Strength Characterisation of Stablised Class "F" Flyash Using Class "C" Flyash

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Abstract. One of the major sources of power generation in India is thermal power plants. Unlike other countries, the flyash generated in India is having poor pozzolanic content (CaO < 5%) and Classified as Class ‘F’. The generation of flyash has already reached more than 130 million tons per annum and disposal of flyash is a challenging problem today. Interestingly, the flyash generated from Neyveli Lignite power Corporation, Tamil Nadu alone is bearing a Classification of Class ‘C’ type flyash which is having free reactive silica and high pozzolanic content (CaO > 15%). An attempt is made to improve the engineering properties of flyash Class ‘F’ by adding flyash Class ‘C’ at various percentages. It is found that the γ_d max, Unconfined Compressive Strength and CBR of Class ‘F’ flyash increased significantly with the addition of increasing percentage of Class ‘C’ flyash . It is concluded that the large scale utilization of Class ‘F’ flyash can be effectively handled by adding another Class 'C' type flyash for various geotechnical engineering applications.

Key words: Flyash , Stabilization, Compaction, UCC Strength

1 Introduction

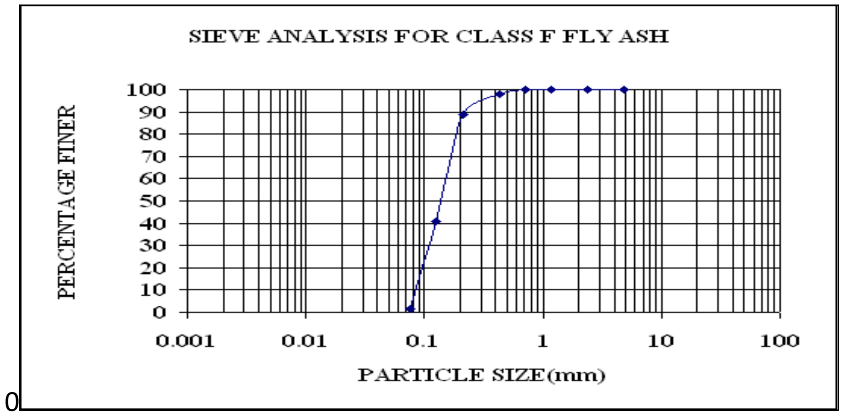
With the rapid growth of industrial activities, power generation sector is currently under maximum stress. With the depletion and scarcity of high quality coal, thermal power plants are forced to invariably use low quality coals. This has increased the quantum coal ashes generated. Huge quantities of coal ashes generated coupled with their low specific gravity makes the problem of ash handling and disposal very acute. It is estimated that the current worldwide annual production of coal ash is more than 700 million tones, of which, about 70% is flyash , Malhotra and Mehta (2002). Out of these, nearly 130 million tons of coal ash is produced in India itself. Flyash is classified in to two categories viz: Class ‘C’ and Class ‘F’. While Class ‘F’ flyash is having low lime content (CaO<5%), Class ‘C’ flyash possesses (CaO >15%) of high lime content. American Coal Ash Association (ACAA), reported that, the quantity of Class ‘F’ flyash generated in India is more compared to Class ‘C’ flyash. This study aims to stabilizing Class ‘F’ flyash using Class ’C’ flyash so as to use the former for geotechnical engineering applications. The main objective of the study is to enhance the engineering behaviour of Class ‘F’ flyash using Class ‘C’ flyash and thereby large scale solid waste flyash utilization is envisaged.

2 Materials And Methods

Two different type flyash es namely Class ‘F’ and Class ‘C’ are considered in the present investigation to explore the possibilities of intermixing these flyash es so that the advantages of Class ‘C’ flyash can be best used for improving Class ‘F’ flyash .

The grain size distribution of flyash was carried out in accordance with IS: 2720 (Part 4), 1985. The grain size distribution curves as seen from Fig. 1(a) and (b) indicates that both the types of flyash predominantly consist of silt sized particles.

