Unconfined Compressive Strength of Jet-Grouted Columns with and Without Fibre-Reinforcement

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***Abstract*: This research studies the unconfined compressive strength, tensile reinforcement and the ductility performances of soil-cement columns with and without fibre-reinforcement. This experimental setup consist of Unconfined-Compressive-Strength test on 72 specimens. The columns were casted at various proportions of materials with w/c ratio of 1:1 before conducting the UCS tests. These columns can be simulated as the vertical drains. Columns were casted with various fibre contents for comparison with columns without fibre-reinforcements. Relationship between binder content and compressive strength at different percentages of fibre had been evaluated through UCS test. The results indicated that the increase in binder or cement content cause an increase in the unconfined compressive strength of jet-grouted columns. Whereas by increasing the polypropylene fibre content the ductility and tensile strength of columns increases. However, the results indicated that up-to the polypropylene content of 0.5% of the dry weight of sand the unconfined-compressive-strength of columns has increased. Now further the increase in fibre content, e.g. polypropylene content of 1% of the dry weight of sand decreases the unconfined-compressive-strength of jet-grouted columns with fibre-reinforcements. Failure of columns was characterized by compression.**

***Keywords*: Columns, Ductility, Fibre, Jet-Grouted, Unconfined Compressive Strength.**

I. INTRODUCTION

Earthen constructions are usually accounted as sustainable since it consist of the use of native soil and nearby available materials thus decreasing transportation cost and the use of factory-made materials [1], [2]. (Chen et al., 2015) Cement-clay with polypropylene reinforcement was tested through unconfined compressive strength test, at 0.50% of fibre content the strength was maximum, further the increase in fibre content may affect the soil strength as decreasing [3]. (Correia et al., 2015) Soft clay has been simulated to know the fibre and cement contents in order to determine the unconfined compressive strength of specimen with polypropylene reinforcement [4]. Ground improvement technique is important in construction of infrastructure and sub-structures in deep soil conditions, i.e. deep mixing technique [5]-[7], shallow soil used to be as a subgrade of a road [8] and jet-grouted columns [9]-[12]. Continuously the researchers have worked on the strength of aggregates and soil by the addition of fly ash and cement in order to improve the compressive strength [13]-[19]. Because of the expensive cost of materials and environmental point of view the researchers are working on the fibre-reinforcements in order to reinforce the jet-grouted specimens. It is obvious that the soil is good in shear and compression whereas the soil is weak in tension. Using fibre-reinforcement improves the durability and strength of soil. Due to the nonappearance of latent failure plane improvements are required in the fields of cohesion and frictional angle [20]-[29].

II. MATERIALS & METHODS

1. Sand

Sand is the type of soil and it is composed of minerals and fine separated rock. It is coarser than silty soil and finer than granular soil. This was the A-3 soil according to AASHTO soil classification system. This non-cohesive soil was obtained from the vicinity of Al-Manzar, Jamshoro (fig. 1). The specific gravity of this sand was 2.665 and water content was 15.815.

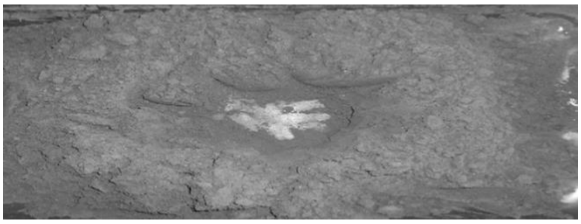

Figure 1. Sand

2. Polypropylene

Monofilament polypropylene fibre is the type of polypropylene or polypropene fibres (fig. 2). This fibre was used as a reinforcement in jet-grouted columns. It is the thermoplastic polymer which is used in different types of applications. Mono

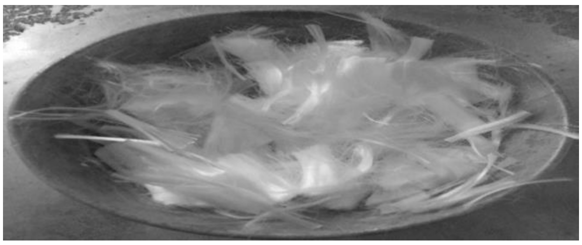

Figure 2. Polypropylene Fibre

means one and poly means many, so, this fibre is the product which is produced through polymerization process from monomer. It is partially non-polar and crystalline.

