International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 4 (2019) pp. 1025-1030

Soil stabilization with Flyash and Corn Waste Ash – Improvements in Engineering Characteristics

Robert M. Brooks
PhD, PE, F.ASCE
Associate Professor,
Department of Civil and Environmental Engineering
Temple University, Philadelphia 19122,

Abstract

Infrastructure plays an important role in a nation's development. Clay soils play significant part of the strength of any infrastructure built over them. The objective of this paper is to stabilize soil with the fly ash and Corn Waste ash. For this purpose, a soil with high clay content was mixed with fly ash and Corn Waste ash. Several engineering improvements were reported and discussed as a result of this study.

The impact on UCS at 15% flyash and 6% CWA, for a 28 day curing period, is 840 kPa. At 15% flyash and 12% CWA, for a 28 day curing period, the UCS is 959 kPa When the CWA content was increased from 0 to 12%, CBR improved from 3.7 to 10.6% for 25% flyash.

Keywords: Construction Materials, Clays, Corn Waste Ash, Flyash.

INTRODUCTION

Infrastructure plays an important role in a nation's development. An example of infrastructure is highways. Clays cause uneven settlements of highways[1]. Clays have low resistance to permanent deformation[2,3]. This property plays a significant part of the strength of any pavement built over clay soil. Pavement structures are designed to serve their design life. However, several factors affect their serviceability and cause premature failures. The subgrade factors include high clay content, poor compaction, and insufficient drainage,

Adding admixtures to such type of subgrade using fly ash and Corn Waste ash is a doable method. This would make the needed modifications in the engineering characteristics. The objective of this paper is to stabilize soil with the fly ash and Corn Waste ash.

MATERIALS

Soils

As per the USCS classification system, the soil is a CH soil.

Flyash

Table 1 shows the constituents of Class C flyash used in this study.

Table 1: Constituents of Fly Ash.

Constituents	%
SiO_2	56.0
Al_2O_3	21.0
Fe_2O_3	6.5
CaO	12.2
MgO	3.6
Alkali	1.1
SO_3	1.6
Heavy Metals	trace

Corn Waste Ash

In this investigation, CWA passing through No. 100 sieve (150 micrometers) was used. The chemical composition of CWA is listed in Table 2. The CWA had 60% silica content. This amount provides good pozzolanic action.

Table 2: Chemical Composition of Corn Waste Ash

Constituent	%
Silica – SiO_2	60
Alumina – Al_2O_3	1.1
Calcium Oxide – CaO	5.0
Potassium Oxide - K_2O	15
Sulfur Trioxide - SO_3	1.2
Magnesium oxide - MgO	3.0
Phosphorus Oxide – P_2O_5	7.1

EXPERIMENTS

Several simple but valuable tests were conducted to support the importance of this paper. These include the following tests: UCS, CBR, compaction and swell-shrinkage tests.

Compaction

The tests were performed in accordance with ASTM D 1557. The specimens were of 102mm diameter and 116mm height.

UCS

The UCS tests were performed in accordance with ASTM D 2166. The sample sizes were of 40mm diameter and 80mm length.

CBR

The CBR test is an important one used for determining the strength of various layers of pavements. The layers include sub grade soil, sub base, and base course material. The CBR test results can play an instrumental role for the comparison of designed thickness for highways and airfield pavements. The CBR tests were conducted in accordance with ASTM D 1883. The sample sizes were of 152mm diameter and 126mm length.

Swelling

Consolidation test (ASTM D 2435) setup was used for determining the cyclic swell-shrink behavior of the soil. The sample sizes were 76mm and 50mm in diameter and height respectively. The samples were prepared at Proctor’s dry densities. The compacted admixture was cured for 14 days and placed over the expansive soil. The efficacy of CWA as a cushioning layer between the foundation and subgrade was also tested using the consolidation test.

TEST RESULTS AND DISCUSSION

The effect of flyash content on the UCS of CWA is presented in Figure 1. The effect of flyash on the stress strain behavior of the clay specimens in UCS test is shown in Fig. 2. The flyash content varied from 0 to 30%. When flyash was increased from 0 % to 25 %, the compressive strength improved from 429 to 694 kPa at a strain of 6%. When flyash was increased from 0 % to 25 %, the compressive strength improved from 341 to 871 kPa at a strain of 9%.

