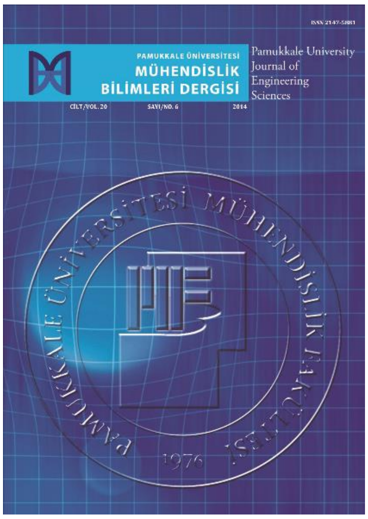
Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi

Pamukkale University Journal of Engineering Sciences



Kabul Edilmiş Araştırma Makalesi (Düzenlenmemiş Sürüm)

Accepted Research Article (Uncorrected Version)

Makale Başlığı / Title	Experimental investigation on dewatering behavior of a fly ash by small scale laboratory tests Küçük ölçekli laboratuar deneyleri ile bir uçucu külün susuzlaştırma davranışı üzerine deneysel araştırma
Yazarlar / Authors	Doğan ÇETİN, Tayfun ŞENGÜL
Referans No / Reference No	PAJES-48295
DOI	10.5505/pajes.2016.48295

Bu PDF dosyası yukarıda bilgileri verilen kabul edilmiş araştırma makalesini içermektedir. Sayfa düzeni, dizgileme ve son inceleme işlemleri henüz tamamlanmamış olduğundan, bu düzenlenmemiş sürüm bazı üretim ve dizgi hataları içerebilir.

This PDF file contains the accepted research article whose information given above. Since copyediting, typesetting and final review processes are not completed yet, this uncorrected version may include some production and typesetting errors.

Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi
Pamukkale University Journal of Engineering Sciences

Experimental investigation on dewatering behavior of a fly ash by small scale laboratory tests

Küçük ölçekli laboratuar deneyleri ile bir uçucu külün susuzlaştırma davranışı üzerine deneysel araştırma

Doğan ÇETİN[1], Tayfun ŞENGÜL[2]

[1]Civil Engineering Faculty, Faculty of Civil Engineering, Yildiz Technical University, Istanbul, Turkey.
dogancetin56@hormail.com,
[2]Civil Engineering Faculty, Engineering Faculty, Dumlupınar University, Kütahya, Turkey.
tayfun.sengul@dpu.edu.tr

Received/Geliş Tarihi: 10.04.2016, Accepted/Kabul Tarihi: 27.07.2016
doi: 10.5505/pajes.2016.48295
* Corresponding author/Yazışılan Yazar
Research Article/Araştırma Makalesi

Abstract

The trend of increasing fly ash production due to coal combustion is a big challenging issue for developed and developing countries. This issue will continue in the future as a concern because of increasing energy demand. Although the coal ash is being used as an additive material, re-using percentage is very low. Countries are constantly looking for proper method for disposal and carrying of the fly ash. Geotextile tubes are considered as an effective method for disposal of industrial waste materials. A woven geotextile was used in this study to investigate the dewatering behavior of a C class fly ash based on the small scale laboratory tests such as Pressure Filtration Test (PFT) and Jar Sedimentation Test (JST). Effect of fiber and polymer inclusion was also investigated in terms of dewatering time. It was concluded that polymer and/or fiber inclusion decreased the dewatering time of fly ash slurries. The relationship between PFT and JST was investigated. It can said that there is clear relationship between dewatering time obtained from PFT and the ratio of final height of solid sediment over initial height of the slurry obtained from JST.

Keywords: Fly ash, Dewatering time, Pressure filtration test, Jar sedimentation test, Fiber, Polymer

Öz

Kömür yakımı deneniyle üretilen uçucu küldeki artış gelişmiş ve gelişen ülkeler için zorlayıcı bir meseledir. Bu mesele gelecektede enerjiye olacak talep nedeniyle ilgi gösterilecek bir konu olacaktır. Her ne kadar uçucu kül bir katkı maddesi olarak kullanılsa da, tekrar kullanılma yüzdesi çok düşük düzeydedir. Ülkeler sürekli uçucu küllerin bertarafı için uygun metotlar araştırmaktadırlar. Geotekstil tüpler endüstriyel atık mazlemelerin bertarafı için efektif metod olarak düşünülmektedir. Bu çalışma da bir dokuma geotekstil C sınıfı bir külün susuzlaştırma davranışının küçük ölçekli deneyler olan Basınç Kontrollü Filtreleme Deneyi (PFT) ve Serbest Oturma Deneyi (JST) yöntemleri kullanılarak araştırılmıştır. Lif ve sentetik polymer kullanımının uçucu külün susuzlaştırma süresini kısalttığı sonucuna ulaşılmıştır. PFT ile JST yöntemleri arasındaki ilişki araştırılmıştır. Yapılan analizler sonucunda susuzlaştırma zamanı ile katı kısmın son yüksekliğinin süspansiyonun ilk yüksekliğine oranı arasında yakın bir ilişki olduğu söylenebilir.

