Characterisation of Soft Soil Microstructure Stabilised With Binary Blending Using Two Waste Fly Ashes

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Abstract:

This paper represents an investigation on the microstructures of soil stabilised with binary blending using two different types of waste fly ashes. The microanalysis was conducted in order to realise the improvement in the strength of the stabilised soil. The soil used in this study was an intermediate plasticity silty clayey soil with medium organic matter content. FA1 was optimised in a previous study dependant on the unconfined compression strength (UCS) test conducted on specimens of soil treated with various percentages of FA1. The optimum percentage of FA1 was 12% of the dry weight of the soil. In this study, UCS test was conducted on specimens of soft soil treated with 12% of binder produced by binary blending of FA1 and FA2 with different proportions and the specimens were kept for curing at different periods (3, 7, 14, and 28 days) prior to being subjected to UCS testing. Scanning electronic microscopy (SEM) testing was employed to investigate the mechanism of strength improvement in the most remarkable soil-binder mixture. The results showed a significant development in stabilised soil strength. Moreover, the bond building sequences and subsequent changes in the microstructures of the stabilised soil due to the chemical reaction of the added fly ashes were observed.

1. Introduction:

The self-cementing property for some of waste materials, and pozzolanic property for others have been motivating researchers to conduct laboratory experimental works to produce new cementitious materials since the mid-nineties of the last century [1]. Moreover, many researchers have adopted binary, ternary and even quaternary blending systems to produce new cementitious materials from different types of waste materials and fly ashes [2 – 5].

Many researchers have concentrated their experimental works to study the improved properties of stabilised soil, however a low number of researchers investigated the mechanism of how these improvements happened. Therefore, this study elucidates the changes in the microstructures in stabilised soils using cementitious materials to provide a clear understanding about the hydration kinetics taking place in the microstructures of soil stabilised by binary blending using two different fly ashes. Scaning electronic microscopy testing (SEM) was employed in this study to observe the changes in microstructures of the soil specimens trteated with unary and binary mixtures of the fly ashes used in this study after being subjected to different periods of curing (3, 7, and 28 days). Additionally, the optimum binary blending paste was also investigated by SEM for the same periods of curing to observe the hydration reactions and the formation of ettrengite and cementitious products.

2. Materials and methods:

2.1 Soft Soil:

An intermediate plasticity silty clay soil was used in this study. The soil samples were extracted from a shallow depth ranged between 300 – 500mm below the ground level from the riverbank of the River Alt in High Town which is located to the north of Liverpool city centre in the United Kingdom. The main properties of the soil used in this study are illustrated in Table 1.

Table 1: Main properties of the soft soil used in this study.

Property	Value
NMC %	52.14
LL %	44
PI	20.22
Sand %	13.08
Silt %	43.92
Clay %	43.00
Specific Gravity (Gs)	2.57
MDD g/cm^3	1.57
OMC %	23
pH	7.78
Organic Matter Content %	7.95
UCS of compacted soil (kPa)	202

g/cm^3= gram/cubic centimetre, kPa = kilopascal.

2.2 Fly Ashes:

The fly ashes employed in this study were two different types of waste materials produced from incineration processes in local power plants using different types of fuel. The first fly ash (FA1) has high calcium content while the other fly ash (FA2) has significant amount of pozzolanic compounds (silica dioxide (SiO2), Aluminium oxide (Al2O3) and iron oxide (Fe2O3)).

2.3 Methods and samples preparation:

Several specimens of soil treated by 12% of binary blending with different proportions of FA1 and FA2 were prepared for UCS testing with standard dimensions of 38mm in diameter and 76mm in height. The specimens were subjected to different periods of curing 3, 7, 14, and 28 days under a degree of temperature about 20ºC and 100% humidity using a humidity cabinet prior to testing. The UCS test was carried out according to BS 1377-7:1990 [6]. Table 2 illustrates the mixing procedure for FA1 and FA2 percentages which were added by 12% of the dry weight of the stabilised soil in this study.

