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Energy Absorption, Secant Modulus and Compressive Strength of Fiber Reinforced High Fly Ash Content Cement Treated Soil

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Abstract: ***This paper presents the results of an experimental investigation that was conducted to study the behavior of fiber-reinforced, high fly ash content and cement treated soil specimens under unconfined compression tests. The effect of fiber inclusions, curing time and fly ash-cement (FA/C) ratio on unconfined compressive strength (UCS), energy absorption (E_A), secant modulus of elasticity (E_S) and brittleness index (I_B) have been studied. Fly ash of 50% and 70%, and cement content of 1.5% and 2% by weight of soil were used in this study. The fly ash and cement as a cementing agent played a significant role in increasing the compressive strength. The unreinforced mix specimens showed a significant improvement in UCS. The fiber inclusions further increased the compressive strength and improved the ductility of the mix specimens. The increase in fiber inclusion was observed to have an increasing effect on UCS, energy absorption, and secant modulus. The increase in curing period (0, 7, 14 and 28 days) also had similar effect on UCS, E_A, and E_S. However, the increase in fiber content decreased the brittleness index whereas the increase in FA/C ratio increased the brittleness index of the mix specimens. The study suggests a viable method for improving UCS and reduce brittleness of the soil media which may be beneficial for subgrade stabilization.***

***Keywords* : Brittleness index, Energy absorption, Fiber, Secant modulus, Stabilized soil.**

I. INTRODUCTION

Different methods of soil stabilization have been studied and reported by many researchers. One of them is soil stabilization using fly ash, lime or cement. This method has proved advantageous in improving weak soil by adding additives that are locally available. Additives such as fly ash, lime are pozzolanic in nature, which has cementing property when mixed with water or added with a small amount of cement under favorable conditions. However, with the improvement in strength, its brittleness also increases. This brittleness of mix specimens can be improved by the addition of fibers. The reinforcement in the form of fibers of different nature added to soil mass is reported to improve the strength significantly. The use of synthetic fibers such as polypropylene fiber [1]-[3], glass fiber [4]-[6], tyre chips [7], coir fiber [8], plastic waste [9] have been studied and reported to be beneficial in improving the strength of soil. Consoli, Prietto [10] studied the influence of cement and glass fiber in sandy soil and reported that the addition of cement increases stiffness, brittleness and peak strength, fiber inclusions increased both peak and residual strength and it also made the cemented soil specimens more ductile in behavior.

Fly ash is a fine residue which is collected from thermal power plants after the burning of coal. The worldwide production of coal is growing every year and is causing environmental problems when disposed of in an open field or in water bodies. Therefore, the significance of more research work to strengthen its proper utilization on a large scale will play an important role in preserving our environment. Fly ash is a silt-sized non-cohesive material with specific gravity relatively smaller than that of the soil. Fly ash, being a pozzolanic material has been explored extensively by researchers to improve the strength properties of weak soil. [11] reported the use of class F fly ash amended soil to be beneficial as highway base materials. [12] reported that the expensive soil can be successfully stabilized by adding both high-calcium and low-calcium class C fly ash. [7] reported that the unconfined compressive strength of fly ash-lime-gypsum mixes reinforced with tire chips increases with increase in curing period and was significant up to 90 days. The effect of curing temperature on the strength of sand-fly ash-lime mixes was studied by [13], they reported that temperature is an efficient catalyzer up to threshold and does not further enhance strength after extinction of soil-lime-fly ash reactions. [14] reported that a higher temperature accelerates the pozzolanic reaction, resulting in rapid soil strength development for a lime treated highly expansive and extremely plastic clay soil. The fiber inclusions increase the strength of soil-fly ash as well as cement stabilized specimens and also change their brittle behavior to ductile behavior [15]. [10] reported that addition of cement to soil increases stiffness and peak strength. The peak friction angle of soil increases due to fiber inclusions and reduces the brittleness index of the cemented soil. [4] studied soil reinforcement using a combination of glass-fiber-reinforced polymer pipe and pressure grouting and observed that the increase in grouting pressure provided a higher pullout resistance and it was a viable alternative for soil nailing for slope stabilization. [16] studied the stress-strain-strength behavior of an artificially cemented sandy soil produced through the addition of cement. [17] conducted experimental work to study the strength and dilatancy of silt stabilized with the addition of cement-fly ash mixes in a slurry form.

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[18] studied the effect of cement content, curing period, and curing conditions on the development of the strength of stabilized Class F fly ashes with reference to their use as pavement base courses. This paper presents the result of an extensive unconfined compression test conducted on soil-fly ash-cement mixes of both reinforced and non-reinforced specimens. Curing periods of 0, 7, 14 and 28 days were followed for each set of specimens. The peak compressive strength and residual strength were studied. Effect of fiber inclusion, curing time, fly ash-cement ratio on unconfined compressive strength (UCS), energy absorption (E_A), secant modulus of elasticity (E_S) and brittleness index (I_B) have been studied and discussed.

II. MATERIALS AND METHODS

A. Soil

The soil used for the study was procured from Karsingsa, India. The soil was characterized as sandy soil having 96% of sand, which included 21%, 67% and 8% of course, medium and fine sand respectively. The soil was poorly graded having coefficient of uniformity (C_u) = 4.61. The grain size distribution curve of the soil is shown in Fig. 1. The maximum dry density (MDD) and optimum moisture content (OMC) of the soil were 17.95 kN/m^3 and 13.69% respectively.