Anahtar kelimeler: Uçucu kül, Susuzlaştırma zamanı, Basınç kontrollü filtreleme deneyi, Serbest oturma deneti, lif, polimer

1 Introduction

In power plants, generation of coal ash and related by-products has been an increasing trend in energy generation around the world since the 1920's [1],[3]. About one billion tons of coal ash were produced in 2012 [2] compared to 350 million tons in 2000 [3]. 41% of world electricity demand was obtained from coal-fired generation in 2006. As an estimation, this percentage will be 43% in 2030 [4]. Coal-fired generation will be more attractive because of the probable high price of oil and natural gas in the future. This ongoing trend shows that fly ash generation is becoming a challenging issue for developed and developping countries, such as the USA, India, Japan and China, because of limited impoundment capacity and utilization of a low percentage of fly ash.

Re-using or utilization efforts of fly ash tend to increase with increasing generation of fly ash because utilization of fly ash has some benefits, such as minimizing the disposal cost, decreasing the disposal permission requirements, obtaining some returns from sale of by-products and protecting scarce natural resources [1]. Therefore, fly ash can be used for cement and concrete production, constructive filling, space filling under the surface, water purification, improvement of soil properties, etc. as a low cost additive [5].

Concrete production by adding fly ash has been gaining attention. Many studies have looked at fly ash mixed concrete. Investigations report that mixing fly ash with cement decreases the proportion of water to cement [1]. A number of studies have been conducted into the effect of fly ash in cement and concrete. It has been reported that decreasing the cement by 35-50%, water demand can be reduced by 5-7%. It has been concluded [7] that a high percentage of fly ash in cement creates a resistance to alcali-silica reaction. An investigation was performed into the effect of fly ash and the optimum dose of fly ash for improvement of concrete strength [8]. The utilization of fly ash in concrete dam construction was investigated. It was reported that the compressive strength of soil that contains 50% fly ash under compression for three-months was higher than soils conditioned with 30% fly ash or those without fly ash added [9].

Mine backfilling is a good way to use the fly ash generated in plants near coal mines. For places where a natural aggregate source is limited, filling of old mines with fly ash is an attractive alternative. During 1999-2000, in India, old mines were filled with fly ash backfill [10]. In spite of these efforts, only 16% of the total generated ash is recycled or utilized. For instance, India recycles only 13% of produced fly ash. Dry form and slurry form are the main options for transporting generated fly ash. The slurry form of fly ash requires dewatering before reuse or utilization. In current applications, the dewatering process is conducted using geotextile tubes. Higher retained sediment capacity, easy construction process, high efficiency, reduced labor costs, and elimination of environmental concerns can be considered the benefits of using geotextile tubes for dewatering dredged or waste materials, in comparison to other methods [11]. Geotextile tubes were first used in the late 1990s to dewater municipal sludge [12].

Using the polymer in geotube applications is generally beneficial to control particle interaction, which means that dewatering rate can be controlled at the same time [13]. The optimum dewatering consists of two main issues: maximum filtration efficiency and minimum dewatering time. Mori et al. [14], Koerner and Koerner [15], Lawson [16], Khachan et al. [2] and Maurer et al. [17] used polymer flocculants to obtain better dewatering performance. However, they did not provide definite criteria to describe the efficient polymer type, optimum polymer dose, etc. Therefore, for every application and soil, the polymer type and its optimum dose must be determined by performing small scale laboratory tests.

Using fibers as a reinforcing additive is a common application in the geotechnical area. Shear strength, compressibility, density and hydraulic conductivity can be improved by reinforcement of soil using different types of fibers [18]. In this technique, reinforcement additive-fibers are distributed randomly in the soil body, thus providing improvements in soil properties [19]. The concept of reinforcement of soil with different natural materials has been known since ancient times [20]. Soil reinforcement framework was first expressed by Vidal [21]. It was shown that reinforcement additives caused an increase in the shear stress of the soil. After Vidal [21], the soil reinforcement technique has been used widely in the geotechnical area.

The fiber mixed with soil is generally in dry form in the studies. The soil is used as a slurry in current geotube applications. Slurry form soil needs to be mixed with some additives, such as different types of fibers, to enable increased geotube strength after the dewatering phase because geotubes are stacked in utilization. However, the studies of mixing fiber into slurry form soil are very limited. A flexible polyvinyl alcohol (PVA) fiber 6 mm in length with 1% by dry solid mass was used by Maurer et al. [17]. It was found that the strength of filter cake increased remarkably with the PVA fiber inclusion.

In this experimental study, dewatering with geotextile tubes is considered as an effective method of dewatering fly ash slurries. The proposed method decreases the transportation and operation costs of slurry form fly ash and prepares it for reuse in engineering applications. The investigation was carried out on the dewatering characteristics of the fly ash. For this purpose, anionic polymers and short-length synthetic fibers were used to observe their effects on dewatering behavior. Jar Sedimentation Tests that may give some idea about the dewatering rate of the slurries were also conducted and the results were compared with the results of dewatering time of fly ash.

2 Test materials

2.1 Fly Ash

Fly ash was obtained from Coal Creek Station in Underwood, ND, USA, which is one of the largest power plants in the US. The fly ash is class C fly ash (d_{85}=0.1 mm). Particle size distribution and a scanning electron microscope image of the fly ash can be seen in Figure 1 and Figure 2, respectively. According to Figure 1, the fly ash has silt-size spherical particles. However, 4% of the particles are clay-size grains.

