Durability Studies on Calcium Carbide Residue-Fly Ash

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Abstract. Present study investigates the possibility of using calcium carbide residue (CCR), a by-product of the acetylene production process, to enhance the engineering properties. For this purpose, unconfined compressive strength (UCS), and durability test was performed on Fly ash-CCR mix. The experimental results suggest that the properties improved with increase in curing period and CCR content. The highest strength improvements were attained with 6% of CCR. The excess $Ca(OH)_2$ in CCR reacts with fly ash and gives significant improvement of the strength and durability. The durability against wetting and drying (w-d) cycles of the FA-CCR mix is considered low according to the recommendations of the ASTM and can be marginally acceptable as a pavement sub-base material.

Keywords: CCR, Fly Ash, UCS, CBR, Durability

1 Introduction

The aim of the study presented in this paper is to use fly ash (FA) as pavement sub-base material. The most important reason for replacing conventional sub-base materials with fly ash is economy and waste utilization [9]. Additionally, fly ash sub-base may continue to increase its strength for a long time due to pozzolanic reactivity [4]. However, class F fly ash is not self-cementitious by itself, and therefore, in order to be used as a sub-base course for a road pavement, they should be mixed with a stabilizing agent. In this study fly ash (FA) were stabilized with calcium carbide residue (CCR).

Horpibulsuk et al. (2012) evaluated the use of fly ash (FA) and calcium carbide residue (CCR) to improve the strength of silty clay, appraising specifically the influence of moisture content, binder content, fly ash to calcium carbide ratio, and curing time [5]. Horpibulsuk et al. (2012a, 2013) and Kampala and Horpibulsuk (2013) investigated the engineering properties of the CCR stabilized clay to ascertain the performance in the fill and pavement applications. They proved that the CCR stabilization is more effective than the lime stabilization in terms of engineering, economical, and environmental viewpoints [6,7].

Kampala et al. (2014) studied the durability of silty clay stabilized with CCR and FA subjected to wet-dry cycles to determine how it would perform in pavements [8]. Their unconfined compressive strength analysis showed that the durability of these blends is related to their un-soaked strength prior to any wet-dry cycles [13]. Liu et al.

(2016) studied the feasibility of loess stabilization with fly ash–based polymer and observed that the binding effect of geopolymer gel contributed to the improvements in the mechanical properties of stabilized loess samples [1]. Phummiphan et al. (2017) studied the use of CCR and FA to develop geopolymer binders for stabilizing marginal lateritic soil as a sustainable pavement base.

The majority of previous studies have focused on the application of CCR for stabilizing natural and local soils[2,3,12]. However, very limited information exists in the literature regarding the performance of CCR stabilization with Fly ash.

The study of soil stabilization with a mixture of CCR and pozzolanic materials is an engineering, economic, and environmental challenge for geotechnical engineers and researchers. Present study can provide alternative construction material for those areas in which are lacking in land resources and aggregated rocks, whereas rich in fly ash.

2 Experimental Programme

2.1 Material Used

The experimental program was designed with the objective of investigating performance of fly ash (FA) from thermal power plants and calcium carbide residue (CCR) from oxygen industries which have rich binding properties as sub-base Material in pavement construction. Fly was collected from Eklahare thermal power station, Nashik, India and calcium carbide residue (CCR) from Nashik Oxygen industries, Nashik, India. The CCR was oven-dried at 100°C for 24 h and was also pulverized with a Los Angeles abrasion machine [11]. The CCR was passed through a sieve No. 40 (425 μm). The specific gravity of CCR was 2.4. The major chemical composition of CCR was 70.78% CaO, whereas the minor components were pozzolanic materials (SiO_2, Al_2O_3, and Fe_2O_3) of about 12.29%. The high $Ca(OH)_2$ and CaO contents of the CCR indicate that it can react with FA and produce cementitious products such as calcium silicate hydrate (CSH) (Kampala et al.2014).

