I.J. Engineering and Manufacturing, **2016, 3, 1-11**
Published Online May 2016 in MECS (http://www.mecs-press.net)
DOI: 10.5815/ijem.2016.03.01

Available online at http://www.mecs-press.net/ijem

Assessment of the Deterioration of used Engine Oil Soaked Fly ash Concrete and its Analysis using Automated SEM Analysis

Nandini M.Naik [a], Girish S.Kulkarni [b], K.B.Prakash [c]

[a] *Associate Prof. Chemical Engineering Department K.L.E DR M.S.Sheshagiri College of Engineering & Technology,Udyambag,Belgaum-590008.Karnataka.*
[b] *Professor, Environmental Science and Technology and Director Shivaji University Kolhapur, Maharashtra.*
[c] *Professor, Civil Engineering Department and Principal of Govt. Engineering College Haveri. Karnataka.*

Abstract

The determination of strength properties i.e compressive strength, flexural strength and splitting tensile strength is essential to estimate the load at which the concrete members may crack especially in aggressive environment. The paper reports an experimental investigation on deterioration of used engine oil (UEO) soaked flyash concrete with respect to its strength properties and effective automation of classification of data sets returned by the SEM test on the same set of samples. In the former part, concrete cube ,beam and cylinder specimens with fly ash admixture as partial replacement of cement by 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% were subjected to water curing and then to UEO soaking. Gradual decrease in the strength properties of concrete specimens with respect to time was observed. An attempt has been made to study the permeation properties like soroptivity with the addition of fly ash in concrete. The SEM analysis of test results was in good agreement to this. An attempt was made to automate this analysis phase using correlation coefficient and Support Vector Machines (SVM). It was found that the latter achieved better results in terms of performance.

Index Terms: Flyash, Concrete, Used engine oil, SEM, Correlation Coefficient, SVM.

1. Introduction

Concrete structures coming in contact with petroleum products is a common scenario in places like garages, petrol bunks, storage tanks, etc. Storage of petroleum products is done by either steel or concrete tanks [1]. Due to corrosion hazards, concrete is preferred for storage of petroleum products. Drastic decrease in compressive strength by 18-90 % in concrete were found in the case of samples coming in contact with crude oil [2].Very little is known about the flexural behavior of concrete in direct contact used engine oil. Many attempts have

* Corresponding author.
E-mail: address: sneha2bandekar@gmail.com

been made to enhance the strength properties by the addition of pozzolans. In spite of this, it was found that concrete undergoes considerable amount of degradation when it comes in contact with used engine oil. So efforts to minimize this or completely avoid this degrading effect have to be carried out.

Various proportions of pozzolans exhibited enhancement in strength of concrete. But the selection of right pozzolan with the right proportion against a specific environment (UEO in this case) has always been a challenging issue. The detrimental effect on concrete can be assessed using flexural strength analysis and SEM tests. The former is easier to evaluate than the latter. In the latter case, molecular images of the specimens are retrieved which is often difficult to manipulate visually. Hence an automated tool to achieve this has to be introduced.

Over a period of three years, the dynamic modulus of concrete was analyzed for samples soaked in crude oil. When compared to water saturated samples, the increase in the dynamic modulus for crude oil soaked samples was less [3]. The compressive strength was found to be decreased for concrete specimens soaked in crude oil. Comparison of physico-chemical influence between water and oil lead to a conclusion that polar molecules within hydrocarbon chain were harmful to concrete. Water moles are small dipoles geometrically and when they act positively on concrete, the strengthening occurs. The hydrocarbon chain is non-polar and non-harmful, but in connection with hydrophilic part the problem is found to be raised [4].

Petroleum or petroleum products pose adverse effects on concrete and thus degrades it. Hence concrete structures get easily deteriorated under such circumstances. The proposed study makes an attempt to assess this degrading effect on concrete, minimize it using flyash addition and automate the process of analyzing the results using support vector machines.

The rest of the paper is organized as follows. Correlation coefficient and Support Vector Machines used exclusively for the automation of the SEM data analysis are briefed in Section 2. Section 3 gives a detailed description of the materials and methods used. The implementation details are elaborated in Section 4. The results and discussions of the proposed implementation are given in Section 5. Finally, the paper is concludes in Section 6.