1(a) Class ‘F’ flyash



1(b) Class ‘C’ flyash

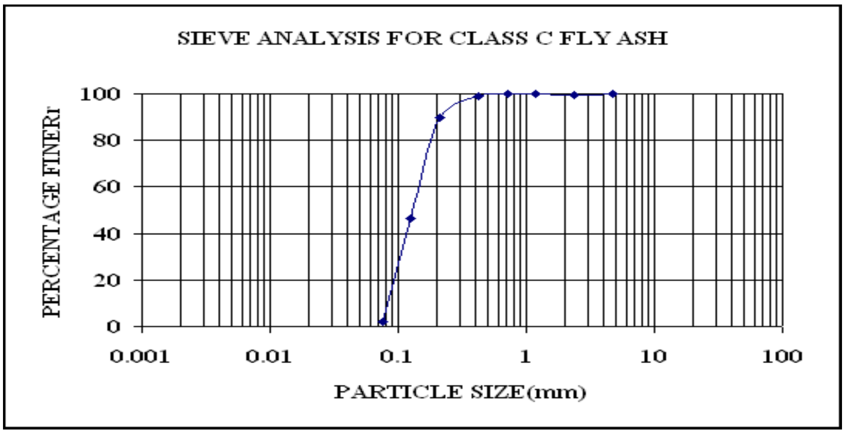


Fig. 1. Grain size distribution of (a) Class ‘F’ flyash (b) Class ‘C’ flyash .

The laboratory tests such as Compaction, Unconfined Compressive Strength as per IS: 2720 (part 10) – 1991, and CBR were conducted on the flyash Class 'C' and Class 'F' mixes as per IS: 2720 (part 16) – 1986. The percentage of Class 'C' flyash in Class 'F' flyash has been varied as 2, 10, 15, 20, 25, 35 and 50% by weight.

The Standard Proctor Compaction tests were conducted by using miniature compaction equipment. The compaction tests were repeated for 4 trials and the average γ_d (max) value and the optimum moisture content (OMC) were obtained.

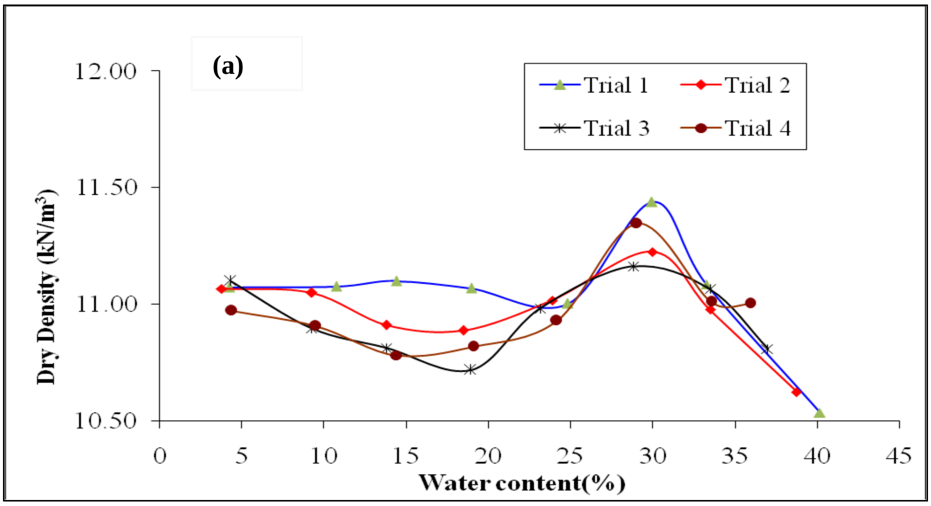
The UCC specimens were prepared in the split mould corresponding to γ_d max and OMC of the respective Class 'F' and Class 'C' flyash mix by hand remoulding. A split mould is used to prepare the specimens of 38 mm diameter and 76 mm in length between the spacers of the moulds. The prepared samples were wrapped with moisture proof cover immediately and placed inside the humidity control chamber at 30 ± 1°C and relative humidity ≥ 95% for a specified curing period of 1, 3, 7, 14 and 28 days.

CBR tests were conducted for various combinations of flyash ('F' and 'C') as per IS: 2720 (part 16)-1986 corresponding to γ_d (max) and OMC of flyash mixes.

