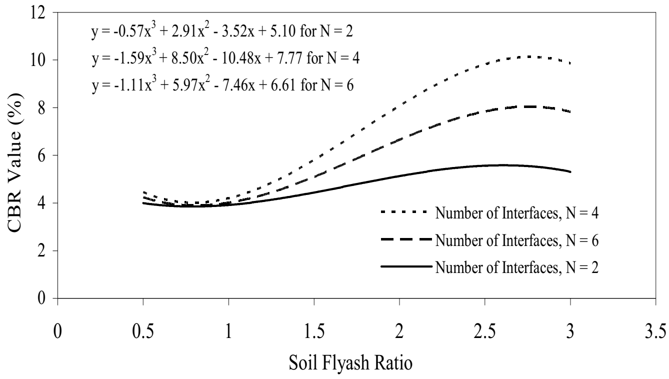



**Fig. 17** Effect of soil flyash ratio on CBR values with number of interfaces

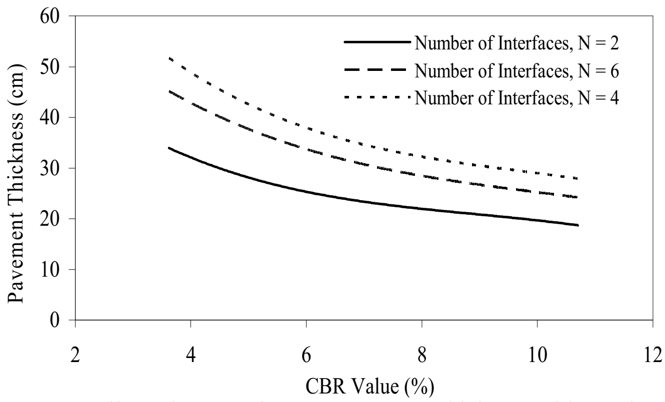



**Fig. 18** Effect of CBR values on pavernent yhickness with number of interfaces

## 6. Conclusions

The following conclusions have been drawn from the present study

The study shows that the swelling pressure of clayey soil decreases steadily with the increase of soil-flyash ratio, but for any soil-flyash ratio, swelling pressure reduced up to optimum level of interfaces, N = 4 and slightly decreased at N = 6. The swelling pressure of soil-flyash layered system having maximum CBR value was reduced to 72 % with respect to plain soil.

The maximum CBR value was reported as 10.7 % for optimized layered system of soil-flyash sample having ratio (S:F) 1:2.5 with number of interfaces N = 4. In the same arrangement of layered system, the magnitude of soil and flyash components was taken as 29 % and 71 % respectively.

The percentage increase in the CBR value for optimized layered system of soil-flyash with respect to plain soil and flyash was reported as 195 % and 85 % respectively.

The stabilization of soil by using flyash in layered system along with the number of interfaces provides a strong material for subgrade of roads and runway pavements, especially in areas surrounding the thermal power plants. The cost of construction of pavement of optimized soil-flyash layered technique with respect to conventional stabilization reduced up to 24.5 %.

The study confirms that considerably high amount of thermal power plant waste (flyash) can be used, which prevent environmental pollution and saving our valuable land and handle disposal problem of flyash from dump yards. A general equation, $y = C_1 x^3 + C_2 x^2 + C_3 x + C_4$ has been generated for CBR values, $y$ (%) in terms of soil-flyash ratio (S:F), $x$ and number of interfaces (N).

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