B. Fly Ash

The fly ash used in this study was a class F type with low lime (CaO). The grain-size distribution curve of the fly ash is shown in Fig. 1. The fly ash contained, silt-sized=71%, sand-sized=21% and clay-sized=8%. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) of fly ash were 3.75 and 0.96, respectively. The specific gravity of the fly ash was 2.4. The MDD and OMC were found to be 13.83 kN/m^3 and 18.34% respectively. For typical fly ashes in India, the specific gravity lies between 1.99 to 2.55 and maximum dry density between 9 kN/m^3 16 kN/m^3 with optimum moisture content between 18% to 38% [9]. The chemical compositions of the fly ash were, SiO_2=43.94%, Al_2O_3=33.60%, Fe_2O_3=4.40%, CaO=12.73%, MgO=0.21%, loss on ignition 2.32%. In this present study fly ash content of 50% and 70% by dry weight of soil was used.

C. Cement

The cement used in this study was Ordinary Portland Cement (OPC) of 53 grade. The specific gravity of the cement used was 3.15. The cement content was varied from 1.5 to 2% by dry weight of soil.

D. Glass Fiber

Glass fiber used in this study as a reinforcing agent was kept 30 mm in length. The thickness of an individual fiber varied from 10 to 12 μm and some single strand of fiber contained many individual fibers. The specific gravity of glass fiber was 2.55. The percentage of fiber used in this study was 0.25, 0.5, 0.75 and 1%.

E. Mix Designations

In this study, the mix designations were followed to represent different mixed specimens. Letters used for indicating different materials include *S* for soil, *FA* for fly ash, *C* for cement and *F* for glass fiber. For example, a mixed specimen represented as *S*70*FA*2*C*1*F* indicates a combination of soil with 70% fly ash, 2% cement and 1% fiber content.

III. RESULTS AND DISCUSSION

A. Compaction Tests

Standard proctor tests were conducted for soil with different mix proportions. The tests were conducted as per [19]. The water content and dry density curve are shown in Fig. 2. For soil with 1.5% cement, when fly ash was increased from 50% to 70%, the MDD decreased from 17.24 kN/m^3 to 16.78 kN/m^3, and MDD decreased from 17.64 kN/m^3 to 16.82 kN/m^3 for 2% cement content. For soil with 50% fly ash, MDD decreased from 17.95 kN/m^3 to 15.46 kN/m^3 and OMC increased from 13.69% to 16.78%. For soil with 70% fly ash, MDD decreased from 17.95 kN/m^3 to 14.56 kN/m^3 and OMC increased from 13.69% to 17.32%. It was observed that with the increase in cement content, MDD increased and OMC decreased. A similar kind of result was obtained by [20] for sandy soil treated with cement and attributed this result to the presence of large, high-density aggregate particles. [21] also reported that a similar observation for fly ash mixed silty sand. The increase in MDD of sand-cement mix can be attributed to the higher specific gravity of the cement which occupies the voids in the soil media.

The fly ash inclusion had the opposite effect of cement, which decreased the MDD and increased the OMC. The lower specific gravity of fly ash, than the soil, causes MDD to decrease as the percentage of fly ash is increased. The increase in OMC can be attributed to the presence of a hollow spherical shape of fly ash particles called cenosphere. These hollow spheres tend to absorb water which increases the moisture retention capacity of soil-fly ash mix, thus increasing the OMC. [22] reported a similar effect of fly ash in MDD and OMC.

B. Unconfined Compression Tests

The unconfined compression tests were conducted on soil-fly ash-cement mixes in accordance with [23]. Table 2 shows the unconfined compression strength (q_u) and the residual strength (q_{res}) for reinforced and unreinforced mix specimens. Fig. 3 shows the stress-strain curve of unreinforced soil treated with fly ash and cement. The unreinforced specimens had a clear and distinct peak failure stress and showed a brittle behavior. The addition of fiber reinforcement showed a significant improvement in terms of ductility of the specimens. Fig. 4 shows the stress-strain curve for fiber-reinforced specimens. The lowest UCS (201 kPa) was observed for unreinforced soil with 70% fly ash and 1.5% cement without curing. With the fiber inclusion the peak UCS increased up to 682 kPa, and the residual stress increased from 108 kPa to 545 kPa. However, the highest UCS (803 kPa) was obtained for soil stabilized with 70% fly ash, 2% cement and 1% fiber content.

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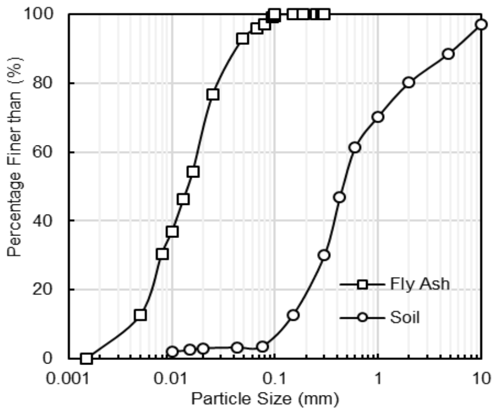