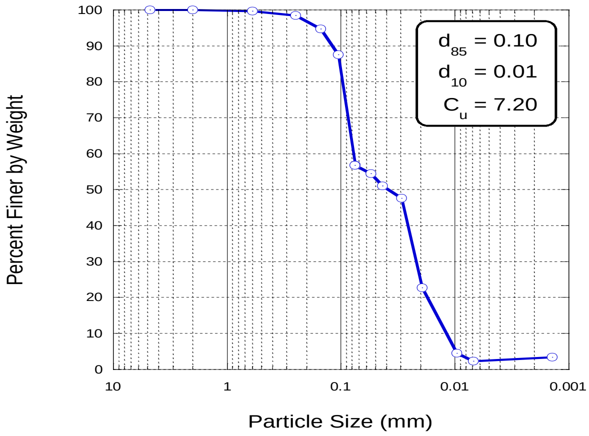


Figure 1: Fly Ash grain size distribution curve.

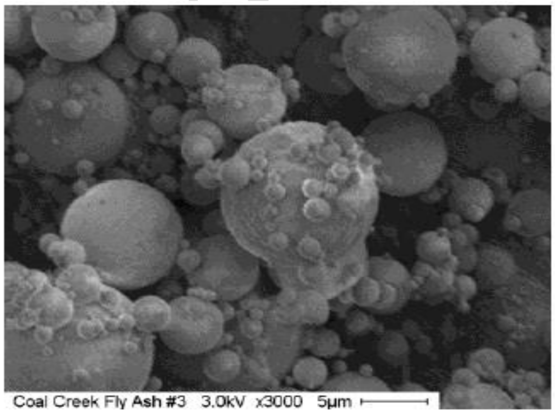


Figure 2: Scanning electron microscope image of the fly ash.

2.2 Geotextile

W1, Woven type made of polypropylene geotextile, was used in dewatering experiment of fly ash slurries. This type of geotextile has been used frequently by the researchers [2],[24],[25]. The physical and hydraulic properties of the geotextile are shown in Table 1.

Table 1: Physical and hydraulic properties of W1 geotextile.

Geotextile Properties	
Polymer Type	PP
Structure	Woven, Monofilament
AOS (mm)	0.25
Permittivity (s^{-1})	0.37
MPUA (g/m^2)	585
Thickness	1.04
WW-TS (kN/m)	96*70

PP: Polypropylene, AOS: Apparent opening size, MPUA: Mass per unit area, WW-TS: Wide-With tensile strength.

2.3 Flocculant

Polymers as flocculants are commonly used in many applications, such as paper making, water treatment, biotechnology and the mining industry [22]. Flocculation is an essential step in applications that require dewatering because slurry contains significant quantities of very fine particles [23]. Flocculation can be defined as a process of clumping fine particles into larger units, which provide rapid dewatering and high solid retention in geotube applications. Three anionic polymers were used. Molecular weight of the polymers is high but charge densities vary. Table 2 give properties of selected polymers.

Table 2: Polymers properties.

Polymer	CD (meq/g)	MW
A_1	1.97	High
A_2	2.64	High
A_3	4.21	High

CD: Charge density, MW: Molecular weight.

2.4 Fibers

Two different fibers were used in this study to investigate the effect of the fibers on dewatering rate of fly ash slurries. Fiber properties were given in Table 3. The photo images of the fibers are shown in Figure 3.

Table 3: Fiber properties.

Fiber Type	Material Type	d(μ)	L(mm)	Gs	Water Absorption
RC	Nylon	9	6	1.15	3%
RSC15	PVA	38	8	1.30	≤1%

L is the length of the fiber, d is the diameter of the filament. Water absoption capacity is by mass of the fibers.

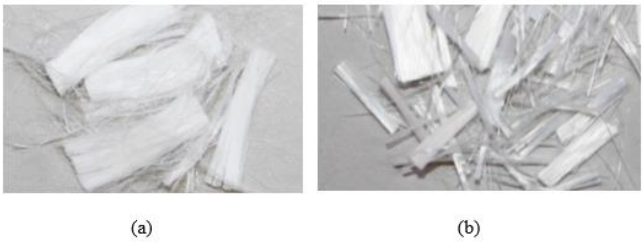


Figure 3: The images of the fibers used in the study.

Figure 3a is an image of RC (nylon) fiber while Figure 3b is an image of RSC 15 (PVA) fiber.

3 Test methods

3.1 Jar test

The jar tests is generally used in research to determine optimum dose of the polymers. A 30% solids by mass fly ash suspension was prepared in a beaker. The polymer was added in increments. The slurries were mixed for 3 minutes to ensure the complete mixing of soil and polymer. After 3 minutes of mixing, supernatant samples were taken from the middle of the beaker using a syringe. Turbidity was determined after a two minute wait. Turbidity was expressed as nephelometric units (NTU). Dose versus turbidity was then plotted and analyzed, and the optimum dose was estimated to be the lowest possible dose which provided minimum turbidity. Three different anionic polymers of 2500 ppm density were used in jar tests to determine their effect on turbidity of the fly ash slurries.

One anionic acrylamide based synthetic polymer (A3) was selected as the effective flocculant based on supernatant turbidity. Figure 4 shows the relationship between polymer dose and turbidity in NTU units.

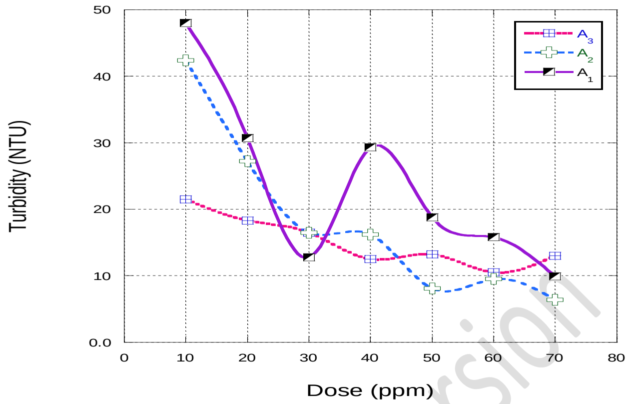


Figure 4: Relationship between the polymer dose and turbidity for all anionic polymers.