3 Results And Discussion

a. Compaction Tests

From the compaction tests, the average γ_d (max) value and the OMC of Class 'F' flyash are obtained as 11.25 kN/m^3 and 30% respectively. Similarly, the γ_d (max) value of Class 'C' flyash is found to be 13.5 kN/m^3 and OMC is 29.5% as shown in Fig. 2.



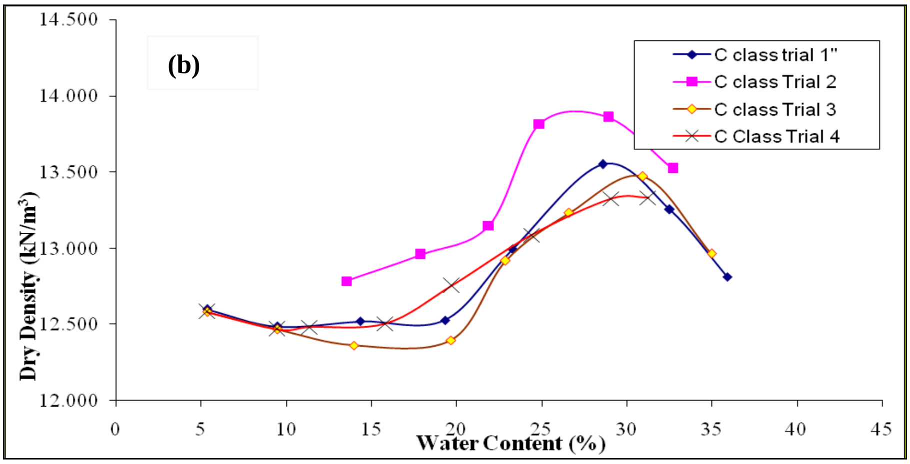


Fig. 2. Compaction Curves for (a) Class 'F' flyash (b) Class 'C' flyash .

b. Maximum dry density

The percentage of Class 'C' flyash is varied from 5% to a maximum of 50% in Class 'F' flyash . Fig. 3 shows the compaction curves of Class 'F' and Class 'C' flyash mixes to determine the γ_d (max) and OMC values. The γ_d (max) values of Class 'F' flyash increased from 11.25 kN/m^3 to a maximum value of 12.62 kN/m^3 corresponding to F 50% + C 50%. It is expected that the γ_d (max) values of Class 'F' flyash would further increase with the increase in percentage of Class 'C' flyash Fig. 4.

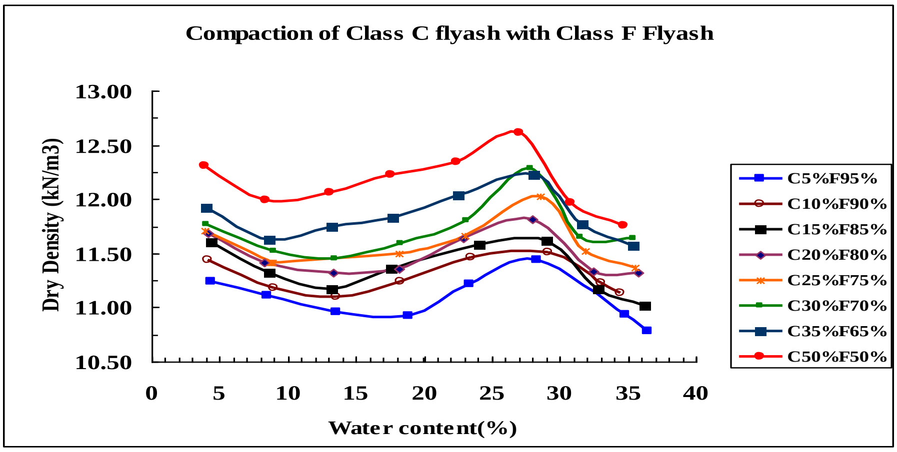


Fig. 3. Compaction Curves of Class 'C' Flyash + Class 'F' Flyash mixes.