The ieffect of CWA on CBR of clay-flyash mix is shown in Fig. 3. At any flyash content, addition of CWA up to 12% led to increases in CBR. Further increase in CWA decreased CBR, indicating that 12% is the optimum value of CWA. When the CWA content was increased from 0 to 12%, CBR improved from 2.1 to 7.8 for 0% flyash. When the CWA content was increased from 0 to 12%, CBR improved from 3.7 to 10.6% for 25% flyash as shown in Figure 3.

Low cohesion makes CWA a poor cushioning and construction material. However, after stabilizing with flyash and curing for 28 days, CWA acquires better cushioning properties and hence it can be used as a construction material between the subgrade and foundations.

Fig. 4 shows the influence of number of cycles on swell percent. Fig. 5 shows the influence of swell reduction layer thickness ratio on percent swell for various surcharges.

At 15% flyash and 12% CWA, for a 28 day curing period, the UCS is 959 kPa as shown in Figure 1. As per Kate and Katti[4], this qualifies as a cushioning material at 15% flyash. Similar results were found by Sivapulliah et al.[5] for an CWA-lime mixture.

References 6 through 17 deal with more research studies on the behavior of clays and admixtures of other waste materials. References 18 through 37 indicate the importance of this research study which is applied in class room teachings for the benefit of engineering students.

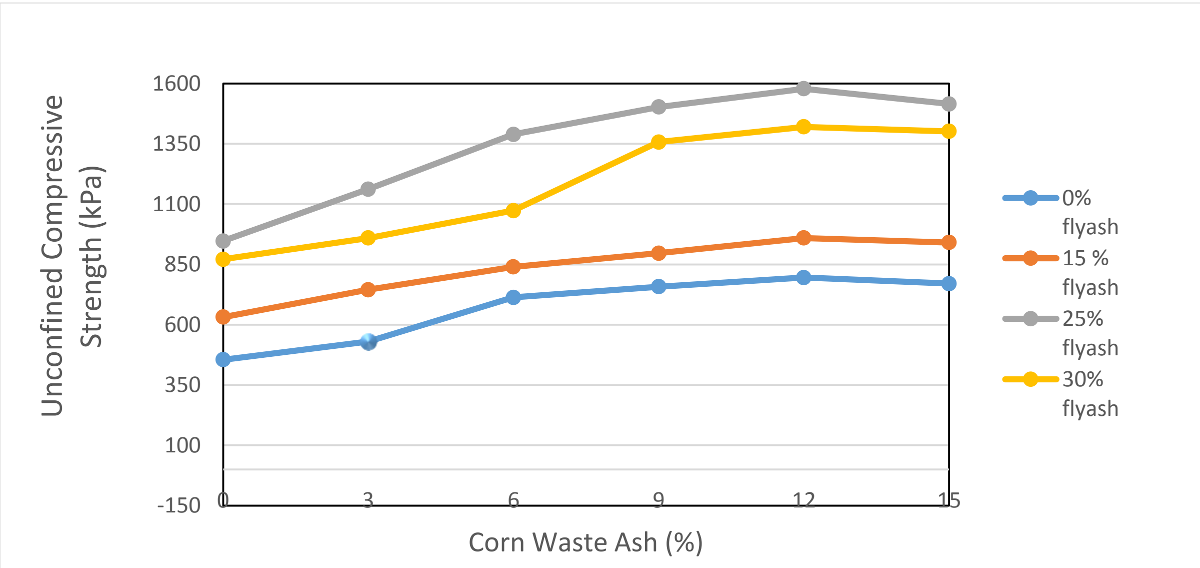

Fig. 1. Influence of Corn Waste Ash on UCS for clay-flyash mixture.