3. Cement

The cement is an adhering material that hardens and sets with other substances for binding those with each other. This material gets hardened by the process of heat of hydration which works by the addition of water with it. It is the most widely used civil engineering material and is the second most used material behind water on the planet.

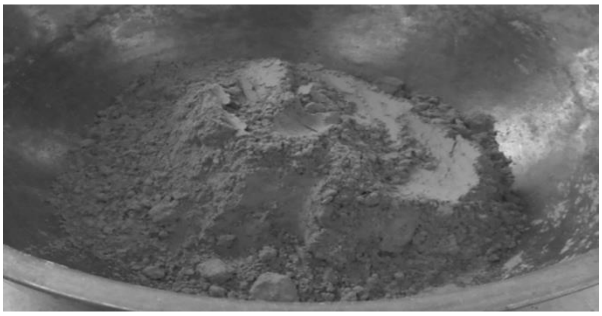

Figure 3. Cement

III. RESULTS AND DISCISSIONS

The proportioning of materials while casting of jet-grouted columns were carried out on the basis of percentage by dry weight of the sand. After casting of jet-grouted columns with and without fibre-reinforcement the unconfined compressive strength of columns was determined by conducting the UCS test. Total 72 number of columns were tested from which 18 specimens were casted without fibre-reinforced whereas further 54 columns were casted with fibre-reinforcement. The columns were simulated during and after compression loading (fig. 4), (fig. 5). The unconfined compressive strength of columns at different fibre contents is shown in Fig. 6, Table 2 and Fig. 7, Table 3 based on curing periods of 14 days and 28 days respectively. Following results were obtained in unconfined compressive strength test:

- It was observed that by increasing the fibre content in columns, e.g. at fibre contents of 0.25% and 0.50%, the unconfined compressive strength of columns continuously got increased.
- At 1.00% fibre content the unconfined compressive strength of columns was even less than the unconfined compressive of columns with 0% fibre content.
- The unconfined compressive strength was maximum at the fibre content of 0.50% [3].

Fig. 4: Simulation of Columns during Compression

Fig.5: Simulation of Cracks after Compression

Material Evaluation for Unconfined Compressive Strength Test

$$Diameter\ of\ mould = d_m = 5.08\ cm$$

$$Height\ of\ mould = H_m = 10.16\ cm$$

Since, 30% more material is being used and 6 specimens for each proportioning of materials are prepared. Therefore the volume would be considered as:

$$Volume\ of\ mould = V_{mould} = 370.667 cm^3$$

Since:

$$Dry\ weight\ of\ sand = Density\ of\ sand \times Volume\ of\ mould$$

$$Dry\ weight\ of\ sand = W_d = \gamma_{sand} \times V_{mould}$$

Since: $\gamma_{sand} = 2\frac{gm}{cm^3}$;

$$W_d = 2\frac{gm}{cm^3} \times 370.667 cm^3$$

$$W_d = 740.333 gm$$

<u>Note:</u> water/cement ratio = w/c = 1:1
20% cement content by dry weight of sand = 148.066gm
And, water content at 20% cement content by dry weight of sand = 148.066ml

25% cement content by dry weight of sand = 185.083gm
And, water content at 25% cement content by dry weight of sand = 185.083ml

30% cement content by dry weight of sand = 222.099gm
And, water content at 30% cement content by dry weight of sand = 222.099ml

0.25% fibre content by dry weight of sand = 1.850gm
0.50% fibre content by dry weight of sand = 3.701gm
1.00% fibre content by dry weight of sand = 7.403gm

Results of Unconfined Compressive Strength Test
Important parameters:

- Weight of Sand (gm) = W = 706.95gm
- Length of Column (mm) = L = 101.6mm
- Diameter of Column (mm) = D = 50.8mm
- Area of Column (mm) = A = 2026.83mm^2

Table 2: Unconfined Compressive Strength of Columns after 14 Days of Curing

Curing Period = 14 Days			
Curve	**% Fibre Content**	**% Cement Content**	**Average Stress(14 days)**
	0	20	2.66508
	0	25	5.01193
A	0	30	6.63104
	0.25	20	3.10616
	0.25	25	5.52571
B	0.25	30	8.25674
	0.5	20	3.81877
	0.5	25	5.9931
C	0.5	30	8.37186
	1	20	2.3041
	1	25	3.51534
D	1	30	3.64609