Fig. 1. Grain size distribution curve of Fly Ash and Soil

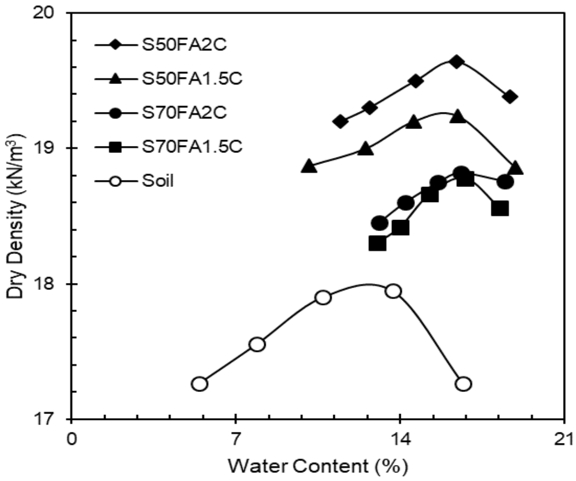

Fig. 2. Water content and dry density curve of soil with different percentages of fly ash and cement

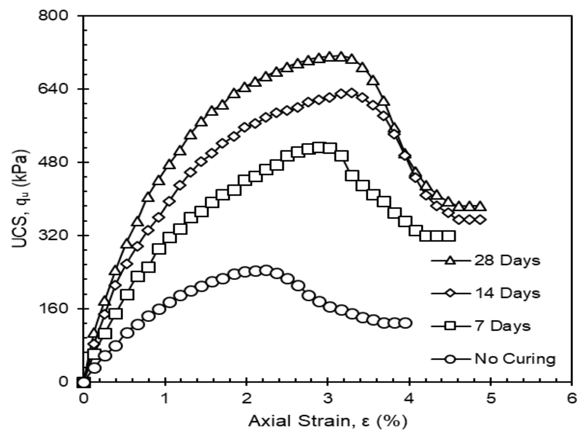

Fig. 3. Stress-strain curve for unreinforced soil stabilized with fly ash and cement at different curing time

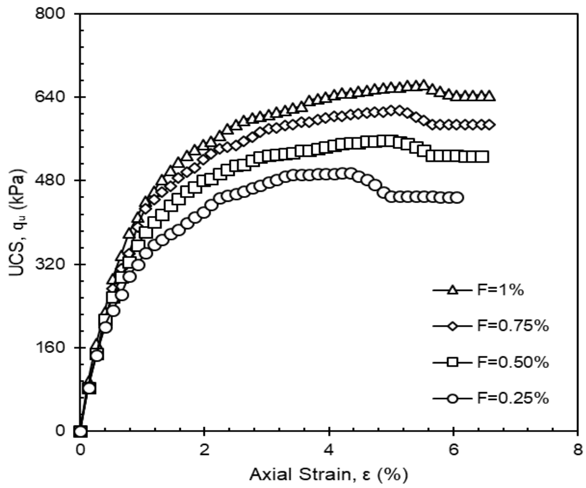

Fig. 4. Stress-strain curve for fiber reinforced soil stabilized with fly ash and cement

Table 1. Maximum dry density and optimum moisture content of soil-fly ash-cement mixes with different fiber content

Mix	Fiber content (F)							
	F=0.25%		F=0.5%		F=0.75%		F=1%	
	MDD (kPa)	OMC (%)	MDD (kPa)	OMC (%)	MDD (kPa)	OMC (%)	MDD (kPa)	OMC (%)
S50FA1.5C	16.86	11.68	16.24	11.64	16.68	11.78	16.24	11.88
S50FA2C	17.10	11.21	16.68	11.62	16.84	11.72	16.20	11.80
S70FA1.5C	16.48	14.22	15.22	14.21	15.68	13.62	15.62	12.88
S70FA2C	16.68	14.10	15.20	14.00	15.98	13.48	15.82	12.64

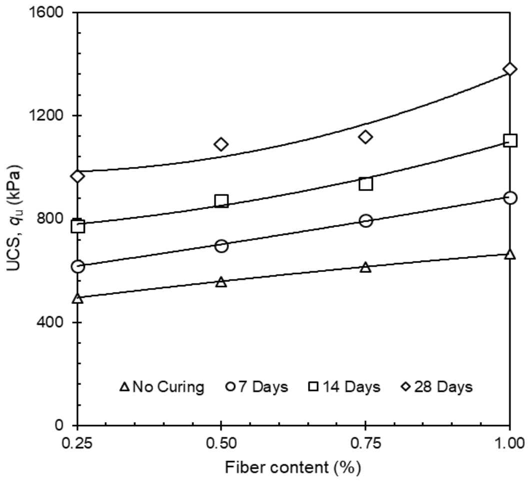

Fig. 5. Variation of UCS for fly ash-cement stabilized soil with different fiber content at different curing time

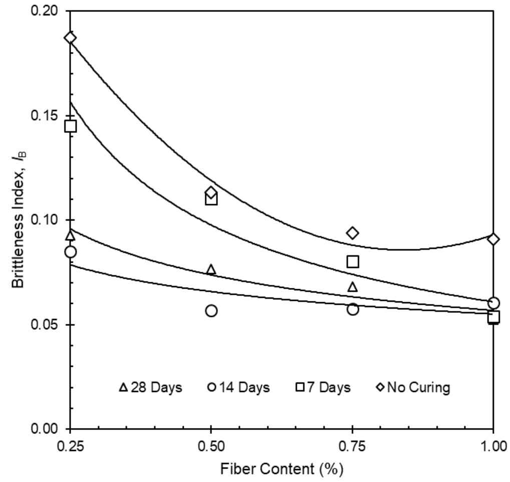

Fig. 8. Variation of brittleness index with fiber content for fly ash-cement stabilized soil at different curing time