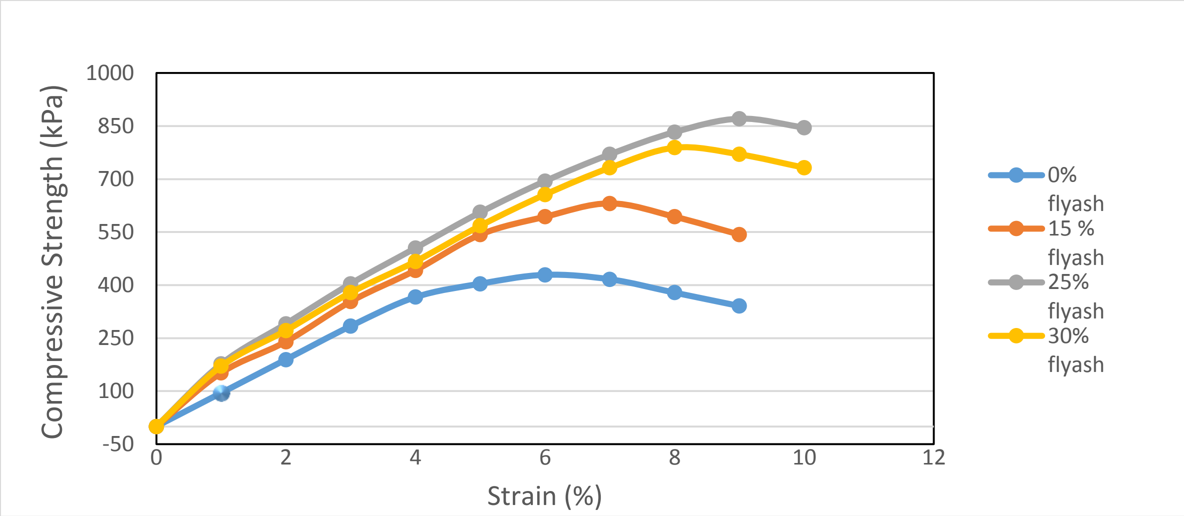

Fig. 2. Influence of flyash on the stress-strain behavior of the soil.

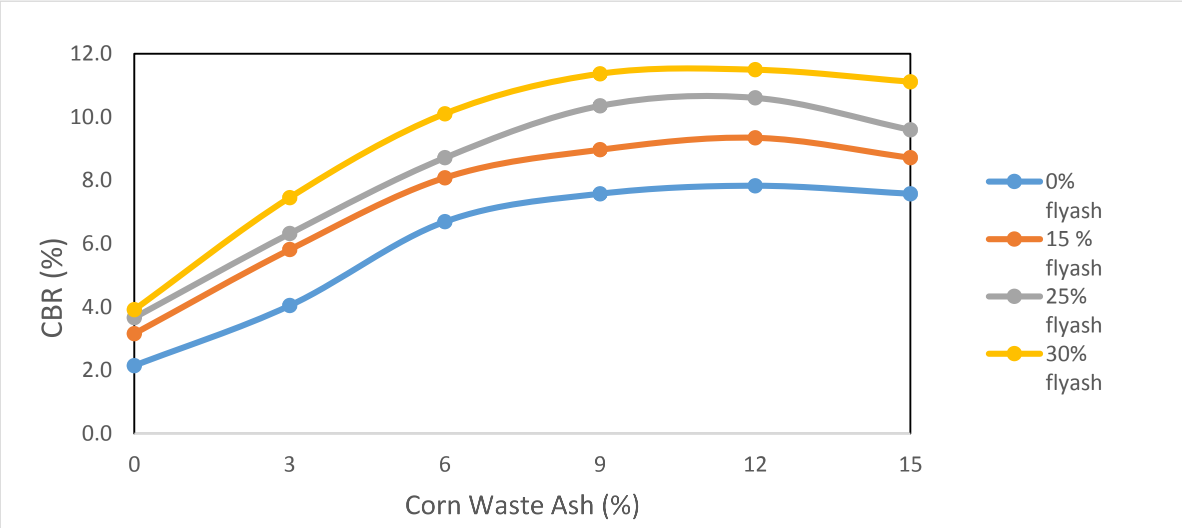

Fig. 3. Influence of Corn Waste Ash on CBR for clay-flyash mixture.