2. Mathematical Review

A. Correlation coefficient

It is a method employed for measuring the degree of linear relationship that exists between two quantities under test. It was developed in 1895 by Karl Pearson. The Pearson's correlation coefficient is given by [5]:

$$r = \frac{\sum_i (x_i - x_m)(y_i - y_m)}{\sqrt{\sum_i (x_i - x_m)^2}\sqrt{\sum_i (y_i - y_m)^2}} \tag{1}$$

where x_m and y_m correspond to the mean intensity values of the 1st and 2nd image respectively. x_i and y_i represent the intensity values of the ith pixel in 1st and 2nd images respectively; If the two images are absolutely identical, then the value obtained from the correlation coefficient is 1, the value of r = 0 indicates that the two images are uncorrelated. The value of r = -1 specifies that the two images are anti-correlated [6].

The major advantage of the correlation coefficient is that it condenses the comparison of two entities down to a single scalar value, r. The main shortcoming here is that it is computationally intensive. Also, it goes undefined in some cases due to division by zero error (when images have uniform, constant intensity).

B. Support Vector Machines (SVM)

SVM is a well-known binary classifier and it can be extended to multi class problems as well. SVM is associated with machine learning domain. The credit of formulating it goes to Vladimir N. Vapnik. They are basically supervised learning models to scrutinize the data and identify patterns [7, 8]. This is basically used for regression analysis and classification. More specifically, a SVM builds a boundary or classifier to distinguish or classify a set of data. It is a straight line in case of 2 D feature vector, while in 3D, it is a plane. For other higher dimensions, it is called hyperplanes. A good classifier is supposed to provide a larger separation between the feature vectors of different classes. Intuitively, this is to assure that the classification is general when the feature vectors are subjected to change due to noise.

Many of the traditional algorithms for classification are based on an assumption that the classifier once trained, cannot be subjected to amendments during run-time. Hence it requires the entire data specific to an entity to be present during training period, which is highly not feasible in real -time applications. However, SVM classifiers overcome this shortcoming by identifying the entities that are not present in the training database. These unknown faces can be used to retrain the classifier.

SVM algorithm is extensively used in applications like Bioinformatics (Protein classification, Cancer classification), text and hypertext categorization, hand written character recognition, brain-wave [12, 15] data analysis [9, 10], and image classification. Face images with considerable amount of variations like pose, occlusions, illumination, skin tone, ethnicity, age, etc. can also be recognized by SVM [11, 13, 14].

The performance of classifiers in image processing has been boosted due to the introduction of Support Vector Machines (SVM). They have been proved to be robust when compared to the traditional classifiers available. This paper aims at using SVMs to classify the results returned by the Scanning Electron Microscope (SEM) test, thereby reducing the manual effort involved to do so. The algorithm was tested on two sets of images of fly ash mixed concrete of different proportions, which were subjected to water curing and UEO soaking. Though the number of samples in the training database was comparatively low, the classifier was capable of effectively identifying the class of the samples in the test database.

3. Materials and Methods

A. Materials

A.1. Cement

Ordinary Portland cement, 43 grade conforming IS: 8112-1989, containing CaO 60%-67%, SiO_2 17%-25%, Al_2O_3 3%-8%, Fe_2O_3 0.5%-6%, MgO 0.5% -4%, Na_2O_2%-3.5% and SO_3 2%-3.5%.

A.2. Fly ash

Fly ash used was obtained from Raichur Thermal Power Station, Shaktinagar, containing Silica (SiO_2)-38% - 63%, Iron oxide Fe_2O_3 -3.3%-6.4%, Aluminium trioxide Al_2O_3- 27% - 44%, Titanium oxide TiO_2 – 0.4 -1.8%, Potassium oxide K_2O 0.04%- 0.9%, Calcium oxide CaO 0.2%-8.0%, Magnesium oxide MgO 0.01% 0.5%, Phosphorus pentoxide P_2O_5, Sulfate SO_4 and Disodium oxide Na_2O 0.07%-0.43%.