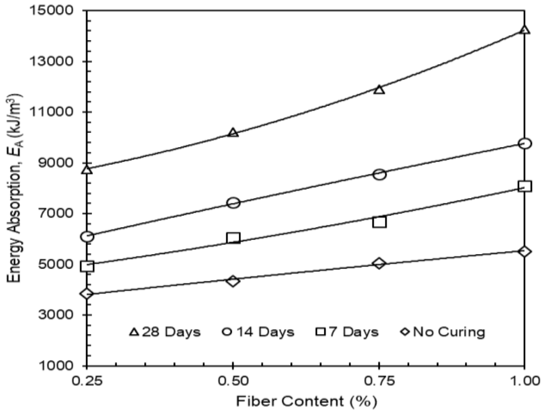

Fig. 6. Variation of energy absorption with fiber content for soil stabilized fly ash and cement at different curing time

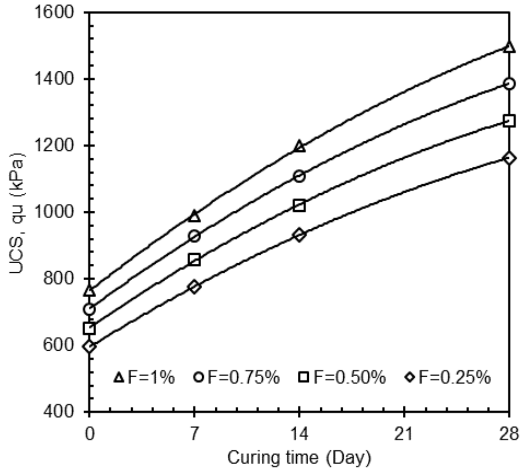

Fig. 9. Variation of unconfined compressive strength at different curing time for reinforced soil stabilized with fly ash and cement

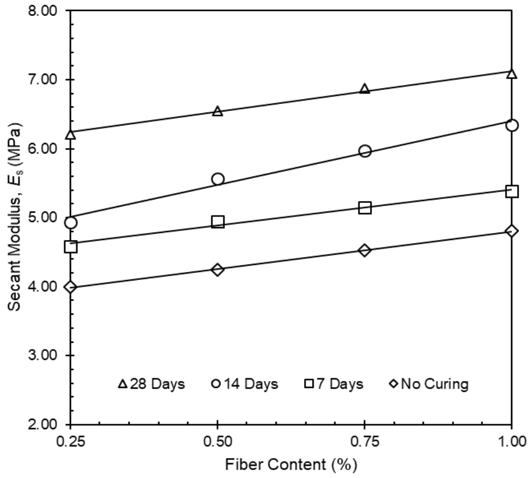

Fig. 7. Variation of secant modulus with fiber content for soil stabilized with fly ash and cement at different curing time

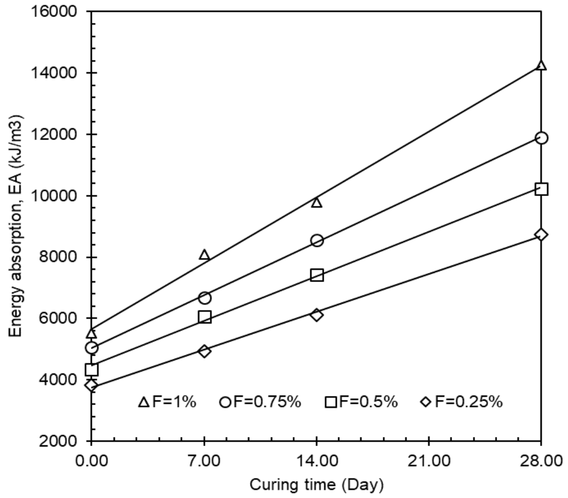

Fig. 10. Variation of energy absorption with curing time for fly ash-cement stabilized soil

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Table 2. Different parameters of reinforced and unreinforced fly ash-cement stabilized soil specimens at curing time of 0 day and 7 days.

Mix	Curing time									
	No curing					7 days				
	q_u (kPa)	q_{res} (kPa)	E_A (kJ/m^3)	E_S (MPa)	I_B	q_u (kPa)	q_{res} (kPa)	E_A (kJ/m^3)	E_S (MPa)	I_B
S50FA1.5C	225	132	508	3.68	0.70	413	272	1298	4.87	0.52
S50FA2C	291	162	707	4.27	0.80	502	327	1516	5.92	0.54
S70FA1.5C	201	108	343	4.28	0.86	464	298	956	7.89	0.56
S70FA2C	245	130	364	5.47	0.88	512	320	984	8.37	0.60
S50FA1.5C0.25GF	495	450	1702	5.69	0.10	619	580	2026	6.74	0.07
S50FA1.5C0.5GF	558	528	2256	5.65	0.06	698	658	2643	6.89	0.06
S50FA1.5C0.75GF	615	588	2540	5.94	0.05	795	754	2836	8.05	0.05
S50FA1.5C1GF	664	644	2966	6.00	0.03	884	837	3527	8.36	0.06
S50FA2C0.25GF	596	529	2817	5.63	0.13	778	678	3110	6.75	0.15
S50FA2C0.5GF	653	596	3226	5.78	0.10	859	753	3721	7.02	0.14
S50FA2C0.75GF	710	649	3670	5.80	0.09	928	813	4388	7.04	0.14
S50FA2C1GF	767	726	4050	5.93	0.06	989	897	4904	7.37	0.10
S70FA1.5C0.25GF	531	444	2899	3.70	0.20	689	595	3678	4.73	0.16
S70FA1.5C0.5GF	594	497	3223	4.35	0.20	743	660	4433	4.85	0.13
S70FA1.5C0.75GF	648	545	3772	4.59	0.19	810	735	5424	4.85	0.10
S70FA1.5C1GF	682	588	3816	4.68	0.16	889	811	6492	5.10	0.10
S70FA2C0.25GF	621	523	3833	4.00	0.19	776	678	4927	4.58	0.14
S70FA2C0.5GF	679	610	4348	4.24	0.11	897	808	6061	4.95	0.11
S70FA2C0.75GF	746	682	5055	4.53	0.09	968	896	6682	5.14	0.08
S70FA2C1GF	803	736	5515	4.81	0.09	1039	986	8089	5.38	0.05