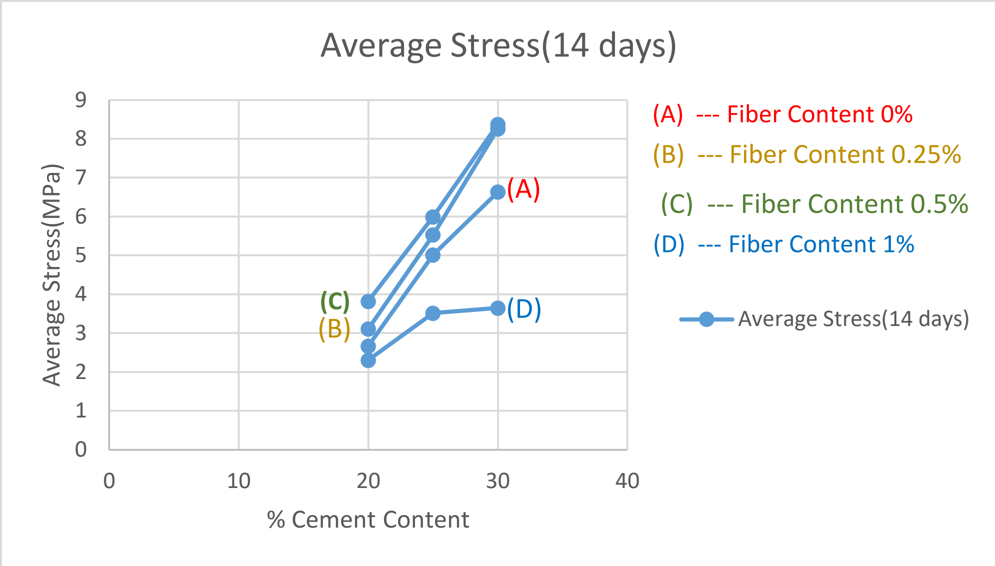

Fig. 6.

Table 3: Unconfined Compressive Strength of Columns after 28 Days of Curing

Curing Period = 28 Days			
Curve	**% Fibre Content**	**% Cement Content**	**Average Stress(28 days)**
	0	20	2.748956
	0	25	5.20698
A	0	30	7.80809
	0.25	20	3.24974
	0.25	25	6.36955
B	0.25	30	8.79534
	0.5	20	4.59963
	0.5	25	6.68318
C	0.5	30	9.10519
	1	20	2.48582
	1	25	4.10329
D	1	30	4.28666

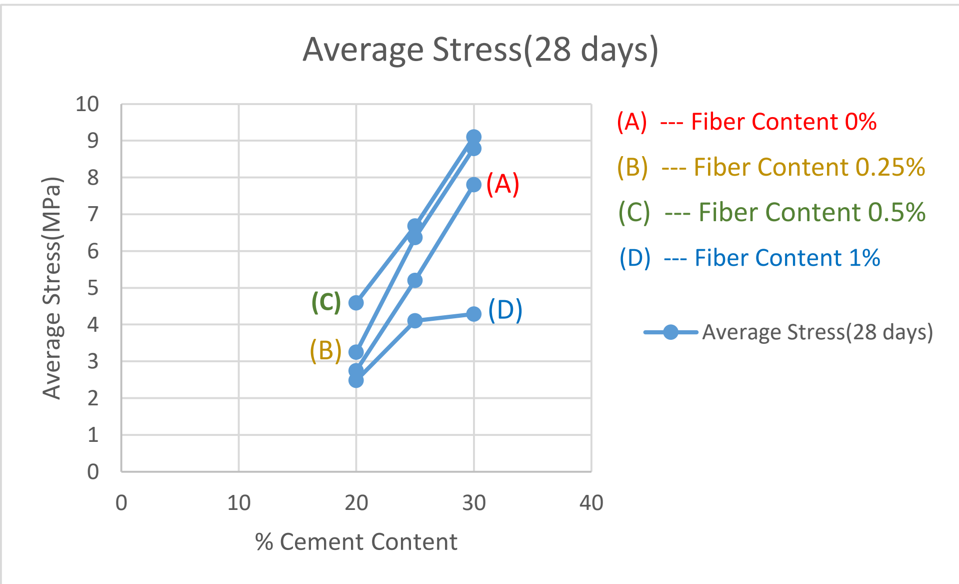

Fig. 7: Relationship Between Average Stress (28 days) (MPa) vs % Cement Content at Various Fibre Contents

