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Improvement of Clayey Soil Using Fly Ash and Cement

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Abstract. Clayey soils are found in abundance in few regions of India. To improve its properties, local soil stabilization by addition of an admixture is important. Stabilizing the locally available weak soils is importance practice in construction industry. The widespread availability of fly ash which is a byproduct of coal combustion requiring effective disposal with bulk utilization on a continuous basis to avoid environmental pollution is widely used for such beneficial stabilization purpose. Many research on the performance assessment of soil-fly ash systems have been published in the literature. The primary goal of this research is to determine the optimal proportion of fly ash that may be added to soil with cement as a stabilising agent, as well as to analyse the index characteristics, influence of compaction, and compressive strength using an unconfined compressive strength (UCS) test. These experimental investigations were carried out for 13 different combinations. The first combination is only virgin clayey soil, followed by 3 combinations of clayey soil + fly ash, and 9 combinations of clayey soil + fly ash + cement. A little addition of cement even at 1% to the soil-fly ash mixes significantly increases the unconfined compressive strength. The unconfined compressive strength increases linearly for 7, 14 and 28 days curing period by about 12 to 30 %. The stabilization of clayey soil with fly ash using and cement is effective in order to enhance the compressive strength by about 6 times. The strength in compression is found to be higher in case of soil stabilized with 30% fly ash and 3 % cement i.e. soaked and un- soaked conditions, indicating the optimum performance of the mix with 30% fly ash at 3% cement content.

Keywords: Clay, Fly ash, Cement; Unconfined compressive strength

1 Introduction

Infrastructure development has been prioritized by our national planners. This has resulted in the enlargement of National Highways (NH) and the construction of new roads in India. Highway engineers have the challenge of supplying highly appropriate materials for highway building. As a result, individuals, corporations, and organizations have been doing and continue to conduct continual research on strategies to enhance the engineering qualities of soils. Because natural soil will not be readily accessible, it will be required to upgrade existing material for use as subgrade material. The majority of accessible soils lack the technical qualities required to withstand the estimated wheel load. So improvements must be done to improve these soils. This leads to the concept of soil stabilisation, which is any treatment (including, technically, compaction) applied to a soil to improve its strength and reduce its vulnerability to water. If the treated soil can withstand the stresses imposed by traffic under all weather conditions without excessive deformation, it is generally regarded as stable.

The present trends indicate need for alternative subgrade fill; hence a detail R&D to adopt regionally available soils and industrial by products such as flyash, slag etc. Also strict environmental regulations on dust nuisance involved with flyash require adequate control. The clayey soil is available abundantly in different parts of India covering Kerala, Rajasthan, West Bengal, Odisha, Karnataka, Gujrat, and Maharash- tra. Sarat Kumar Das and Yudhbir (2005) investigated the differences between low and high calcium fly ash. The research found that low calcium fly ash had less lime concentration than high calcium fly ash. When compared to low calcium fly ash, the strength growth with time for high calcium fly ash is quite considerable. The effect of fly ash on the volume change of expansive clay was presented by Phanikumar and Sharma (2007), who concluded that the compression index of both expansive and non-expansive clay decreased by about 50% at 20% fly ash content, indicating thatthe addition of fly ash reduced compressibility characteristics of both expansive and non-expansive clays. Yoon et al. (2009) investigated the field performance of fly ash and bottom ash as embankment fill and found that a maximum settlement of 80 mm was observed at the bottom of the embankments, with the settlement stabilizingroughly 5 months after the conclusion of embankment construction. Anagnostopoulos and Chatziangelou (2008) published a novel statistical model that describes the com- pressive strength of cement-stabilized soils. The model was developed based on ex- tensive laboratory research into the compressive strength of nine distinct silt clay soilsstabilized with varying amounts of cement. The laboratory data were utilized to createa non-linear regression equation that optimally links the compressive strength of a stabilized soil to the aforementioned descriptor variables. A study conducted byKalantari and Prasad (2014) on cement treated and moist cured (submerged in water during curing period) peat samples shows that the gain in unconfined compressive strength of the stabilized peat specimen was only significant after a minimal dosage of250 kg/m^3 binder with 75% (187.5kg) cement and 25% slag (62.5kg) used in the peat and cement mixture. With the quantity of binder increased to 300 kg/m^3, the UCS value reached 142.5 kPa, while the stabilized soil specimens provided a higher UCS value of 178.6 kPa.