Table 3. Different parameters of reinforced and unreinforced fly ash-cement stabilized soil specimens at curing time of 14 days and 28 days.

Mix	Curing time									
	14 days					28 days				
	q_u (kPa)	q_{res} (kPa)	E_A (kJ/m^3)	E_S (MPa)	I_B	q_u (kPa)	q_{res} (kPa)	E_A (kJ/m^3)	E_S (MPa)	I_B
S50FA1.5C	538	320	1547	7.15	0.68	637	375	1348	11.29	0.70
S50FA2C	617	361	1796	7.71	0.71	721	415	1874	10.54	0.74
S70FA1.5C	592	347	1396	8.68	0.71	656	361	1564	10.72	0.82
S70FA2C	631	355	1485	9.92	0.78	712	385	1641	10.44	0.85
S50FA1.5C0.25GF	773	705	2723	7.47	0.10	967	871	3979	8.06	0.11
S50FA1.5C0.5GF	872	822	3216	8.06	0.06	1090	101	4771	8.73	0.08
S50FA1.5C0.75GF	937	888	3807	7.97	0.06	1118	101	5125	8.64	0.10
S50FA1.5C1GF	110	105	4533	9.78	0.05	1381	129	6393	10.48	0.07
S50FA2C0.25GF	931	835	4087	7.33	0.12	1164	103	4795	10.10	0.12
S50FA2C0.5GF	102	918	4859	7.74	0.11	1275	116	5727	10.04	0.10
S50FA2C0.75GF	110	999	5564	8.13	0.11	1387	122	7149	9.82	0.13
S50FA2C1GF	119	108	6323	8.60	0.11	1498	144	1069	8.51	0.04
S70FA1.5C0.25GF	830	738	4857	5.26	0.12	1037	935	6303	6.39	0.11
S70FA1.5C0.5GF	928	810	5603	5.72	0.15	1160	104	7050	6.85	0.11
S70FA1.5C0.75GF	982	884	6674	5.64	0.11	1266	113	8956	6.98	0.11
S70FA1.5C1GF	106	100	7611	6.04	0.06	1304	120	1028	6.93	0.08
S70FA2C0.25GF	905	834	6109	4.94	0.09	1213	111	8747	6.21	0.09
S70FA2C0.5GF	106	100	7430	5.57	0.06	1326	123	1022	6.55	0.08
S70FA2C0.75GF	116	110	8555	5.97	0.06	1457	136	1189	6.88	0.07
S70FA2C1GF	125	118	9781	6.35	0.06	1568	149	1426	7.09	0.05

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C. Effect of Fiber Content

Fiber inclusions had a significant improvement on UCS of specimens. For soil stabilized with 70% fly ash and 1.5% cement, when the fiber content was increased from 0.25% to 1%, the UCS increased from 531 kPa to 682 kPa without curing. Fig. 5 shows the effect of fiber content on UCS of mix soil specimens. The trend line drawn for different curing time shows the increase in UCS with increase in fiber content.

Fig. 6 shows the effect of fiber on energy absorption. Energy absorption is the amount of energy absorbed by specimens while undergoing deformations due to an external load. It can be measured by calculating the area under the stress-strain curve. This energy absorption can be increased by reinforcement with fiber addition. In other words the extent of deformations in the specimens under an external load can be delayed by fiber addition thereby improving the energy absorption capacity of the specimen. The increase in fiber content from 0.25% to 1% had an increasing effect on energy absorption. The highest energy absorbed (14261 kJ/m^3) was observed for soil stabilized with 70% fly ash, 2% cement and 1% fiber content. Fig. 7 shows the effect of fiber inclusion on the secant modulus of the specimens. Secant modulus is a term used to measure the stiffness of a specimen. It is the slope of a line joining the origin to a specific point on the stress-strain curve. The stress-strain is usually measured at one-half of the peak stress. The fiber content increased the secant modulus of the specimens. The increase in secant modulus can be attributed to the cementing action of fly ash and cement in binding the soil particles and fiber together. The cohesion between fiber and soil increases the peak strength. When the bond between soil particles fails and leads to crack formation, the tensile strength of fiber acts against the deformation and it leads to further increase in the peak strength of specimen. Fig. 8 shows the effect of fiber content on the brittleness index. Brittleness index is a term used to indicate the measure of brittleness of a specimen, more specifically used for a soil media stabilized with cement, lime or fly ash. It is defined as the ratio of the difference of peak and residual stress to the residual stress of specimen. Its value ranges between 0 and 1, in which 0 indicates a perfectly ductile behavior. It was observed that, with increase in fiber content, value of brittleness index decreased, meaning that the specimen became more ductile due to fiber inclusion of 0.25% to 1%.