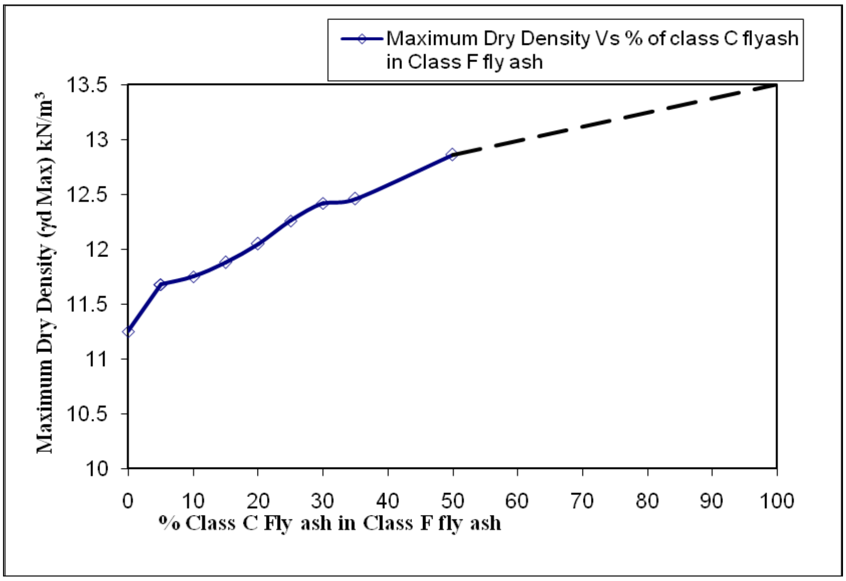


Fig. 4. Maximum Dry Density Vs Percentage of Class 'C' in 'F' flyash .

c. Optimum Moisture Content (OMC)

The OMC values of flyash mixes are ranging between a lower value of 27.8% corresponding to F70% + C30% (F and C represent the Class of flyash) to the maximum of 29.16% for F90% + C10%. Unlike variation of γd (max) values of the flyash mix, there is no proper trend noticed in the changes of OMC of Class 'F' + Class 'C' flyash mixes. Interestingly, the OMC of the mixes at any percentage between 0 to 50% of Class 'C' are well below the OMC of either of the flyash constituents shown in Fig. 5. It is indicating that the flyash mixture behaviour is better than the individual constituents. However, if the OMC of 10% flyash 'C' is not considered, then a general decreasing trend is noticed. Sridharan et.al (2007) stated that the OMC of Indian flyashes are ranging between 17.9 to 62.3% irrespective of whether Class 'C' or Class 'F' flyashes. It is well known that, the workability of soil would be better as construction materials when OMC keeps decreasing (Mitchell, 1976).

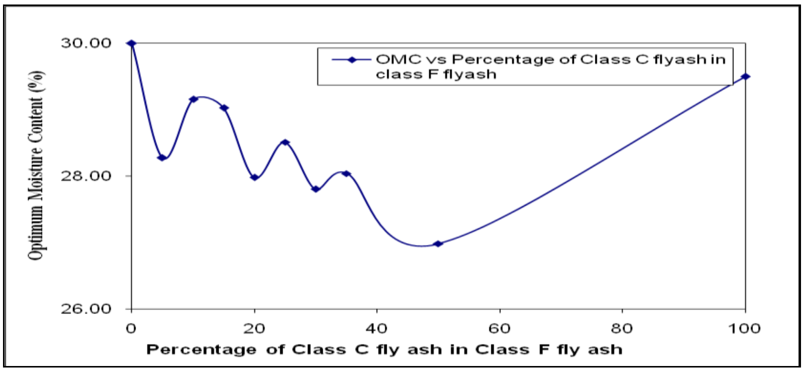


Fig.5. OMC Vs Percentage of Class ‘C’ in ‘F’ flyash

d. Compression Strength (UCC) Characteristics of Flyash Mixes

The unconfined compression tests of Class 'F' could not be carried out without curing condition because of its unstable nature. However, Class 'C' is flyash is stable enough to test without curing and hence, UCC strength values are reported. While one day cured Class 'F' flyash alone showed ultimate failure strength of 38.68kPa, for the same period Class 'C' resulted the ultimate strength of 5869.32kPa, which is 150 times higher than the earlier. Fig. 6 shows the stress-strain graph of Class 'F' and Class 'C' flyash each with three trials of tests and the average values are reported in Table 1. The difference in the strength of Class 'F' and Class ‘C’ flyash are mainly due to higher amount of pozzolanic content (CaO>15%) present in Class 'C' flyash and for Class 'F' flyash because of its poor cementing components of CaO<5%.