Fly ash is not a waste product, but it is also detrimental to human health. According to the given literature, a substantial amount of work has been published on the performance assessment of soil-fly systems and fly ash-soil-cement systems. Keeping in mind some of the gaps in the literature on clayey soil improvement of flyash and ce- ment, an experimental research was conducted to determine the strength characteris- tics of flyash stabilized with varying percentages of cement with clayey soil. The performance of cohesive soil employing flyash with cement combination as fill or subgrade material is discussed in this research. The UCS test was used to assess the performance of clayey soil + flay ash + cement in various combinations. The study is to quantify the optimal amount of clay, fly ash, and cement on the strength parame- ters, which may have potential uses in providing a strong foundation for plastering and a strong road sub-base for rural roads. The following aims are given in this study.

1. To assess the influence of clay and fly ash on the engineering qualities of cement.
2. To investigate the performance of the composite system in terms of strength at various clay and fly ash concentrations.
3. To assess the mechanical qualities, namely the unconfined compressive strength, of the aforementioned composite material system.

2 Materials Used

Soil samples of high plastic clay (CH) and fly ash was collected from Gujarat Industrial Power Corporation Limited, Nani Naroli, Kim, of Surat district.

Table 1. Properties of clayey soil and fly ash.

Test		Physical Properties				Chemical Properties of Fly Ash (% content)	
		Soil		Fly-ash			
		Test 1	Test 2	Test 1	Test 2		
		% Passing					
IS Sieve size in mm [1]	4.75	100	100	100	100	SiO_2	24.30
	2.00	100	100	100	100	Al_2O_3	13.11
	1.00	97	96	100	100	Fe_2O_3	17.16
	0.425	95	95	100	100	TiO_2	2.51
	0.250	95	94	100	100	CaO	27.00
	0.075	76	75	79	78	MgO	0.32
Specific Gravity [2]		2.497	2.488	2.547	2.526	Na_2O	1.05
Liquid Limit [3]	Immediate	58	61	44	45	K_2O	0.16
	After 24 Hrs Soaking	-	-	51	52	SO_3	9.50
	After 48 Hrs soaking	-	-	62	61	LOI (Loss on Ignition)	4.78
Plastic Limit [3]		34	38	NP	NP	-	
Plasticity Index		24	23	-	-		
Standard Proctor Test [4]	MDD in kN/m^3	16.20	16.10	1.29	1.26		
	OMC in %	23.5	23.5	32.0	33.0		
Free Swell Index in % [5]		50	48	-	-		

Note: [1]Grainsize distribution as per IS 2720 Part 4. [2]Specific Gravity as per IS 2720 Part 3 Section I. [3]Liquid & Plastic Limit test as per IS 2720 Part 5. [4]Compaction test as per IS 2720 Part 7. [5]Free Swell Index test as per IS 2720 Part 40.

Physical properties of the soil sample were determined by standard laboratory tests. Physical and chemical properties of fly ash were also tested and results are presented in Table 1. The cement used in the investigation comprised of Ordinary Portland Cement (53 Grade). Cement used in the experimental programme is available from the retailer hardware shop.

3 Laboratory Results

Experiments are being conducted to evaluate the performance of clayey soil with fly ash utilising a cement system in 13 distinct combinations. The current study's goal is to analyse the index characteristics, compaction impact, and compressive strength by performing an unconfined compressive strength (UCS) test. The initial combination tested was merely virgin clayey soil, followed by three distinct combinations of clayey soil + fly ash and nine various combinations of clayey soil + fly ash + cement. Depending on the quantities of the mix, the ingredients were fully combined in a dry condition, and the specimens were created and stored in desiccators for humidity control curing. The optimal moisture content (OMC) and maximum dry density (MDD) of each of the 13 clayey soil, fly ash, and cement mixes were estimated using the standard proctor test. Table 2 displays the different combinations employed in the research on percentage by weight basis, as well as the related OMC and MDD.