D. Effect of Curing

Fig. 9 shows the effect of curing time on unconfined compressive strength of fiber-reinforced fly ash-cement stabilized soil specimen. It was observed that the UCS increased with the increase in curing time from 0 to 28 days. The increase in UCS can be attributed to the cementing action of fly ash and cement. The favorable condition provided for pozzolanic action during curing helps in development of strength in the specimen. This strength development was observed to increase with the increase in curing time. The UCS of unreinforced soil with 50% fly ash and 2% cement without curing was 251 kPa. After 28 days of curing the UCS increased to 721 kPa. For 1% of fiber-reinforced soil stabilized with 70% fly ash and 2% cement, UCS increased from 803 kPa to 1568 kPa after 28 days of curing time.

Fig. 10 shows the effect of curing time on the energy absorption of the specimens. It was observed that energy absorption increased linearly with the increase in curing time. For unreinforced soil stabilized with 50% fly ash and 1.5% cement, energy absorption increased from 508 kJ/m^3 to 1348 kJ/m^3 after 28 days of curing. For 1% fiber reinforced soil and stabilized with 70% fly ash, and 2% cement, energy absorption increased from 5515 kJ/m^3 to 14261 kJ/m^3 after 28 days of curing.

Fig. 11 shows the effect of curing time on the secant modulus of specimens. It was observed that increase in curing time had an increasing effect on the secant modulus. This can be attributed to the increase in peak compressive strength of specimens due to cementing action of fly ash and cement. Since the secant modulus is calculated for one-half of the peak compressive strength. Therefore, a higher value of compressive strength would yield a higher secant modulus.

Fig. 12 shows the effect of curing on the brittleness index of the specimens. It was observed that increase in curing time decreased the brittleness. The decrease in brittleness was observed till 14 days of curing time and after that the brittleness index remained almost same till 28 days of curing time. The brittleness index largely depends on the peak compressive strength and residual strength. Since the increase in curing time, increased the residual strength. This increase in residual strength results in the decrease in brittleness index. Therefore, a general trend observed in almost all cases of mix specimens was that the increase in curing time had a decreasing effect on brittleness index till 14 days of curing time and after that it had very little or no effect till 28 days of curing time.

E. Effect of Fly Ash to Cement Ratio

In this study, fly ash-cement ratio of (50/1.5) = 33, (50/2) = 25, (70/1.5) = 47 and (70/2) = 35 have been considered. Fig. 13 shows the variation of UCS with respect to FA/C ratio. It was observed that, when the cement content was increased from 1.5 to 2% (FA/C ratio of 33 and 25 respectively) and keeping the fly ash content constant at 50%, the UCS increased for all cases of fiber content. This means that the increase in cement content had increasing effect in UCS. When fly ash was kept constant at 70% and cement was increased from 1.5 to 2%, the same increasing trend in UCS was observed. However, the UCS of specimens with 70% fly ash content was slightly higher than that of specimens with 50% fly ash content. It indicates that the increase in fly ash content helped in slight increase in UCS of specimens.

Fig. 14 shows the effect of fly ash-cement ratio on the secant modulus of specimens. It was observed that the specimens with 50% fly ash and cement content of 1.5 to 2% had no significant changes on secant modulus. A similar trend was observed for specimens with 70% fly ash content. However, the secant modulus of specimens with 50% fly ash content was much higher than that of 70% fly ash specimens.

The effect of fly ash to cement ratio on energy absorption is shown in Fig. 15. It was observed that, when FA/C decreased from 33 to 25 or when cement content increased from 1.5% to 2%, there was slight increase in energy absorption.

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The same trend was observed in specimens with 70% fly ash content. It was also observed that FA/C ratio of 35 and 47 had significantly higher energy absorption than that of FA/C ratio of 25 and 33.

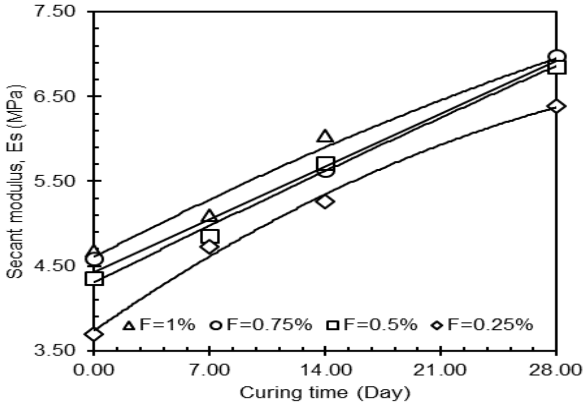

Fig. 11. Variation of secant modulus with curing time for soil with FA=70%, C=1.5% and reinforced with different fiber content

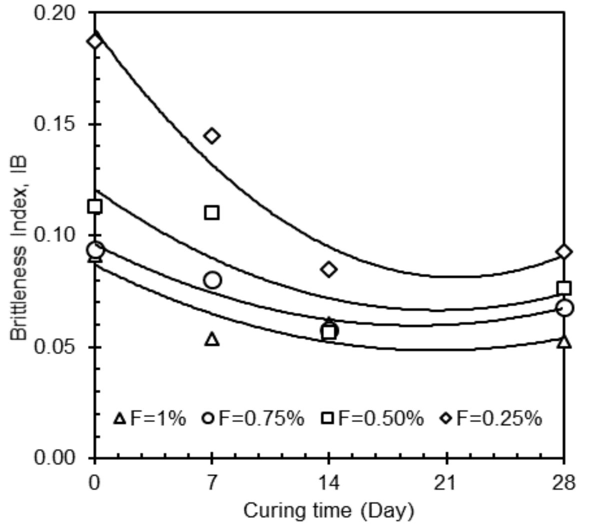

Fig. 12. Variation of brittleness index with curing time for soil with FA=70% and C=2% reinforced with different fiber content