A.3. Sand

Locally available sand of specific gravity 2.64 and coarse aggregates of (d max=20 mm) 2.90 were used.

A.4. Water

Clean potable water from city source is used for both concreting and for curing; the water aided the hydration of cement, which resulted in setting, and hardening of the concrete.

A.5. UEO

Used Engine oil could be stock or synthetic but all have additive packages mixed into it.

The engine oil used for soaking the concrete specimens are taken from automobile service station. Properties of used engine oil are shown in the Table 1.

Table 1. Properties of used Engine Oil

Properties	**Results**
Kinematics viscosity at 40 °C	111.32
Kinematics viscosity at 100 °C	17.83
Viscosity index	99
Flash Point, °C	230
Pour Point, °C	-10
TBN	-
Sulfated ash, wt %	4.5
Specific gravity	0.928

B. Methods

B.1. Preparation of specimens

M 30 grade concrete was designed as per IS: 10262-2009 which yielded a proportion of 1:1.76: 3.15 with a w/c ratio of 0.48 and various percentages of fly ash was added in the range of 0-40%. Then the mix was placed layer by layer in the moulds to cast the specimens. Standard cube specimens of size150 mm, beam specimens of size100 mm x100 mm x 500 mm and cylindrical specimens of diameter 150 mm and length 300 mm were cast. Hand compaction along with the vibrations from vibrating table was employed in preparing the specimens. This bequeathed fine finishing to the specimens and it was left for 24 hours without disturbing it and then they were demoulded and cured in water for 28 days. The specimens were then separated into two categories (Group A and B). Group A specimens were left without any interruptions in water itself for another 90 days. Simultaneously, the Group B specimens were immersed in UEO for the same interval of time. Both the specimens were tested for their respective compressive, flexural and splitting tensile strengths as per IS specifications. In case of the Group B specimens, the tests on strength properties were performed on 14th, 28th, 40th, 52nd and 90th day of the UEO curing to monitor the consequences of UEO on concrete. Group A specimens were tested on 28th and 90th day of the water curing process as the change in flexural strength in this context is very less.

4. Implementation

Fly ash mixed concrete was used with two variants in the assessment of strength properties, few samples were water cured (designated as Group A samples) and the rest were soaked in UEO (Group B samples). 189 concrete beams with varying proportions of fly ash admixture were cast and water cured for 28 days. On the 28th day, 3 cubes from the 9 samples (with different percentage of fly ash ranging between 0- 40%) were taken and their respective compressive strength was measured. Totally 27 out of 189 samples were tested here. Then, 135 samples were soaked in the UEO (Group B) and the remaining 27 samples were water cured (Group A). At specific intervals (14, 28, 40, 52, 90 days) the compressive strength strengths of Group B specimens were assessed. In case of Group A, the test was conducted for the 28th and 90th day only (the reason being, most of the hydration takes place within 28 days and later the changes in compressive strengths are marginal).The compressive strengths of both the Groups A and B were compared against their corresponding time intervals. Entire concrete cube with its shape intact was used for compressive strength analysis by using Compressive Testing Machine (CTM) and powdered samples were used for SEM testing. Similar procedure was followed in case of beam specimens for flexural strength and cylindrical specimens for splitting tensile strength analysis.

The cubes after casting were cured in water for 28 days and then soaked in used engine oil for 90 days. After completion of 90 days soaking, few cube specimens are taken for sorptivity testing. Before testing the specimens are dried in the oven at a temperature of 105^0C to a constant mass .Then the weight was taken. After cooling the specimens to room temperature, they were immersed in water. The samples were placed in a recipient in contact with level of water capable to submerge them about 5 mm as shown in the figure 1. After every 5 minutes of time, the rise in water level in concrete cube is recorded. Essentially, the sorptivity test determines the rate of capillary rise absorption by a concrete cube which rest on a small support in a manner such that only lowest 2 to 5 mm of the cube is submerge. Larger values of sorptivity give lesser durability.

The instrument specification for SEM testing is JEOLJSM-6360, Vacuum system-Rotary up to 10^{-2}Torr. Micrographs were taken on the 90th day for both the class A and B samples. Globular structure in the image corresponds to samples subjected to water curing (Fig. 2) whereas this globular structure is found to be destroyed in case of Group B samples (Fig. 3), which is indicative of the aggressive effect of UEO on concrete.