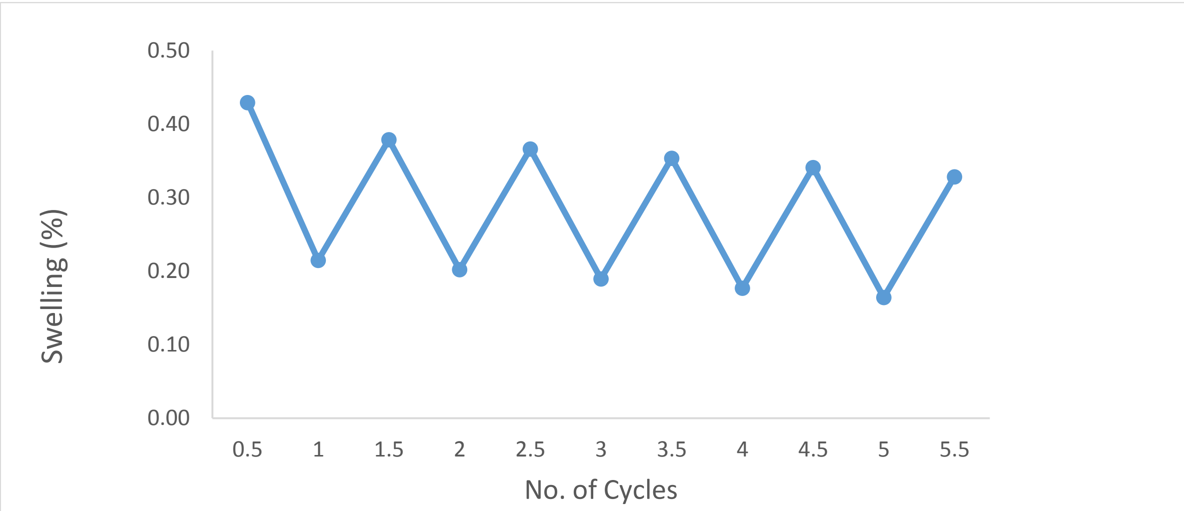

Fig. 4. Influence of number of cycles on swelling of 15% flyash and Corn WA blend under surcharge of 5kPa.