IV. CONCLUSIONS

This study is based on the use of fibre polypropylene at different proportion of materials; e.g. cement and sand, in order to improve the unconfined compressive strength of jet-grouted columns.

Following results were concluded by this research work:

- From 0.00%, 0.25%, 0.50% and 1.00% of fibre content, the unconfined compressive strength of jet-grouted columns is maximum at the provision of 0.50% of fibre content.
- Jet-grouted columns had become ductile and the tensile strength of columns was increased with the provision of polypropylene.
- It was concluded that the polypropylene fibre-reinforcement has increased the strength of jet-grouted columns up-to certain quantity of it.

V. RECOMMENDATIONS

- The content of fibre polypropylene should be used from 0.50% to 1.00% of the dry weight of sand in order to determine more precise results for maximum strength of fibre-reinforced jet-grouted columns.
- Polypropylene fibre can positively be used in order to achieve the ductility and tensile behavior in jet-grouted columns.

REFERENCES

[1]. United Nations Centre for Human Settlements (UN-Habitat), Interlocking Stabilized Soil Blocks-Appropriate Earth Technologies In Uganda, Nairobi 2009.

[2]. Bing Qu, Bradley J. Stirling, Daniel C. Jansen, David W. Bland, Peter T. Laursen, Testing of flexure-dominated interlocking compressed earth block

[3]. walls, Constr. Build. Mater. 83 (2015) 34–43, http://dx.doi.org/10.1016/ j.conbuildmat.2015.02.080. ISSN 0950-0618

[4]. Chen, M., Shen, S., Arulrajah, A., Wu, H., Hou, D., 2015. Laboratory evaluation on the effectiveness of polypropylene fi bers on the strength of fi ber reinforced and cement-stabilized Shanghai soft clay. Geotext. Geomembranes 1–9. https://doi.org/10.1016/j.geotexmem.2015.05.004

[5]. Correia, A.S., Venda, P.J., Cust, D.G., 2015. Effect of polypropylene fi bres on the compressive and tensile strength of a soft soil , arti fi cially stabilised with binders. Geotext. Geomembranes 43, 10. https://doi.org/10.1016/j.geotexmem.2014.11.008

[6]. Shen, S.L., Han, J., Huang, X.C., Du, S.J., 2003a. Laboratory studies on property changes in surrounding clays due to installation of deep mixing

[7]. columns. Mar. Georesour. Geotechnol. 21 (1), 15e35.

[8]. Shen, S.L., Miura, N., Koga, H., 2003b. Interaction mechanism between deep mixing column and surrounding clay during installation. Can. Geotech. J. 40 (2), 293e307.

[9]. Shen, S.L., Han, J., Du, Y.J., 2008. Deep mixing induced property changes in surrounding sensitive marine clays. J. Geotech. Geoenviron. Eng. ASCE 134 (6), 845e854.

[10]. Shen, S.L., Wang, Z.F., Horpibulsuk, S., Kim, Y.H., 2013a. Jet-grouting with a newly developed technology: the twin-jet method. Eng. Geol. 152 (1), 87e95.Shen, S.L., Wang, Z.F., Yang, J., Ho, E.C., 2013b. Generalized approach for prediction of jet grout column diameter. J. Geotech. Geoenviron. Eng. 139 (12), 2060e2069.

[11]. Shen, S.L., Hong, Z.S., Xu, Y.S., 2007. Reducing differential settlements of approach embankments. Proc. ICE-Geotech. Eng. 160 (4), 215e226. Wang, Z.F., Shen, S.L., Ho, E.C., Kim, Y.H., 2013. Investigation of field installation effects of horizontal twin-jet grouting in Shanghai soft soil deposits. Can.Geotech. J. 50 (3), 288e297. http://dx.doi.org/10.1139/cgj-2012-0199.