Table 1. Variation of UCC strength of Class ‘F’ + Class ‘C’ flyash mixes for different curing periods

Type of Flyash		UCC strength, kPa				
		Curing Period in days				
Class F flyash	Class C* flyash	1	3	7	14	28
100	0	39	--	--	--	--
95	5	230	239	238	242	261
90	10	602	631	664	687	707
85	15	690	760	788	780	812
80	20	834	1031	1061	1158	1487
75	25	1567	1263	1559	2053	1719
70	30	2101	2296	2398	2489	2616
65	35	2126	2360	2549	2632	2808
50	50	3909	4071	4619	4708	4851
0	100	5839	--	6669	--	--

*Immediate UCC Strength of Class ‘C’ flyash is 268kPa

For Class 'C' flyash alone, the 7 days cured sample yielded strength of 6668.86kPa, which is only 14% higher than the one day cured sample. Gray et al. (1972) reported UCC strength variation between 300 to 400 kPa for British flyash es corresponding to one day curing strength. Sridharan et al. (1997) observed a strength variation of around 80 kPa, 700KPa, 1100kPa and 1200 kPa corresponding to one day, 7d, 14d, and 28 days curing periods respectively for Neyveli flyash which belongs to Class 'C' flyash category.

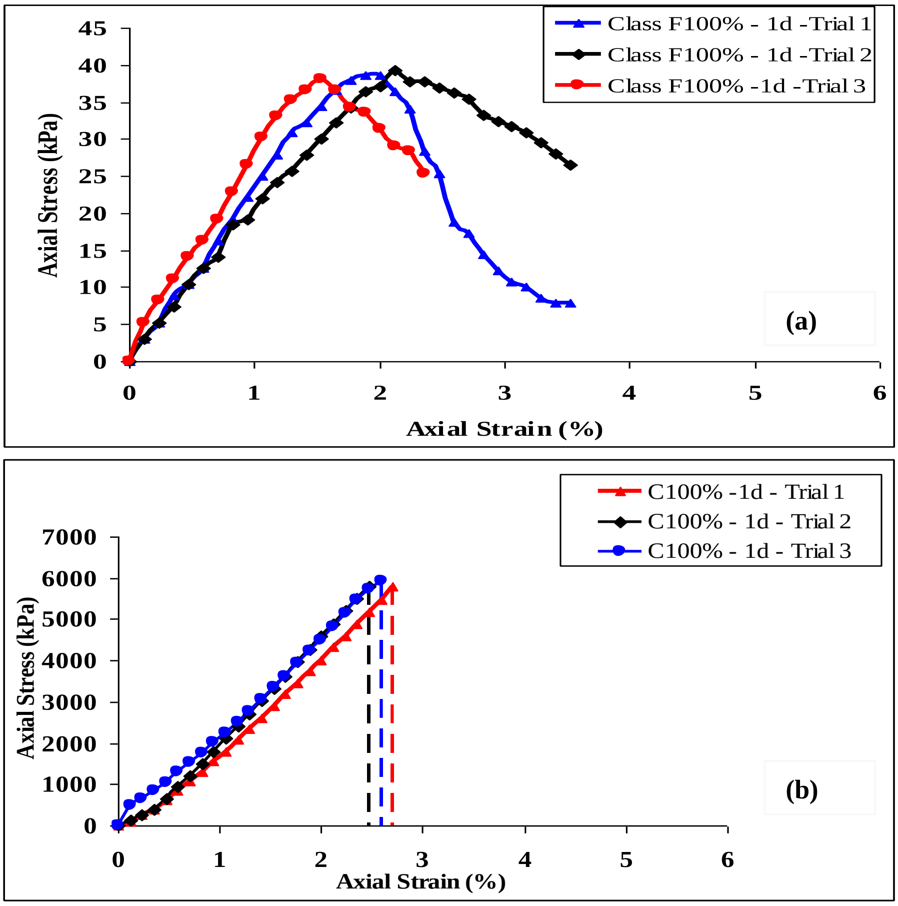


Fig. 6. Stress Vs Strain Curves of flyash Class 'F' and Class 'C' alone for One day curing