Table 2: Mixing proportion of FA1 and FA2

No.	Mixture ID	FA1 %	FA2 %
1	Virgin soil	0	0
2	U	12	0
3	BM1	10.5	1.5
4	BM2	9	3
5	BM3	7.5	4.5
6	BM4	6	6

3. Results and Discussion:

3.1 Unconfined Compressive Strength (UCS) Test:

The results of UCS tests for the soil treated with different types of binary mixtures are shown in Figure 1. The results indicated that there was a significant improvement in the strength of the stabilised soil with the use of binary blending. However, the results indicated that BM2 was the optimum mixture which provided the highest value of UCS.

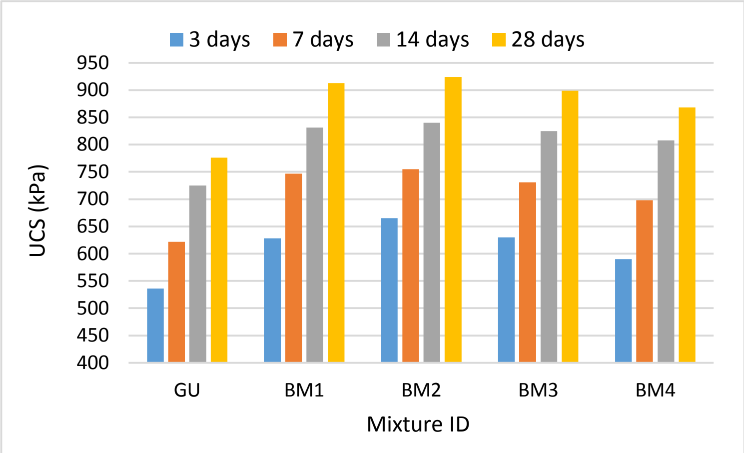
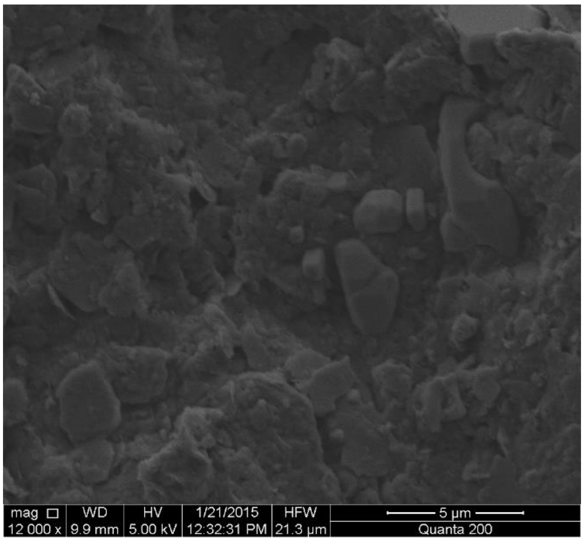


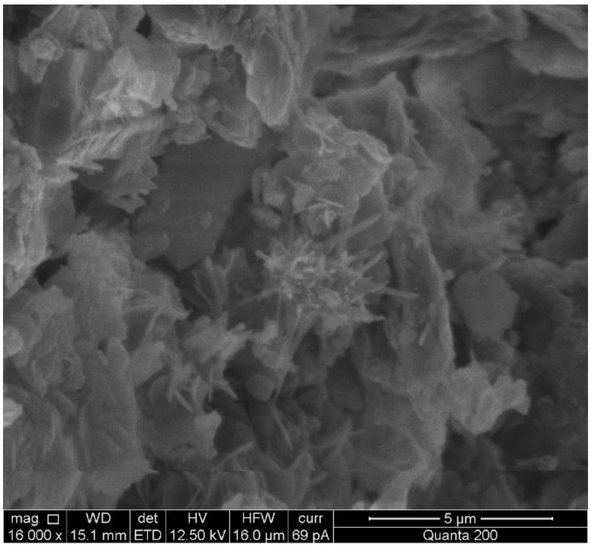
Figure 1: Effect of binary blending on UCS of stabilised soil in different curing periods.