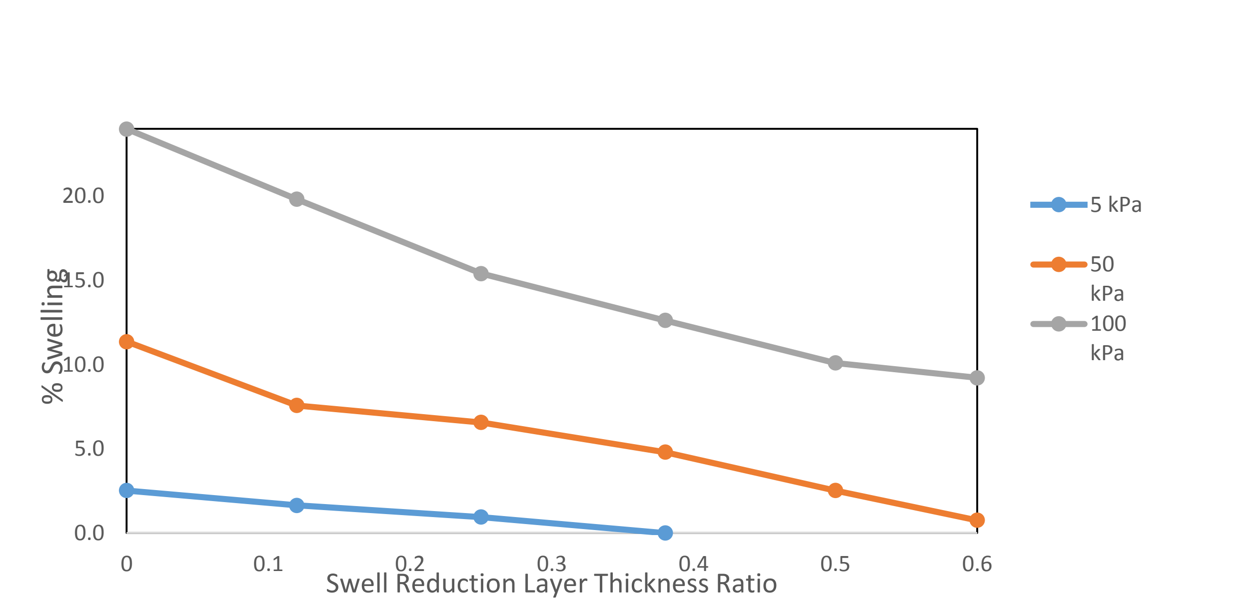

Fig. 5. Influence of Swell reduction layer thickness ratio on swell percentage of soil for various surcharges.

CONCLUSIONS

The following are the conclusions.

1. The impact on UCS at 15% flyash and 6% CWA, for a 28 day curing period, is 840 kPa
2. At 15% flyash and 12% CWA, for a 28 day curing period, the UCS is 959 kPa
3. When the CWA content was increased from 0 to 12%, CBR improved from 3.7 to 10.6% for 25% flyash.

LIMITATIONS OF THIS STUDY

The results of this paper are limited to the materials tested in this study. More materials need to be tested to increase the scope of this study.

ACKNOWLEDGEMENT

Keerthi Takkalapelli, a graduate student of the author conducted the experiments. His work is duly acknowledged.

REFERENCES

[1] Liu, C., and Evett, J., "*Soils and Foundations*", 2008, Pearson-Prentice Hall, Seventh Edition, Upper Saddle River, New Jersey.

[2] Mitchell, J.K., "Practical Problems from surprising soil Behavior," *J. Geotech. Eng.*, 1986, Vol. 112, No. 3, 255-289.

[3] Drumm, E.C., Reeves. J.S., Madgett, M.R., and Trolinger, W.D., "Subgrade Resilient Modulus Correction for Saturated Effects". *Journal of Geotechnical Geo-environmental engineering*, 1997, Vol. 123, No. 7, pp. 663-670.

[4] Kate, J.M. and Katti, R.K., "Effect of CNS layer on the behavior of underlying expansive soils media: an experimental study", 1980, *Indian Geotechnical Journal*, 281-305.

[5] Sivapulliah P.V., Subba Rao K.S., and Gurumurthy, J.V., "Stabilization of rice husk ash as cushion below foundations on expansive soils", *Ground Improvement*, 2004, Vol. 8, No. 4, pp 137-149.

[6] Brooks, R., Udoeyo, F., and Takkalapelli, K. "Geotechnical Properties of Problem Soils Stabilized with Fly Ash and Limestone Dust in Philadelphia." J. Mater. Civ. Eng., American Society of Civil Engineers, 23(5), 711–716, 2011. http://ascelibrary.org/mto /resource/1/jmcee7/v23/i5/p711_s1

[7] R. M. Brooks (Corresponding author), F. Udoeyo, and K. V. Takkalapelli, "Compaction Delay Characteristics of Clay with Cement Kiln Dust", UK Institute of Civil Engineers, Geotechnical Engineering Volume 162, issue 5, ISSN: 1353-2618, pp 283-286, Oct 2009.

http://www.icevirtuallibrary.com/content/article/10.168 0/geng.2009.162.5.283

[8] Robert Brooks (Corresponding author), Mozhgan Bahadory, Fernando Tovia and Hossein Rostami, "Properties of Alkali Activated Fly Ash: High Performance to Lightweight" , International Journal of Sustainable Engineering, Taylor and Francis V3, No.3, 211-218, September 2010,

http://www.tandfonline.com/doi/abs/10.1080/19397038 .2010.487162#preview

[9] Khoury, N., Robert Brooks (Corresponding author), Musharraf M. Zaman, Charbel N. Khoury . "Variations of Resilient Modulus of Subgrade Soils with

Postcompaction Moisture Contents", Transportation Research Record: Journal of the Transportation Research Board, Transportation Research Board of the National Academies, issn 0361-1981, Volume 2101 / 2009, page 72-81. http://trb.metapress.com/content/j2h2j8841p067802/