3.2 Jar sedimentation test

The assessment of sedimentation behavior of sediments is essential to characterize the rate of settlement, clarity of supernatant, need for pretreatment and the final volume of sediment solids after sedimentation [24]. The test is conducted following steps such as monitoring the slurry at certain solid concentrations in a standard cylinder and recording the height of the solid part of the slurry in time intervals to obtain readings versus time. The Jar Sedimentation Test is generally used to assess the sediment suspension characteristics, supernatant clarity, and the final proportion of settled sediments (S_p).

H_i is the initial heigth of the slurry and H_s is the final solid heigth at the end of the test. Final solid ratio can be expressed as following,

$$Sp = \frac{Hi}{Hs} * 100 \qquad (1)$$

Initial settling rate (u_i) was expressed as inclination of the initial linear portion of solid height versus time by Tarleton and Wakeman [25],[29]. If the behavior obtained by performing the test shows that the settling rate is very low and clarity of the supernatant is very poor, chemical treatment, such as using polymer, should be considered to enable improved settlement rate.

The sedimentation tests were conducted at 30% solid concentrations with and without polymer. Hence, it was aimed to determine the effect of the polymer on the settlement rate. Two different fibers were used in settlement rate tests to observe their effects on the settlement rate of the fly ash.

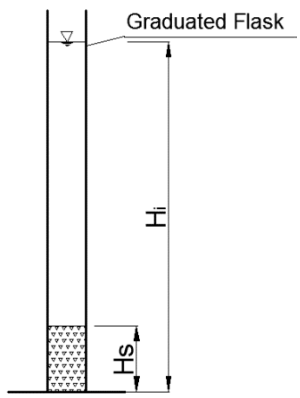


Figure 5: Schematic figure of sedimentation test.

3.3 Pressure filtration test

The Pressure Filtration Test (PFT) is commonly used to simulate the dewatering characteristic of the slurry form of dredge materials or industrial waste materials in laboratory conditions [2],[11],[17],[26]-[28].

A photo and schematic of PFT devices is shown in Figure 6. The PFT is used to determine the rate of dewatering through the geotube. The test device consists of a cylindrical acrylic cistern and threaded slab that secure the geotextile. After 3 minutes of mixing time, the slurry is immediately transferred to the cistern. A force of 34.5 kPa applied at the top of the test device simulates the internal pressure in the geotube.

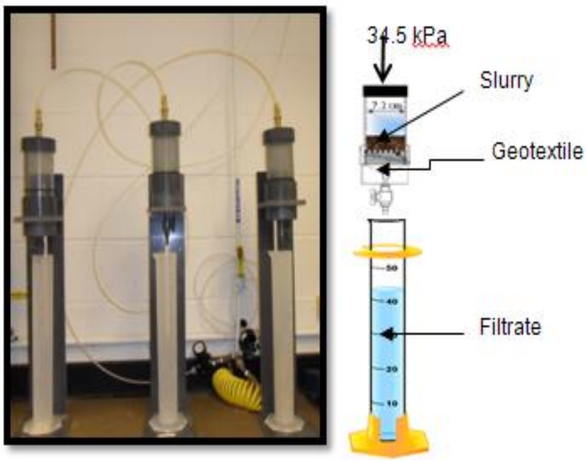


Figure 6: A photo and schematic drawing of PFT.

4 Results and discussion

4.1 Jar sedimentation test

In this study, Jar Sedimentation Tests (JST) were performed at 30% solid concentrations to determine characterization of settlement of fly ash with and without different fibers and polymer. The vertical movement of the interface from the top of the jar was recorded during the test period. Every test was repeated at least two times and average results were used for plotting. Settlement continues until a certain point, after which settlement reaches equilibrium. That point was defined as the critical sedimentation point [24],[25],[29]. Results of fly ash without fiber and polymer were considered as the control data in figures and comparisons were made using these control data.

Figures 7-8 show change of solid height versus time for RSC 15 fiber with and without polymer.

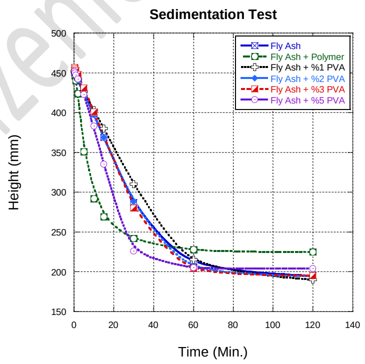


Figure 7: Solid height versus time for RSC 15 (PVA) fiber without polymer.

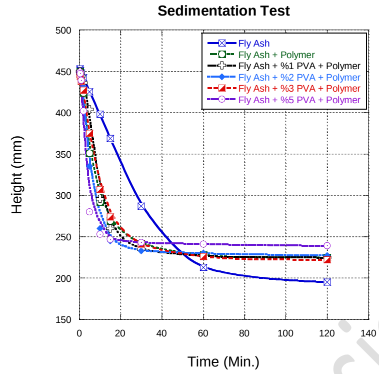


Figure 8: Solid height versus time for RSC 15 fiber with polymer.