2.2 Testing Programme

Several laboratory tests were conducted to evaluate the properties of Fly ash –CCR Mix.

In the first step, the Modified proctor test was conducted by varying the proportions of water for each of the mixes. Optimum moisture content (OMC) and Maximum dry density (MDD) were determined as per IS:2720 (part VIII) 1983 for various percentage of fly ash and calcium carbide residue. Table 1 summarizes the compaction results.

UCS samples were prepared using fly ash and CCR (0, 3, 6, and 9% of weight of fly ash). Total 48 samples were prepared for various mixes. The effects of CCR content on strength of the fly ash-CCR mix have been studied by varying the CCR content from 0% to 9%. The compressive strength of the mixes was determined after 0, 7, 14 and 28 days of curing period [13].

Furthermore, to investigate the durability of the stabilized Fly ash samples, the durability testing was carried out on the optimum combination of fly ash-CCR mix. In this test specimens were cured for 28 days before subjected to several alternate wetting and drying cycles instead of 7 days (specified in ASTM D559-2003) due to the slow development of strength (as adopted by Murthy et al. 1997). One such cycle consisted of 5 hours of soaking in water and 42 hours of heating at 70˚C in a thermostatically controlled oven. After completion of twelve such cycles the weights of the samples were determined.

Table 1. Values of OMC and MDD for various Fly ash- CCR Mixes

CCR (%)	OMC (%)	MDD (gm/cc)
0%	13.66	1.45
3%	14.20	1.49
6%	14.60	1.55
9%	15.09	1.58

3 Results and Discussion

3.1 Compaction Characteristics

Table 1 summarised result of optimum moisture content (OMC) and maximum dry density (MDD). Optimum moisture content was increased with increased in CCR content, due to the water holding capacity of calcium carbide residue. Also, with increase in CCR content, the maximum dry density (MDD) increases due to packing effect.

3.2 Unconfined Compressive Strength Test

Fig 1 shows the variation of compressive strength on different mixes with CCR content. The UCS values of the FA-CCR stabilized with 6% CCR content indicate highest strength with increasing curing period.

The UCS values of the FA-CCR stabilized mix started to decrease when the CCR content exceeded 6 %. [Figs. 1 and 2)]. The UCS reduction can be attributed to the increase in the positive surcharge and the subsequent repulsion of soil particles inside the mixture (Latifi et al. 2016a; Marto et al. 2014). The UCS reduction could also be due to the amount of alkaline stabilizer (pH 12.2) [10], which exceeded the requirement for chemical reactions in the specimens (Latifi et al. 2014; Yilmaz and Civelekoglu 2009). Hence, 6% of CCR were chosen as the optimum dose.