Table 2. Various combination of clayey soil + fly ash + cement

Mix No.	Clayey soil (%)	Fly ash (%)	Cement (%)	OMC (%)	MDD kN/m^3
1	100	0	0	23.5	16.15
2	90	10	0	31.05	12.83
3	80	20	0	30	13.89
4	70	30	0	29.65	14.35
5	89	10	1	15.91	18.64
6	88	10	2	17.12	18.58
7	87	10	3	18.19	18.40
8	79	20	1	16.12	18.04
9	78	20	2	17.76	17.91
10	77	20	3	18.98	17. 86
11	69	30	1	17.24	16.89
12	68	30	2	17.76	16.70
13	67	30	3	18.16	16.65

The total number of unconfined compression test combinations is 13. Three identical samples were produced for each combination. The samples were made in a UCS cylindrical mould with a diameter of 38.10 mm and a height of 76.20 mm. The samples were dehydrated for 7, 14, and 28 days. They were then evaluated for compressive strength in both the soaked and unsoked conditions, with the results reported in Table 3.

It was discovered that increasing the fly ash and cement content, as well as the curing duration, results in an increase in strength. This is owing to a rise in the calcium content of fly ash, as well as better fly ash durability due to the formation of pozzolanic reaction with the addition of cement. As the percentages of fly ash and cement rise, the strength increases linearly. Even a 1% addition of cement to soil-fly ash mixtures greatly boosts the uncon-fined compressive strength. The unconfined compressive strength improves linearly by roughly 12 to 30% after 7, 14, and 28 days of cure. The use of fly ash and cement to stabilise clayey soil increases compressive strength by about 6 times. The strength in compression of soil stabilised with 30% fly ash and 3% cement is shown to be greater in both wet and un-soaked circumstances, showing that the combination with 30% fly ash at 3% cement content performs best.

Table 3. Results of UCS Test.

Sr. No	Clayey soil (%)	Fly ash (%)	Ce-ment (%)	7 days (Kg/cm^2)		14 days (Kg/cm^2)		28days (Kg/cm^2)	
				Un-soaked	Soaked	Un-soaked	Soaked	Un-soaked	Soaked
1	100	0	0	0.97	-	0.81	-	0.89	-
2	90	10	0	0.82	-	0.94	-	1.79	-
3	80	20	0	0.96	-	1.18	-	1.99	-
4	70	30	0	1.05	-	1.37	-	2.00	-
5	89	10	1	3.68	3.03	4.51	3.77	5.59	5.11
6	88	10	2	3.72	3.14	4.84	4.05	6.44	5.75
7	87	10	3	4.24	3.53	5.56	4.7	8.48	7.35
8	79	20	1	4.27	3.51	5.43	4.53	7.05	6.06
9	78	20	2	4.51	3.64	5.82	4.84	7.89	6.68
10	77	20	3	4.91	4.02	6.25	5.29	8.74	7.53
11	69	30	1	5.31	4.79	6.74	5.65	10.53	8.44
12	68	30	2	6.59	5.59	7.55	6.32	11.47	9.68
13	67	30	3	7.57	6.25	8.57	7.17	13.28	11.17

4 Conclusion

On the basis of the experimental investigations the following conclusions are drawn:

- The compressive strength increases linearly for 7, 14 and 28 days curing period by about 12 % to 30 %.
- The value of the UCS increases with increase in curing period.
- With the increase in curing period the durability of fly ash gets improved due to the formation of pozzolanic reaction with the addition of cement.
- The value of strength for soaked condition is about 15 % less than un-soaked condition.
- The stabilization of soil with fly ash using cement is effective in order to enhance the compressive strength by about 6 times.
- The strength in compression is found to be higher in case of soil stabilized with 30% fly ash content and 3 % cement i.e. soaked and un-soaked conditions, indicating the optimum performance of the mix with 30% fly ash at 3% cement content.

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