3.2 Scanning Electronic Microscopy (SEM) Test:

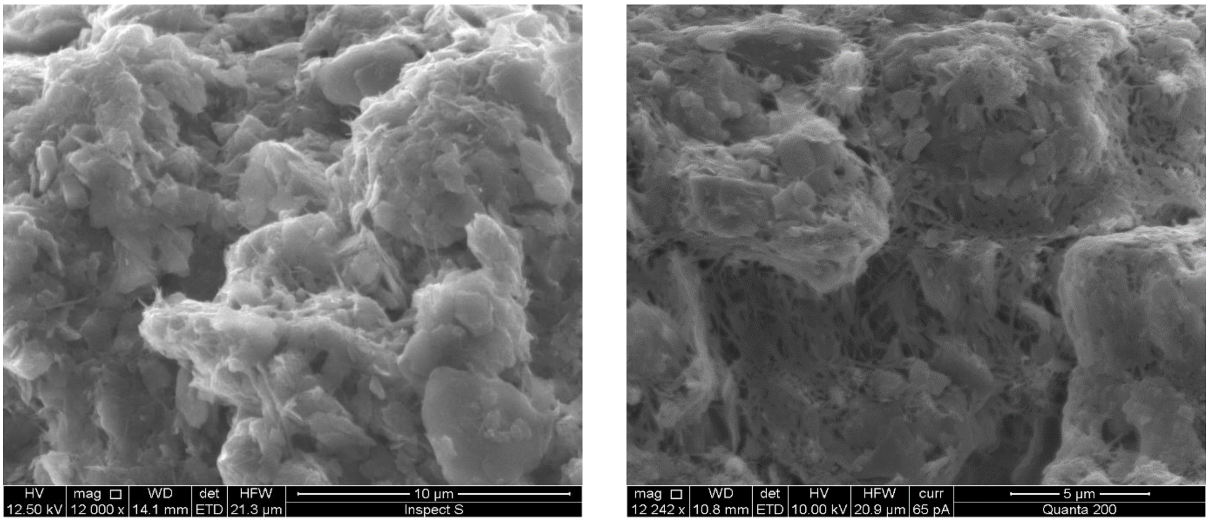
Specimens of compacted untreated soil and soil stabilised with 12% of BM2 were prepared for SEM testing. The soil treated with BM2 were subject to different periods of curing (3, 7, and 28 days) prior to being subjected to SEM testing to investigate the subsequent changes in microstructure of the treated soil throughout the time of curing. Figures 2 (a to d) show the SEM images for untreated soil and 3, 7, 28 days of age of soil treated with 12% of BM2.



(b) Untreated soil



(a) 3 days



(d) 7 days (c) 28 days

Figure 2: SEM test images for (a) untreated soil, and (b), (c), and (d) Soil treated with 12% BM2 with age of curing of 3, 7, and 28 days respectively.

It can be seen that there were clear changes in the microstructures over the time of curing; these changes are characterised by the creation of calcium silicate hydrate compound (C-S-H) in addition to the needle shape particles (ettringite) which formed due to the hydration reaction after mixing BM2 grains with water.

4. Conclusions:

- Results of UCS testing indicated that the use of FA2 in the binary mixture was very effective to enhance the soil strength in comparison to that for soil treated with FA1 only. The results revealed that the optimum binary mixture was BM2 which resulted from mixing 9% FA1 and 3% FA2 by the dry weigh of treated soil.
- Binary blending of FA1 and FA2 (BM2) was found very effective as a binder in soil stabilisation. The soil strength in this study was increased significantly from 200kPa for untreated soil to 924kPa for the soil treated with 12% of BM2 with 28 days of curing; this improvement represents more than 4.5 times that of the UCS for compacted original soil.
- Furthermore, it could be concluded that C-S-H and ettringite, which were produced due to the hydration reaction processes, contributed to the overall strength development of the soil stabilised with the binary mixture.

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