[10] Khoury, N., Brooks, R. (Corresponding author), Khoury, C., and Yada, D., "Modeling Resilient Modulus Hysteretic Behavior with Moisture Variation". Int. J. Geomech, American Society of Civil Engineers ISSN 1943-5622, 2011. http://ascelibrary.org/doi/abs/10.1061/%28ASCE%29GM.1943-5622.0000140

[11] Khoury, N., Ph.D., Robert Brooks (Corresponding Author), Ph.D., P.E., ASCE Fellow, Charbel N. Khoury. Environmental influences on the engineering behavior of unsaturated undisturbed subgrade soils: effect of soil suctions on resilient modulus. International Journal of Geotechnical Engineering, J. Ross Publishing, Inc 1938-6362, Volume 3, Issue 2 / April 2009, page 303-311. http://jrosspub.metapress.com/content/p4310j7pt70707k0/

[12] Hossein Rostami, Robert Brooks (Corresponding Author), Fernando Tovia, Mozhgan Bahadory. Development of Lightweight Construction Material From Alkali Activated Fly Ash. The Journal of Solid Waste Technology and Management. Volume 35. Issue 3, August 2009.

http://solid-waste.org/journal/abstracts-of-published-papers/volume-35-2009/

[13] Brooks, R., Soil Stabilization with Lime and RHA, International Journal of Applied Engineering, IJAER, Volume 5, Number 7. pp. 1077-1086, 2010.

http://www.ripublication.com/Volume/ijaerv5n7.htm

[14] Brooks, R. M. Soil Stabilization with RHA and Flyash, International Journal of Research and Reviews in Applied Sciences V 1, Issue 3, pp.209-217, 2009.

http://arpapress.com/Volumes/Vol1Issue3/IJRRAS_1_3_01.pdf

[15] Kingsley Donaldson, Robert M. Brooks (Corresponding author), Felix F. Udoeyo, and Keerthi V. Takkalapelli. Effects of Fly Ash on Engineering Properties of Clays. International Journal of Applied Engineering Research. Volume 6, Number 1, pp. 43-52, 2011. http://www.ripublication.com/Volume/ijaerv6n1.htm

[16] Khoury, N., Robert M Brooks (Corresponding Author), Santhoshini Yadav Boeni, and Damodar Yada "Variation of Resilient Modulus, Strength, and Modulus of Elasticity of Stabilized Soils with Postcompaction Moisture Contents", Journal of Materials in Civil Engineering, American Society of Civil Engineers, Volume 25, Number 2, ISSN 0899-1561, pp.160-166, February 2013.

http://ascelibrary.org/doi/abs/10.1061/(ASCE)MT.1943-5533.0000574

[17] Robert M. Brooks and Mehmet Cetin. "Water Susceptible Properties of Silt Loam Soil in Subgrades in South West Pennsylvania", International Journal of Modern Engineering Research. Vol.3, Issue 2, ISSN: 2249-6645, S. No: 57, March- April, 2013, pp. 994-948. http://www.ijmer.com/papers/Vol3_Issue2/CE32944948.pdf

[18] Robert Brooks, S. Jahanian, A Pedagogical Strategy for Gradual Enhancement of Creative Performance of the Students, European Journal of Engineering Education Volume 24, No,1 1999.

[19] S. Jahanian, and Robert Brooks (a/k/a James Matthews). Multidisciplinary Project-A tool for Learning the Subject Journal of American Society of Engineering Education, V 88, No.2, pp153-162, April 1999.