As can be seen in Figure 7, fiber inclusion in different percentages has no significant effect on final solid height. For Figure 8, at 5% fiber content with polymer, solid height is the maximum that gives the maximum S_p value. u_i and S_p values of fly ash with RCS 15 fiber and/or polymer are given in Table 4.

Table 4: u_i and S_p values for RSC 15 fiber with and without polymer.

Condition	u_i (cm/s)	S_p (%)
FA only	$6.67*10^{-3}$	43.05
FA and Polymer	$11.55*10^{-3}$	50.00
FA and 1%RSC15	$6.58*10^{-3}$	42.04
FA and 2%RSC15	$6.75*10^{-3}$	43.11
FA and 3%RSC15	$7.03*10^{-3}$	42.67
FA and 5%RSC15	$6.86*10^{-3}$	45.13
FA and 1%RSC15withPolymer	$11.94*10^{-3}$	50.00
FA and 2%RSC15withPolymer	$12.00*10^{-3}$	50.60
FA and 3%RSC15withPolymer	$11.38*10^{-3}$	49.70
Faand 5%RSC15withPolymer	$11.55*10^{-3}$	53.20

FA: Fly Ash.

As can be seen in Table 4, results of fly ash with different fiber contents have no significant difference in comparison with results of the control data, in terms of u_i and S_p values. However, results of fly ash conditioned by polymer show quite a difference in comparison with that of control data in terms of u_i and S_p values. However, S_p and u_i values of fly ash formed with fiber and polymer are not quite as different. It can be said that the contribution of fiber usage is excessively low in comparison with polymer usage in fly ash slurries.

Figures 9-10 show the change of solid height versus time for RC fiber, with and without polymer.

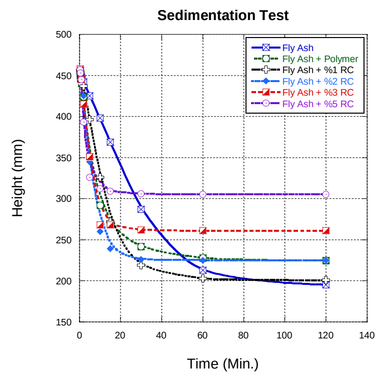


Figure 9: Solid height versus time for RC fiber without polymer.

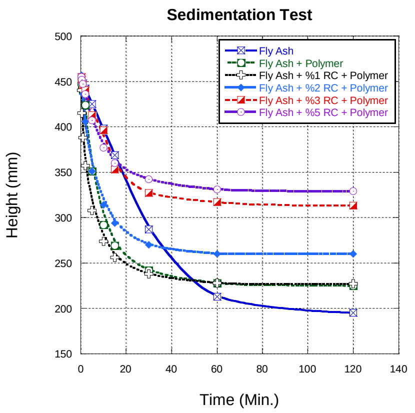


Figure 10: Solid height versus time for RC fiber with polymer.

As can be seen in Figure 9, Solid height of fly ash with 1% fiber is not much different than that of fly ash alone. At 2% fiber content, solid height of slurry is equal to that of fly ash with polymer. At 3% and 5% fiber content, solid height increased significantly, which indicates that open soil body structure may be created with 3% and 5% fiber inclusion.

In Figure 10, it can be seen that solid height of fly ash slurries continued to increase by adding polymer and fiber into the slurry at the same time. Unlike Figure 9, solid height of the slurry at 3% fiber and polymer is close to that of the slurry at 5% and polymer. It can be said that polymer effect with 3% fiber content has a more positive effect than that with 5% fiber content.

Compared to the previous results presented in Table 4, quite different results can be seen in Table 5. The 30-minute point can be defined as the critical settlement point for fly ash with RC fiber and polymer. u_i and S_p values increased with increasing fiber content for samples without polymer condition. S_p value of fly ash with 5% fiber is 55% different than that of control sample. Similarly, u_i value for fly ash with 3% fiber content is almost 5 times higher than that of control sample. Nevertheless, at 5% fiber content, u_i value showed a decreasing trend. It can be said that after a certain percentage of fiber, settlement period became very short and S_p value increased significantly. As for polymer and fiber conditioning at the same time, there is an inverse trend for fly ash conditioned by both fiber and polymer-u_i values decreased with increasing fiber content, while S_p values increased. Increasing the fiber content created a very permeable structure. Using polymer with fiber at the same time provided a more permeable body in comparison with fly ash with fiber alone, which has a negative effect on settlement rate.

Table 5: u_i and S_p values for RC fiber with and without polymer.

Condition	u_i (cm/s)	S_p (%)
FA only	$6.67*10^{-3}$	43.05
FA and Poylmer	$11.55*10^{-3}$	50.00
FA and 1%RC	$6.58*10^{-3}$	44.08
FA and 2%RC	$6.75*10^{-3}$	49.45
FA and 3%RC	$7.03*10^{-3}$	56.98
FA and 5%RC	$6.86*10^{-3}$	66.74
FA and 1%RC with Polymer	$11.94*10^{-3}$	50.44
FA and 2%RC with Polymer	$12.00*10^{-3}$	56.90
FA and 3%RC with Polymer	$11.38*10^{-3}$	68.80
FA and 5%RC with Polymer	$11.55*10^{-3}$	72.30

FA: Fly Ash.