e. Effect of curing period on UCC Strength

The changes over the UCC strength is almost constant with curing periods for all the flyash Class 'C' and 'F' flyash combinations (Fig.7). However, the rate of change of strength for any curing period is very high with increasing percentage of flyash 'C' in flyash 'F' as seen from Table 1. Compared to Class 'F95% + C5% mix combinations, the enhancement of UCC strength corresponding to Class F50% + C50% flyash is varying between 15.9 times to the maximum of 19.38 times higher compared to the later. This trend only shows that effect of percentage of 'C' flyash in Class 'F' flyash overrides the effect of curing periods at any combinations (Fig. 8), which means that rather than the curing period the pozzolanic material present in Class 'C' flyash could effectively improve the Class 'F' flyash .

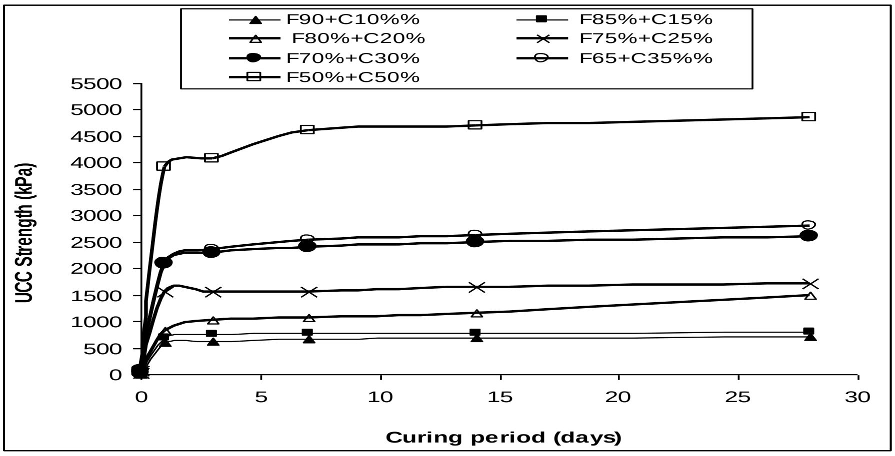


Fig. 7. UCC strength Vs curing period for Class ‘F’ + Class ‘C’ flyash mix combinations

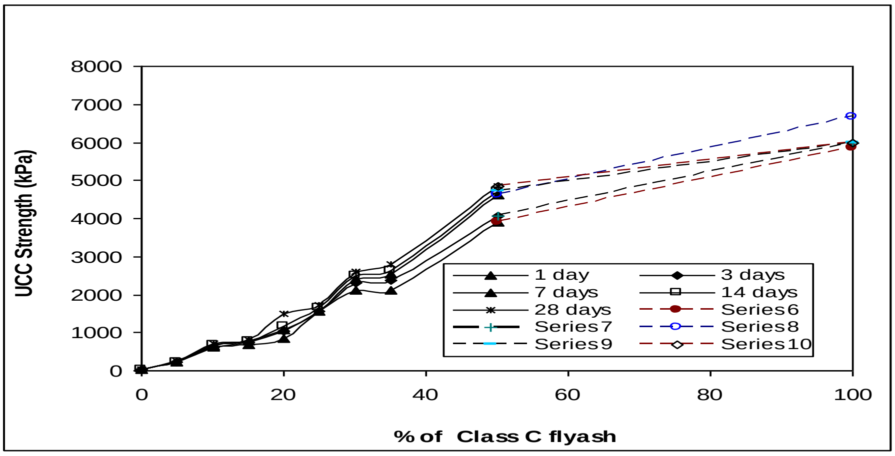


Fig. 8. UCC Strength Vs Percentage of Class ‘C’ Flyash in Class ‘F’. Curing Periods (1d, 3d, 7d, 14d and 28d).