Fig.1. Schematic Diagram of Water Sorptivity Test

A. Automation of classifying of SEM data

Data samples collected from SEM testing were subjected to two classifier machines. One was based on correlation coefficient and the other using support vector machines. In case of the correlation coefficient testing, 12 images was taken for the analysis. The first 5 corresponded to images of fly ash with water curing and the next 7 belonged to images subjected to UEO soaking. The testing methodology is elaborated in the results and discussion section.

The SEM testing was conducted on the fly ash concrete and the images were taken in JPEG format. The results from SEM depicted either the harmful effects of petroleum on concrete or no drastic changes due to water curing. Since the maximum number of classes under which the results fall is two, a two class SVM model was implemented. Images were taken on the 90th day for both the class of specimens. To lessen the intricacy of data labeling, only 10 images from both the cases, totaling to 20 were chosen to train the SVM. The labeling of images were +1 for neutral effect and -1 for the rest. The images were then normalized and resized before feeding them to the SVM. Fig. 1 shows the block diagram of the automation of classification architecture for SVM. Each image was read by the program in a loop and was classified by the SVM as either +1 or -1. The accuracy of classification was tested in each iteration.

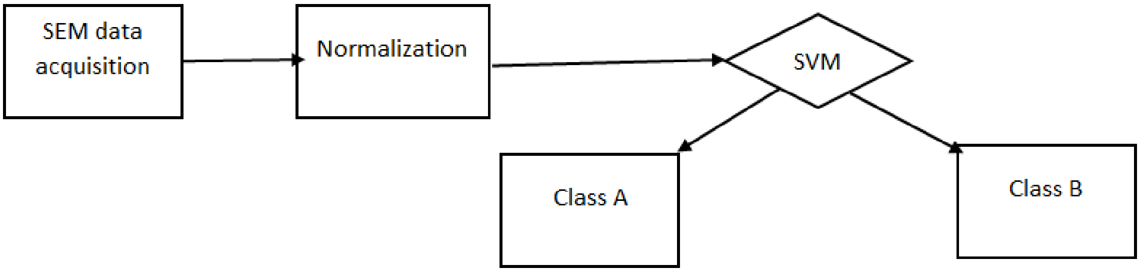

Fig.2. Classification of SEM Data using SVM.

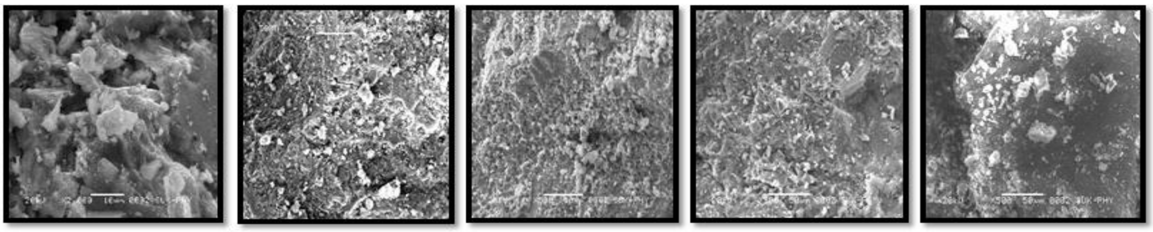

Fig.3. SEM Image of Group a Samples

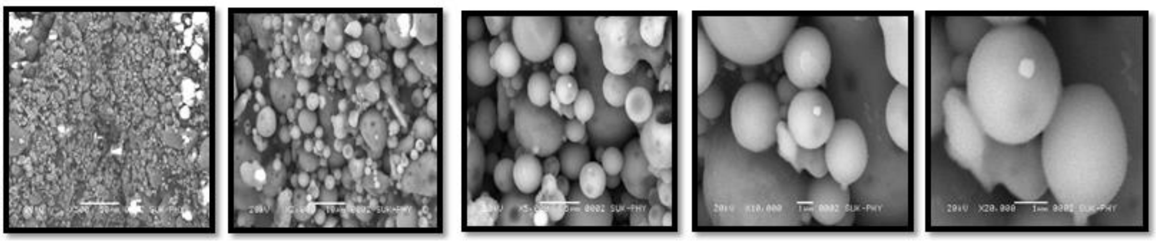

Fig.4. SEM Images of Group B samples.