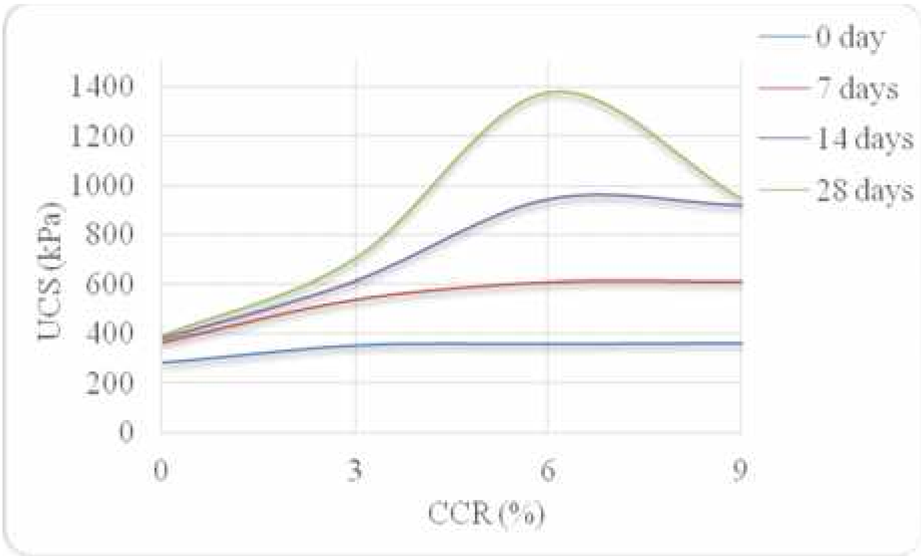

Fig. 1. Variation of UCS value with CCR content

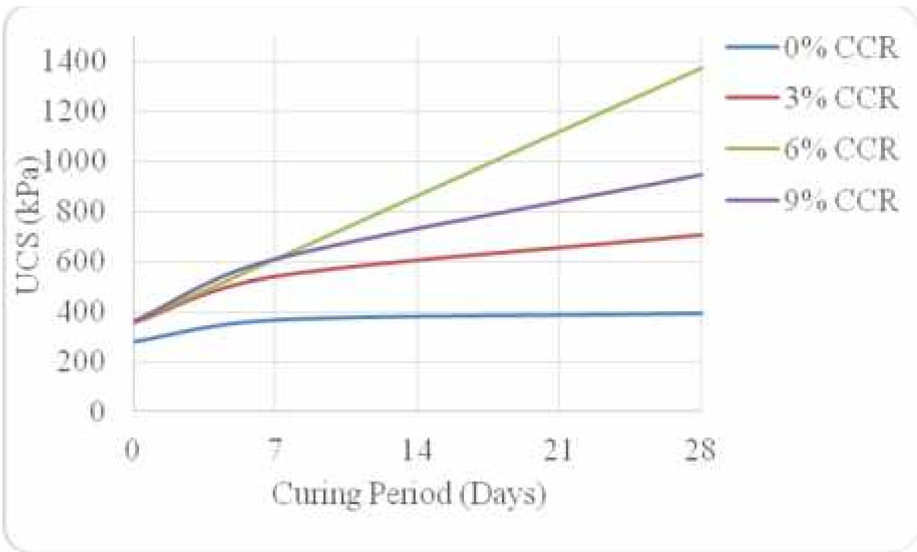

Fig. 2. Variation of UCS value of CCR mix with Curing Period

Fig. 2 shows that the strength increases with increase in curing period for all types of mixes. The major strength gain in the mix is attributed to pozzolonic reaction. With increase in curing period, the gel formation increases which binds more fly ash and CCR leading to increase in strength.

3.3 Durability test

For stabilized materials, apart from the strength gain, durability plays a significant role. Durability against wetting and drying is important because in most of the geotechnical applications [14], stabilized fly ash is subjected to repeated cycles of wetting and drying. The loss in weight was calculated. The total weight loss of the samples was calculated after 12 cycles of drying and wetting was 17.5%.

4 Conclusions

This paper proposed a material composed of fly ash mixed with calcium carbide residue for the construction of road sub-base. Various tests including compaction characteristics, unconfined compressive strength, durability tests were performed to evaluate the material properties and road performance of CCR stabilized fly ash. Based on the study following conclusions can be drawn:

It is observed that with the increase in CCR percentage in mix, the value of OMC and MDD increased.

As per IRC SP: 20 -2002, the minimum laboratory UCS value of Lime-fly ash mix after 28 days curing should be 1500 kPa for use in sub-base course. From the UCS test results it was found out that the mix of fly ash + 6% CCR marginally reach to UCS value of 1375 kPa.

Durability tests performed on the optimum mix of fly ash-CCR. It showed weight loss is 17.5%. Hence, the optimum mix meets the durability criteria (maximum 20%) as per IRC: SP: 89:2010.

The study depicts CCR stabilizing fly ash has potential to be used as a pavement sub-base layer material and in similar applications, where traditional semi-rigid materials used.

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