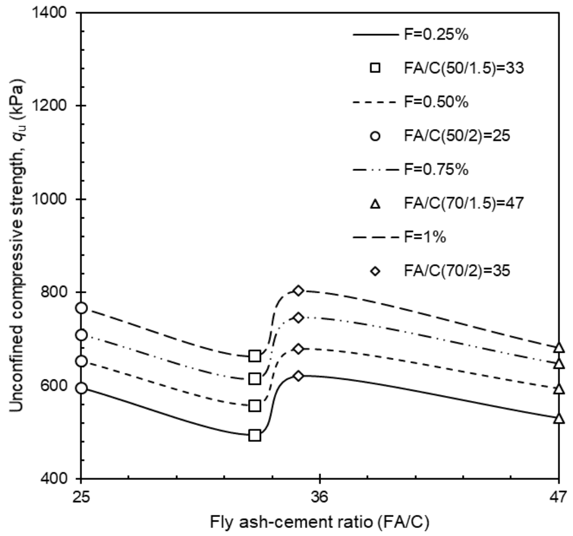

Fig. 13. Variation of unconfined compressive strength with fly ash to cement ratio for fly ash-cement stabilized soil with different fiber content

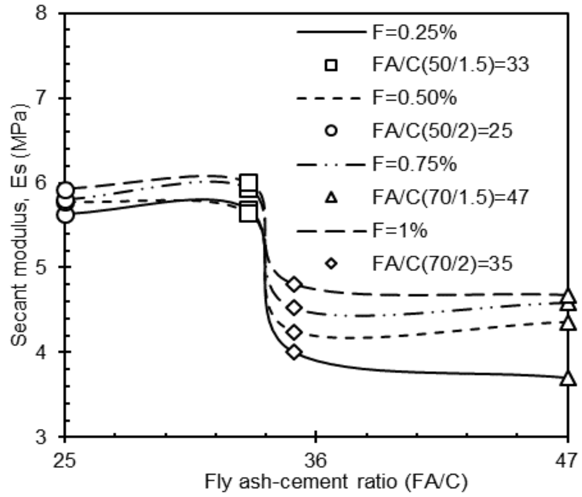

Fig. 14. Variation of secant modulus with fly ash to cement ratio

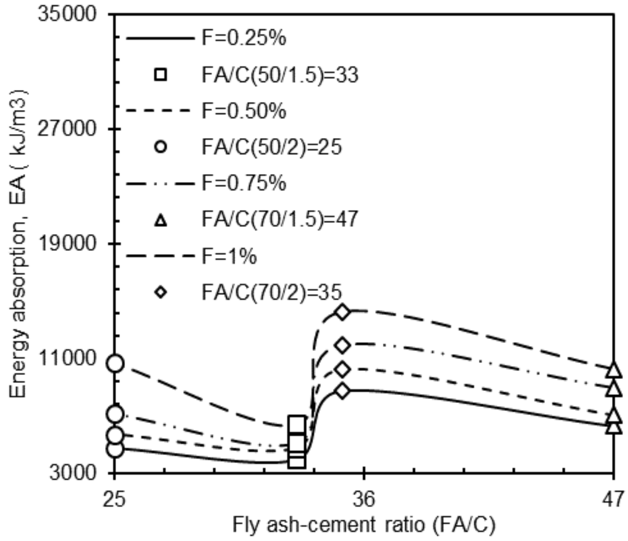

Fig. 15. Variation of energy absorption with fly ash to cement ratio for soil specimen reinforced with different fiber content

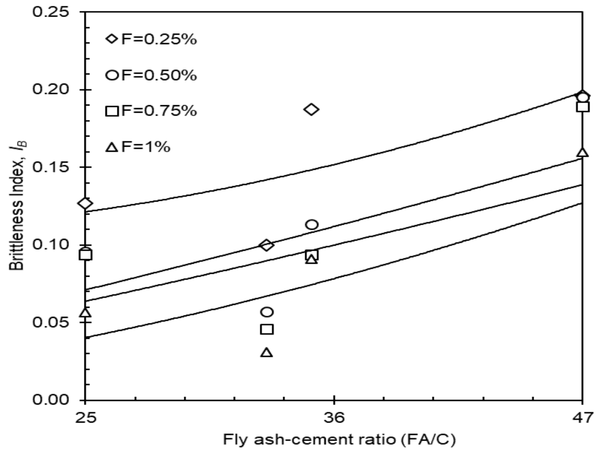

Fig. 16. Variation of brittleness index with fly ash to cement ratio for fiber reinforced soil

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IV. CONCLUSION

From this study on the unconfined compressive strength of fly ash-cement stabilized soil of both reinforced and unreinforced specimens at different curing time, the following conclusions can be drawn:

- Soil stabilization using fly ash and cement showed a significant improvement in compressive strength. In addition to that, the fiber inclusion further increased the compressive strength and also made the specimens more ductile in behaviour which is a favourable improvement in the soil media.
- The addition of fly ash decreased the MDD and increased the OMC of mix specimens, which can be attributed to the lower specific gravity of fly ash and the hollow spherical shape called cenospheres that tend to hold more moisture which increases the optimum moisture content.
- The addition of fiber significantly improved the brittle behavior into ductile one. An increase in fiber content had increasing effect on unconfined compressive strength, energy absorption, and secant modulus. However increase in fiber content decreased the brittleness index of specimens.
- The increase in curing time had an increasing effect on unconfined compressive strength, energy absorption, and secant modulus. The increase in curing time caused a slight decrease in the brittleness index of the specimens.
- The fly ash to cement ratio had an increasing effect on unconfined compressive strength, energy absorption, and secant modulus, when fly ash content was increased from 50% to 70%. However, when cement content was varied from 1.5% to 2%, the brittleness index increased, thus making the specimens more brittle.