The most remarkable differences between these two different fiber were the filament diameter and fiber length. These two parameters are very vital to obtain uniform fiber dispersion, which causes faster settlement and a very permeable soil body. Soil particles attached around the uniform dispersed fibers act as flocculated soil particles. Uniformly dispersed fiber effect in settlement tests may be similar to the effect of flocculant use.

4.2 Dewatering time

Thirty-six PFT were condcuted at 30% solid concentration of fly ash slurries. Obtained results are given in Tables 6 and 7.

Table 6: Dewatering times obtained PFT for RSC 15 fiber.

Condition	DWT (sec)
FA only	816
FA and Poylmer	420
FA and 1%RSC15	660
FA and 2%RSC15	780
FA and 3%RSC15	750
FA and 5%RSC15	690
FA and 1%RSC15 with Polymer	495
FA and 2%RSC15 with Polymer	412
FA and 3%RSC15 with Polymer	415
FA and 5%RSC15 with Polymer	398

FA: Fly Ash.

Table 7: Dewatering times obtained from PFT for RC fiber.

Condition	DWT (sec)
FA only	816
FA+poylmer	420
FA and 1%RC	660
FA and 2%RC	600
FA and 3%RC	390
FA and 5%RC	240
FA and1%RC withPolymer	342
FA and 2%RC with Polymer	262
FA and 3%RC with Polymer	200
FA and 5%RC with polymer	180

According to the results given in Table 6, the best performance was obtained at 1% fiber content without polymer. However, dewatering time of fly ash with polymer is better than that of fly ash with 1% fiber content. Dewatering time of the slurries could not be improved significantly by use of polymer and fiber at the same time. It can be said that use of RSC fiber has no remarkable effect in terms of the dewatering behavior.

Unlike the results given in Table 6, use of RC fiber improved the dewatering time markedly at 3% and 5% fiber contents. Dewatering times for RC fiber at different percentages given in Table 7 indicate that increasing fiber content created an open structure. Use of fiber at different content and polymer at the same time improved the dewatering time of fly ash slurries. Synthetic polymers are the chemical products that may be hazardous to the environment and human health at higher dosages. Therefore, fiber usage that has no hazardous effect may be a good alternative to polymer usage.

4.3 Relationship between PFT and JST

Table 8 shows dewatering time values and S_p values of the fly ash slurries.

The results given in Table 8 indicate that increasing fiber content of RSC 15 fiber (PVA) did not change the DWTs of the fly ash slurry remarkably. S_p values obtained from JST support this interpretation, because S_p values also did not change with increasing fiber content. It can be said that DWT decreases with increasing S_p value. To be able to see the relationship between the results obtained by PFT and JST, regression analysis was done.

Table 8: DWT and S_p values of fly ash and fly ash with RSC 15 fiber.

Condition	DWT (sec)	S_p (%)
FA only	816	43.05
FA and 1%RSC15	775	42.04
FA and 2%RSC15	783	43.11
FA and 3%RSC15	787	42.67
FA and 5%RSC15	690	45.13

FA: Fly Ash.

Figure 11 shows the regression analysis of DWT and S_p values of fly ash only and fly ash with RSC 15 fiber at different percentages.

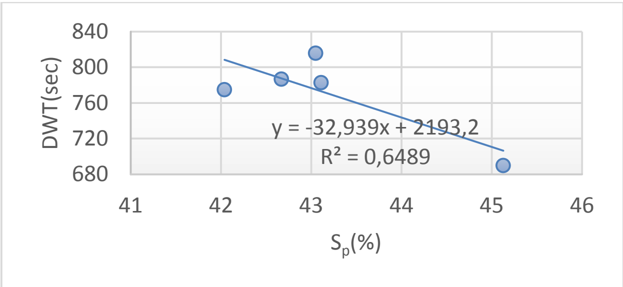


Figure 11: Regression analysis of DWT and S_p values of fly ash and fly ash with RSC 15 fiber.

It may said that DWT and S_p values have strong relationship based on the regression value shown in Figure 11.

In Table 9, it can be seen that DWT decreased notably with increasing fiber content. Increasing fiber content creates an open soil body. Therefore, S_p values increased in direct proportion with increasing fiber content, which indicates that there is a clear inverse relationship between DWT and S_p value.

Table 9: DWT and S_p values of fly ash and fly ash with RSC 15 fiber and polymer.

Condition	DWT (sec)	S_p (%)
FA only	816	43.05
FA and 1%RSC15 withPolymer	495	50.00
FA and 2%RSC15withPolymer	413	50.60
FA and 3%RSC15withpolymer	415	49.70
FA and 5%RSC15withpolymer	398	53.20

FA: Fly Ash.

Regression analysis value shown in Figure 12 shows that the relationship between DWT and S_p value for usage of polymer and fiber stronger than that between DWT and S_p value for usage of fiber only. Table 10 shows the DWT and S_p values for RC fiber inclusion.

Table 10: DWT and S_p values of fly ash and fly ash with RC fiber.

Condition	DWT (sec)	S_p (%)
FA only	816	43.05
FA and 1% RC	660	44.08
FA and 2% RC	600	49.45
FA and 3% RC	390	56.98
FA and 5% RC	240	66.74

FA: Fly Ash.