[12]. Wang, Z.F., Shen, S.L., Ho, C.E., Xu, Y.S., 2014. Jet grouting for mitigation of installation disturbance. Geotech. Eng. ICE Proc. 167 (GE6), 526e536. Horpibulsuk, S., Rachan, R., Raksachon, Y., 2009. Role of fly ash on strength and microstructure development in blended cement stabilized silty clay. Soils Found. 49 (1), 85e98.

[13]. Horpibulsuk, S., Rachan, R., Suddeepong, A., Chinkulkijniwat, A., 2011. Strength development in cement admixed Bangkok clay: laboratory and field investigations. Soils Found. 51 (2), 239e251.

[14]. Kaniraj, S.R., Havanagi, V.G., 1999. Compressive strength of cement stabilized fly ash soil mixtures. Cem. Concr. Res. 29 (5), 673e677.

[15]. Kolias, S., Kasselouri-Rigopoulou, V., Karahalios, A., 2005. Stabilisation of clayey soils with high calcium fly ash and cement. Cem. Concr. Compos. 27 (2), 301e313.

[16]. Porcino, D., Marcian_o, V., Granata, R., 2012. Static and dynamic properties of a lightly cemented silicate-grouted sand. Can. Geotech. J. 49 (10), 1117e1133.

[17]. Disfani, M.M., Arulrajah, A., Haghighi, H., Mohammadinia, A., Horpibulsuk, S., 2014. Flexural beam fatigue strength evaluation of crushed brick as a supplementary material in cement stabilized recycled concrete aggregates. Constr. Build. Mater. 68, 667e676.

[18]. Mohammadinia, A., Arulrajah, A., Sanjayan, J., Disfani, M., Bo, M., Darmawan, S., 2015. Laboratory evaluation of the use of cement-treated construction and demolition materials in pavement base and subbase applications. J. Mater. Civ. Eng. 27 (6), 04014186.

[19]. Kaniraj, S.R., Havanagi, V.G., 2001. Behavior of cement-stabilized fiber-reinforced fly ash-soil mixtures. J. Geotech. Geoenviron. Eng. 127 (7), 574e584.

[20]. Sobhan, K., Mashnad, M., 2002. Tensile strength and toughness of soil-cement-flyash composite reinforced with recycled high-density polyethylene strips. J. Mater. Civ. Eng. 14 (2), 177e184.

[21]. Yetimoglu, T., Inanir, M., Inanir, O.E., 2005. A study on bearing capacity of randomly distributed fiber-reinforced sand fills overlying soft clay. Geotext. Geomembr. 23 (2), 174e183.

[22]. Kumar, A., Walia, B.S., Mohan, J., 2006. Compressive strength of fiber reinforced highly compressible clay. Constr. Build. Mater. 20 (10), 1063e1068.

[23]. Viswanadham, B.V.S., Phanikumar, B.R., Mukherjee, R.V., 2009. Swelling behavior of a geofiber-reinforced expansive soil. Geotext. Geomembr. 27 (1), 73e76.

[24]. Park, S.S., 2011. Unconfined compressive strength and ductility of fiber-reinforced cemented sand. Constr. Build. Mater. 25 (2), 1134e1138.

[25]. Hejazi, S.M., Sheikhzadeh, M., Abtahi, S.M., Zadhoush, A., 2012. A simple review of soil reinforcement by using natural and synthetic fibers. Constr. Build. Mater. 30, 100e116.

[26]. Mirzababaei, M., Miraftab, M., Mohamed, M., McMahon, P., 2012. Unconfined compression strength of reinforced clays with carpet waste fibers. J. Geotech. Geoenviron. Eng. 139 (3), 483e493.

[27]. Onyejekwe, S., Ghataora, G.S., 2014. Effect of fiber inclusions on flexural strength of soils treated with nontraditional additives. J. Mater. Civ. Eng. 26 (8).

[28]. Jamsawang, P., Voottipruex, P., Horpibulsuk, S., 2014. Flexural strength characteristics of compacted cement-polypropylene fiber sand. J. Mater. Civ. Eng. http://dx.doi.org/10.1061/(ASCE)MT.1943-5533.0001205, 04014243.