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REFERENCES

1. Sadek, S., S. Najjar, and A. Abboud, *Compressive Strength of Fiber-Reinforced Lightly-Cement Stabilized Sand*. in *Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris*. 2013.
2. Tang, C.-S., et al., *Tensile strength of fiber-reinforced soil.* Journal of Materials in Civil Engineering, 2016. **28**(7): p. 04016031.
3. Consoli, N.C., et al., *Studies on the dosage of fiber-reinforced cemented soils.* Journal of Materials in Civil Engineering, 2011. **23**(12): p. 1624-1632.
4. Yeung, A.T., et al., *Field evaluation of a glass-fiber soil reinforcement system.* Journal of performance of constructed facilities, 2007. **21**(1): p. 26-34.
5. Ahmad, F., et al., *Assessing the potential reuse of recycled glass fibre in problematic soil applications.* Journal of Cleaner Production, 2012. **35**: p. 102-107.
6. Mali, S. and B. Singh, *A-study-on-shear-strength-of-sand-reinforced-with-glass-fibres.* International Journal of Scientific and Engineering Research, 2013. **4**(5): p. 4.
7. Guleria, S. and R. Dutta, *Unconfined compressive strength of fly ash–lime–gypsum composite mixed with treated tire chips.* Journal of Materials in Civil Engineering, 2011. **23**(8): p. 1255-1263.
8. Sivakumar Babu, G.L. and A.K. Vasudevan, *Discussion: Evaluation of strength and stiffness response of coir-fibre-reinforced soil.* Proceedings of the Institution of Civil Engineers - Ground Improvement, 2009. **162**(4): p. 205-207.
9. Sivakumar Babu, G. and M. Raja Jaladurgam, *Strength and deformation characteristics of fly ash mixed with randomly distributed plastic waste.* Journal of Materials in Civil Engineering, 2014. **26**(12): p. 04014093.
10. Consoli, N.C., P.D. Prietto, and L.A. Ulbrich, *Influence of fiber and cement addition on behavior of sandy soil.* Journal of Geotechnical and Geoenvironmental Engineering, 1998. **124**(12): p. 1211-1214.
11. Arora, S. and A.H. Aydilek, *Class F fly-ash-amended soils as highway base materials.* Journal of Materials in Civil Engineering, 2005. **17**(6): p. 640-649.
12. Cokca, E., *Use of class c fly ashes for the stabilizationof an expansive soil.* Journal of Geotechnical and Geoenvironmental Engineering, 2001. **127**(7): p. 568-573.
13. Consoli, N.C., C. Gravina da Rocha, and C. Silvani, *Effect of curing temperature on the strength of sand, coal fly ash, and lime blends.* Journal of Materials in Civil Engineering, 2013. **26**(8): p. 06014015.
14. Al-Mukhtar, M., A. Lasledj, and J.-F. Alcover, *Behaviour and mineralogy changes in lime-treated expansive soil at 20 C.* Applied clay science, 2010. **50**(2): p. 191-198.
15. Kaniraj, S.R. and V.G. Havanagi, *Behavior of cement-stabilized fiber-reinforced fly ash-soil mixtures.* Journal of geotechnical and geoenvironmental engineering, 2001. **127**(7): p. 574-584.
16. Schnaid, F., P.D.M. Prietto, and N.C. Consoli, *Characterization of Cemented Sand in Triaxial Compression.* Journal of Geotechnical and Geoenvironmental Engineering, 2001. **127**(10): p. 857-868.
17. Lo, S. and S.P. Wardani, *Strength and dilatancy of a silt stabilized by a cement and fly ash mixture.* Canadian Geotechnical Journal, 2002. **39**(1): p. 77-89.
18. Kaniraj, S.R. and V. Gayathri, *Geotechnical behavior of fly ash mixed with randomly oriented fiber inclusions.* Geotextiles and Geomembranes, 2003. **21**(3): p. 123-149.
19. BIS, I., *2720 Methods of Test for Soils: Part 7- Determination of Water Content-Dry Density Relation Using Light Compaction.* 1980.
20. Ateş, A., *Mechanical properties of sandy soils reinforced with cement and randomly distributed glass fibers (GRC).* Composites Part B: Engineering, 2016. **96**: p. 295-304.
21. Chauhan, M.S., S. Mittal, and B. Mohanty, *Performance evaluation of silty sand subgrade reinforced with fly ash and fibre.* Geotextiles and geomembranes, 2008. **26**(5): p. 429-435.
22. Kim, B., M. Prezzi, and R. Salgado, *Geotechnical properties of fly and bottom ash mixtures for use in highway embankments.* Journal of Geotechnical and Geoenvironmental Engineering, 2005. **131**(7): p. 914-924.
23. BIS, I., *2720 Methods of Test for Soils: Part 10-Determination of Unconfined Compressive Strength*. 1991, India.

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