5. Results and Discussions

The variation of strength properties are depicted in Fig. 5, 6 and 7 in which X axis represents the proportion of fly ash used in percentage. Y axis depicts its corresponding strengths. From the figures 5, 6 and 7 it has been observed that the compressive, flexural as well as splitting tensile strengths corresponding to samples soaked in UEO exhibited reduction in their respective strength with respect to time. Further, it has been also observed that the reduction in strengths get lessoned with fly ash replacement in cement. Fig.7, shows the variation in soroptivity with fly ash content which indicates gradual reduction in soroptivity with increase in fly ash. The results in Fig.7suggested that for 25% and at 30% fly ash, considerable lowering in soroptivity is being observed.

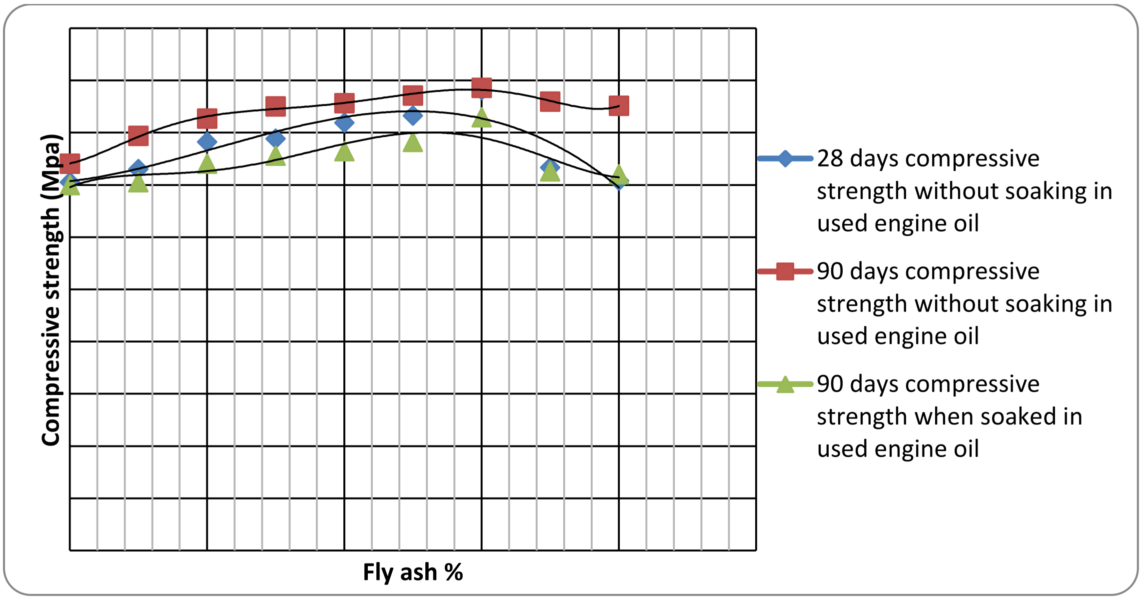

Fig.5. Variation in Compressive Strength with Fly Ash Replacement.