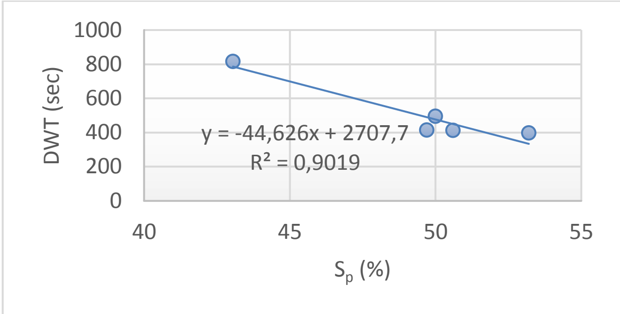


Figure 12: Regression analysis of DWT and S_p values of fly ash and fly ash with RSC 15 fiber and polymer.

Table 10 shows that DWT of slurries decreased very significantly with increasing RC(nylon) type of fiber percentages. At 1% percent fiber content, S_p value is not much different than that of fly ash alone. However, at 3% and 5% fiber contents, DWT of fly ash slurries decreased and S_p values increased, remarkably.

Figure 13 shows the regression analysis between DWT and S_p values for fly ash alone and fly ash with RC fiber at different percentages.

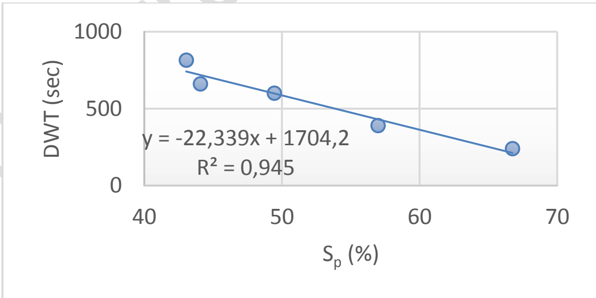


Figure 13: Regression analysis of DWT and S_p values of fly ash only and fly ash with RC fiber.

According to regression value shown in Figure 13, it can be interpreted that for RC fiber at different contents without polymer, the relationship between DWT and S_p values is stronger than that for RSC 15 fiber at different contents without polymer. Table 11 shows the DWT and S_p values for RC fiber and polymer inclusion.

From the results given in Table 11 it can be said that by adding polymer at 1% fiber content, DWT of the slurry equals that of the slurry at 3% fiber content without polymer, which indicates that by adding polymer, better dewatering performance can be obtained with a small percentage of fiber.

According to the regression value shown in Figure 14, it can be interpreted that for RC fiber at different contents with polymer, the relationship between DWT and S_p values is less strong than that for RSC 15 fiber at different contents with polymer.

Table 11: DWT and S_p values of fly ash and fly ash with RC fiber and poylmer.

Condition	DWT (sec)	S_p (%)
FA only	816	43.05
FA and 1%RC with Polymer	343	50.44
FA and 2%RC with Polymer	263	56.90
FA and 3%RC with Polymer	200	68.80
FA and 5%RC with polymer	180	72.30

FA: Fly Ash.

As a summary, according to the values given in Tables 8-11, it can be said that dewatering time decreases with increasing final proportion of solid. Based on the quite high regression values shown in Figures 11-14, it can be interpreted that S_p values obtained from the jar sedimentation test can be used for estimation of dewatering time of the fly ash slurries.

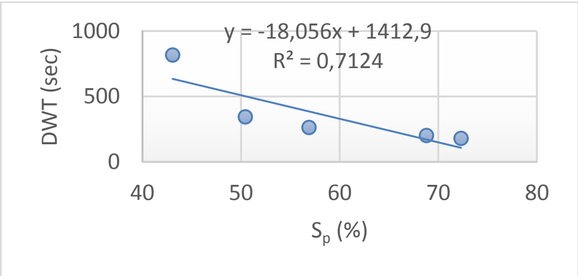


Figure 14: Regression analysis of DWT and S_p values of fly ash and fly ash with RC fiber and polymer.

5 Conclusions

Based on the Jar Sedimentation Test and Pressure Filtration Test results, the following conclusions can be drawn:

1. By fiber inclusion, dewatering rate of the fly ash slurries can be improved. For RSC 15 fiber and RC fiber, dewatering time decreased with increasing fiber content. But, dewatering performance of the slurries formed with RC fiber is better than that of fly ash slurries formed with RSC 15 fiber,
2. For both RSC 15 and RC fibers, the best dewatering performance was obtained at 5% fiber content with and without polymer,
3. Dewatering performance of fly ash slurries formed with different percentage of RC fiber is better than that of fly ash slurries with different percentage of RSC 15 fiber,
4. Dewatering time of the fly ash slurries formed with fiber at different percentage and polymer at the same time is better than that of fly ash slurries formed with fiber,
5. The optimal dewatering performance of slurry belongs to the condition in which fiber at 5% and polymer were used together into slurry,
6. Dewatering performance of the fly ash slurries formed with polymer without fiber is better than that of the fly ash slurries formed with RSC 15 fiber without polymer. However, dewatering performance of the fly ash slurries formed with RC fiber at 3% is better than that of the fly ash slurries formed with polymer only. Therefore, it can be said that to improve the dewatering time of fly ash slurries, fiber inclusion may be a good alternative instead of the use of synthetic polymers that may be hazardous to the environment and human health,
7. Based on the regression values, the dewatering time of the fly ash slurries can be estimated before field application by using S_p values obtained from Jar Sedimentation Test, a very simple small scale laboratory test.

6 Acknowledgements

The authors who were the visiting scholars in Civil and Environment Engineering Department of Syracuse university would like to thank to YÖK for its support to conduct this experimental study in geotechnical laboratory of Syracuse University, Syracuse, NY, USA.