f. CBR Characteristics of Flyash Mixes

Unsoaked CBR values

The unsoaked CBR of Class 'F' and Class 'C' flyash alone are 0.44% and 1.45% for 2.5mm penetration and 0.61% and 1.90% for 5mm penetration respectively without any curing periods. The CBR values of Class 'F' flyash increased from 0.44% to 2.67% for F65% + C35% combinations at 2.5mm penetration. There is an approximate 5 times increase of CBR value for flyash mix of Class F65%+C35% for 5mm penetration compared to Class 'F' flyash alone i.e.,. CBR value increased from 0.60 % to 3.22%. These variations only imply that Class 'F' is a suitable material as sub-base / subgrade on addition of Class 'C' flyash. The unsoaked CBR of results are for only immediate effect and it is expected that curing period would lead to further enhancement of CBR strength (Table 2).

Soaked CBR values

The variation of soaked CBR values for various Class 'F' and Class 'C' flyash mix for 2.5mm and 5mm penetrations are similar to unsoaked CBR value. The soaked CBR also increases with percentage of flyash Class 'C' in flyash Class 'F' but the increasing trend is on a higher side. From a soaked CBR value of 0.29% (for flyash Class 'F' alone), it has raised to 4.22% at F75% and C25% combinations of mix which is 14.5 times higher when compared with flyash Class 'F'' alone. The soaked CBR test could not be conducted for F65%+C35% mixes (Table 2). It is known that the wet curing generally enhances the pozzolanic reaction because of which the flyash specimen becomes very hard (Sridharan and Prakash, 2007).

Table 2. CBR test results for the Class ‘F’ flyash , Class ‘C’ flyash and the various combinations of Class ‘C’ in Class ‘F’ flyash

Flyash mix	Unsoaked CBR (%)		Soaked CBR (%)	
	2.5 mm	5 mm	2.5 mm	5 mm
Class ‘F’ flyash	0.44	0.61	0.23	0.29
Class ‘C’ flyash	1.45	1.90	Hardened	
C5% + F95%	0.84	1.12	0.60	0.80
C10% + F90%	0.36	0.42	0.74	0.97
C15% + F85%	1.52	2.49	3.70	4.43
C20% + F80%	1.56	2.04	3.85	4.87
C25% + F75%	1.67	2.73	4.15	4.22
C35% + F 65%	2.67	3.22	Hardened	

4 Conclusions

In order to improve the Class ‘F’ flyash by another type of Class ‘C’ flyash, experiments such as compaction, UCC strength, and CBR tests were conducted on varying percentage of Class ‘C’ flyash in ‘F’ flyash. From the analysis of test results, the following conclusions may be drawn.

While the maximum dry density keeps constantly increasing with percentage of flyash ‘C’ in flyash ‘F’, the optimum moisture content variation did not show any trend. The enhanced $\gamma_{d(max)}$ of Class ‘F’ flyash on the addition of Class ‘C’ flyash is mainly due to the better packing of coarse sized ‘F’ flyash with finer ‘C’ flyash in addition to the pozzolanic reaction and replacement of high specific gravity (G) Class ‘C’ flyash . (G of ‘F’ flyash = 1.92 and G of ‘C’ flyash = 2.57).

The UCC strength of Class ‘F’ flyash increases with ‘C’ flyash content by many folds (15 to 19 times) higher than that of Class ‘F’ flyash alone. The F95% + C5% flyash mix has ultimate failure strength of 300 kPa, the same is 3500 kPa for F50% + C50% flyash mixtures. Whereas, the UCC strength increases moderately with curing periods at any percentage combination of Class ‘F’ on Class ‘C’ flyash. More than the curing period, it is percentage of Class ‘C’ in Class ‘F’ flyash appears to govern the strength variations. This is attributed to the fact that the availability of pozzolanic material ‘CaO’ content in Class ‘F’ becomes high with increasing percentage Class ‘C’ flyash . (The ‘CaO’ content of Class ‘F’ flyash is hardly less than 5% and whereas for Class ‘C’ flyash CaO component is > 15%).

Thus it can be concluded that solid waste flyash ‘C’ can be used to stabilize flyash ‘F’ which paves the way for its large scale utilization for various geotechnical engineering applications.

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