[20] Robert Brooks, Keerthi V. Takkalapelli, Berk Ayranci, Improvement of Graduate Students Performance In Design, Discovery, And Learning, 2009, AC 2009-2524 ,ASEE 2009 Annual Conference. http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F19%2FAC%25202009Full2524.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

[21] Robert Brooks, Fernando Tovia, Tony Singh, Amithraj Amavasai, Hossein Rostami, Innovative Training Strategy (Its) for Teaching Assistants, AC 2010-264, ASEE 2010 Annual Conference. http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F32%2FAC%25202010Full264.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

[22] Robert Brooks, Fernando Tovia, Keerthi V. Takkalapelli, Amithraj Amavasai, Hossein Rostami, Naji Khoury, Tony Singh, Improving Creativity in A Graduate Course , AC 2010-72 , ASEE 2010 Annual Conference. http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F32%2FAC%25202010Full72.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

[23] Robert Brooks, Mr. Amithraj Amavasai, Rewarding Levels of Knowledge in Graduate Student Exams, AC 2011-143, ASEE 2011 Annual Conference, Ancouver, B. C. Canada, June 26-29 2011. http://www.asee.org/public/conferences/1/papers/143/view

[24] Robert Brooks, Naji Khoury, Jyosthna Kavaturu, Mr. Amithraj Amavasai Correlation between "Ethical Issues" and "Grade" Performance in a Graduate Class, AC 2011-147 , ASEE 2011 Annual Conference, Ancouver, B. C. Canada, June 26-29 2011. http://www.asee.org/public/conferences/1/papers/147/view

[25] Robert Brooks, Jyosthna Kavaturu, Mr. Amithraj Amavasai. Engineering and Technology for Non-Engineering and Non-Science Majors, AC 2011-140, ASEE 2011 Annual Conference, Ancouver, B. C. Canada, June 26-29 2011. http://www.asee.org/public/conferences/1/papers/140/view

[26] Robert Brooks, Jyosthna Kavaturu, Mr. Amithraj Amavasai Development of Best Practices for New Engineering and Math Educators, AC 2011-135, ASEE 2011 Annual Conference, Ancouver, B. C. Canada, June 26-29 2011. http://nee.asee.org/Conference Papers/2011/135.pdf

[27] Robert M. Brooks, Jyothsna K. S., Mehmet Cetin. AC 2012-2992: Creativity for Enhancing The Technological Literacy For Non-Science Majors, ASEE 2012 Annual Conference, San Antonio, June 10-13, 2012. http://www.asee.org/public/conferences/8/papers/2992/view

[28] Robert M. Brooks, Jyothsna K. S., Mehmet Cetin. AC 2012-2979: Critical Thinking: A Pedagogical Instrument For New Engineering And Science Educators. ASEE 2012. Annual Conference, San Antonio, June 10-13, 2012. http://www.asee.org/public/conferences/8/papers/2979/view

[29] Robert M. Brooks, Jyothsna K. S., Mehmet Cetin. AC 2012-2977: Science for Non-Science Majors. ASEE 2012 Annual Conference, San Antonio, June 10-13, 2012. http://www.asee.org/public/conferences/8/papers/2977/view

[30] Robert M. Brooks, Mehmet Cetin., and Jyothsna K. S., Application of Peer Reviewed Journal articles for Enhancing Technological Literacy. ASEE 2013 Annual Conference, Atlanta, June 23-26, 2013.

[31] Robert M. Brooks, Mehmet Cetin, and Jyothsna K. S., Sustainability Perspectives of Graduate Students on Transportation Systems and Management. ASEE 2013 Annual Conference, Atlanta, June 23-26, 2013.

[32] Robert Brooks, etc. Keeping the Civil Engineering Pipeline Filled- Attracting Young Talent ASEE Global Colloquium, Singapore, Oct 2010.

[33] Robert Brooks, etc. Intellectual Dexterity and Strategy to Solutions for Multidisciplinary Problems-Tools for Attracting Students to Study Engineering ASEE Global Colloquium, Singapore, Oct 2010.

[34] Robert Brooks, etc. A Strategy to Increase Shelf Life of Engineers ASEE Global Colloquium, Singapore, Oct 2010.

[35] Robert Brooks, etc. Assessment of ABET Deliverables in a Senior Design Project Course for Effective Engagement of Our Future Engineers, ASEE Global Colloquium 2009.

[36] Robert Brooks, etc. Case Studies - A Tool for Learning Environmental Science Course, ASEE Global Colloquium 2009.

[37] Robert Brooks, etc. Post-test- A Tool for an Effective Engagement of Our Future Engineers, ASEE Global Colloquium 2009.