7 References

[1] Ahmaruzzaman M. A. “Review on the utilization of fly ash”. *Progress in Energy and Combustion Science*, 6, 327-363, 2010.

[2] Khachan M, Bhatia SK, Gustafson AC. “Dewatering and utilization of fly ash slurries using geotextile tubes”. *Indian Geotechnical Journal,* 42(3), 194-205, 2012.

[3] Wang S, Wu H. “Environmental-benign utilization of fly ash as low-cost adsorbents”. *Journal of Hazardous Materials B*, 136(3), 482-501, 2006.

[4] Meawad AS, Bojinova DY, Pelovski YG. “An overview of metals recovery from thermal power plant solid wastes”. *Waste Management*, 30(12), 2548-2559, 2010.

[5] Sridharan A, Prakash K. “Coal ash utilization and sustainable waste management”. *The First US-India Workshop on Global Environmental Engineering Challenges*, New Delhi, India, 2010.

[6] Ravina D, Mehta PK. “Properties of fresh concrete containing large amounts of fly ash”. *Cement and Concrete Research*, 16(2), 227-238,1986.

[7] Alasali MM, Malhotra VM. “Role of concrete ıncorporating high volumes of fly ash in controlling expansion due to alkali-aggregate reaction”. *ACI Material Journal, 88, 159-163.*

[8] Oner A, Akyuz S Yildiz R. “An experimental study on strength development of concrete containing fly ash and optimum usage of fly ash in concrete”. *Cement and Concrete Research*, 35(6), 1165-1171,2005.

[9] Gao P, Lu X, Lin H, Li X, Hou J. “Effects of fly ash on the properties of environmentally friendly dam concrete”. *Fuel*, 78, 137-142, 2007.

[10] Pan PN. “Prospect of utilization of fly ash in coal mines- a prospective”. *Proceedings of the workshop on fly ash utilization: Issues and strategies,* 2000.

[11] Muthukumaran AE, Ilamparuthi K. “Laboratory studies on geotextile filters as used in geotextile tube dewatering”. *Geotextiles and Geomembranes,* 24(4), 210-219, 2006.

[12] Fowler J, Bagby RM, Trainer E. “Dewatering sewage sludge with geotextile tubes”. *49th Canadian Geotechnical Conference.* St John’s, Canada, 2005.

[13] de Krester RG, Usher SP, Scales PJ, Boger D, Landman KA. “Rapid filtration measurement of dewatering design and optimization parameters”. *American Institute of Chemical Engineers Journal,* 47(8), 1758-1769, 2001.

[14] Mori H, MiKi H, Tsuneoja N. “The geotube method for dioxin contaminated soil”. *Geotextiles and Geomembranes,* 20(5), 281-288, 2002.

[15] Koerner GR, Koerner RM. “Geotextile tube assesment using a hanging bag test”. *Geotextiles and Geomembranes*, 24(2), 129-137, 2006.

[16] Lawson CR. “Geotextile containment for hydraulic and environmental engineering”. *Geosynthtetics International,* 15(6), 385-427, 2008.

[17] Maurer BW, Gustafson AC, Bhatia SK, Palomino AM. “Geotextile dewatering of flocculated, fiber reinforced fly-ash slurry”. *Fuel*, 97, 411-417, 2012.

[18] Kazemian S, Huat K, Prasad A, Barghchi M. “A review of stabilization of soft soils by ınjection of chemical grouting”. *Australian Journal Basic and Applied Science*, 4(12), 5862-5868, 2010.

[19] Li C. Mechanical Response of Fiber-Reinforced Soil. PhDThesis, Faculty of the Graduate School of the University of Texas, Austin, 2005.

[20] Yetimoglu T, Salbas O. “A study on shear strength of sands reinforced with randomly distributed discrete fibers”. *Geotextiles and Geomembranes*, 21(2), 103-110, 2003.
[21] Vidal H. “The principle of reinforced earth”. *Highway Research Record*, 282, 1-16, 1969.
[22] Gregory J, Barany S. “Adsorption and flocculation by polymers and polymer mixtures”. *Advances in Colloid and Interface Science*, 169(1), 1-12, 2011.
[23] Hogg R. “Flocculation and dewatering”. *International Journal of Mıneral Processing,* 58(1-4), 223-236, 2000.
[24] Satyamurty R, Bhatia SK. “Effect of polymer conditioning on dewatering characteristics of fine sediment slurry using geotextiles”. *Geosynthetics International*, 16(2), 83-96, 2009.
[25] Tarleton S, Wakeman R. *Solid/Liquid Seperration: Equipment Selection and Process Design*. London, UK, Butterworth-Heinemann, 2007.
[26] Moo-Yong HK, Douglas AG, Xinghua M. “Testing Procedures to Assess the Viability of Dewatering with Geotextile Tubes”. *Geotextiles and Geomembranes*, 20(5), 289-304, 2002.
[27] Bhatia SK, Liao K. “Overview of Geotextile Tube: Application and Research”. *International Conference on Geosynthetics and Geoenvironmental Engineering*, Bombay, Mumbai, India, 2004.
[28] Liao K. Dewatering of Natural Sediments Using Geotextile Tubes. Ph.D Dissertation, Syracuse University, Syracuse, NY, USA, 2008.
[29] Satyamurty R. Experimental Investigations of Geotextile Tube Dewatering. Ph.D Dissertation, Syracuse University, Syracuse, NY, USA, 2008.