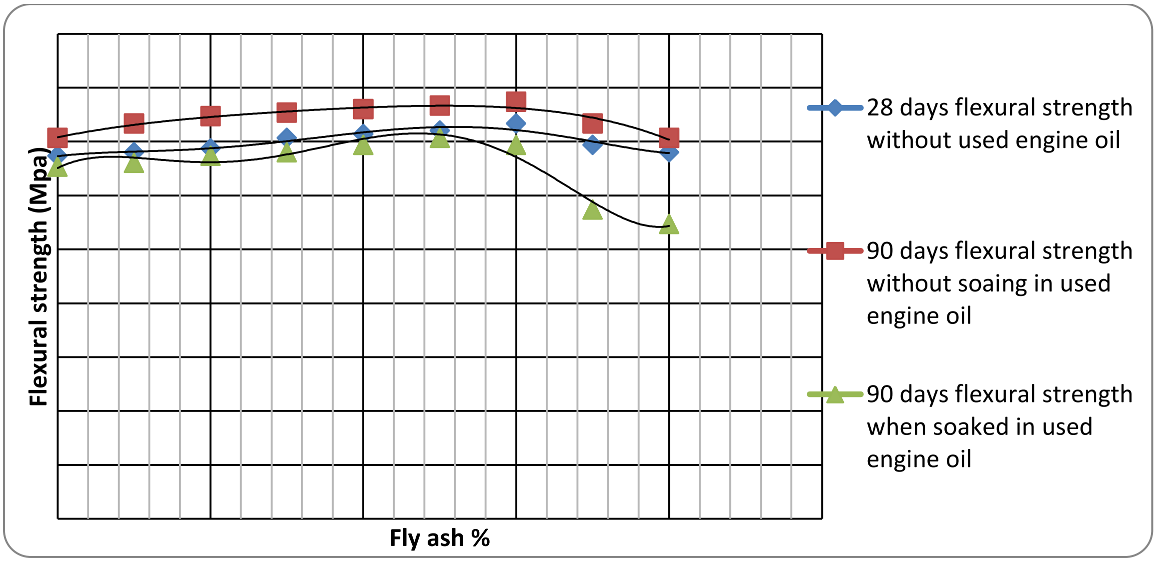

Fig.6. Variation in Flexural Strength with Fly Ash Replacement

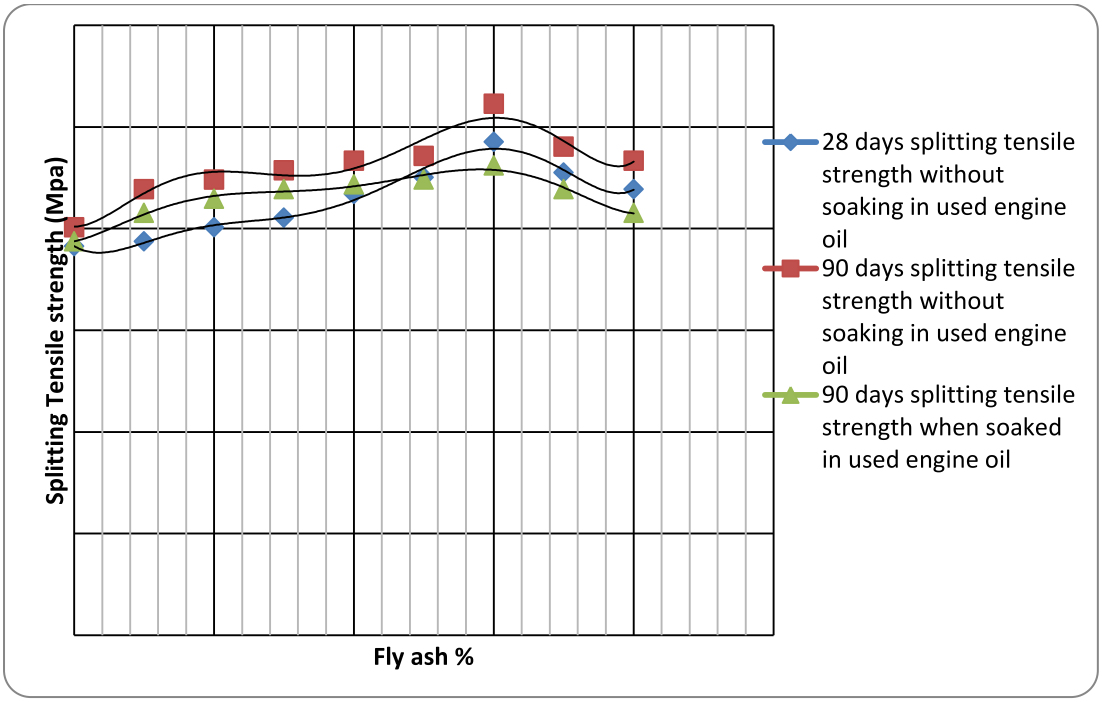

Fig.7. Variation in Splitting Tensile Strength with Fly Ash Replacement.

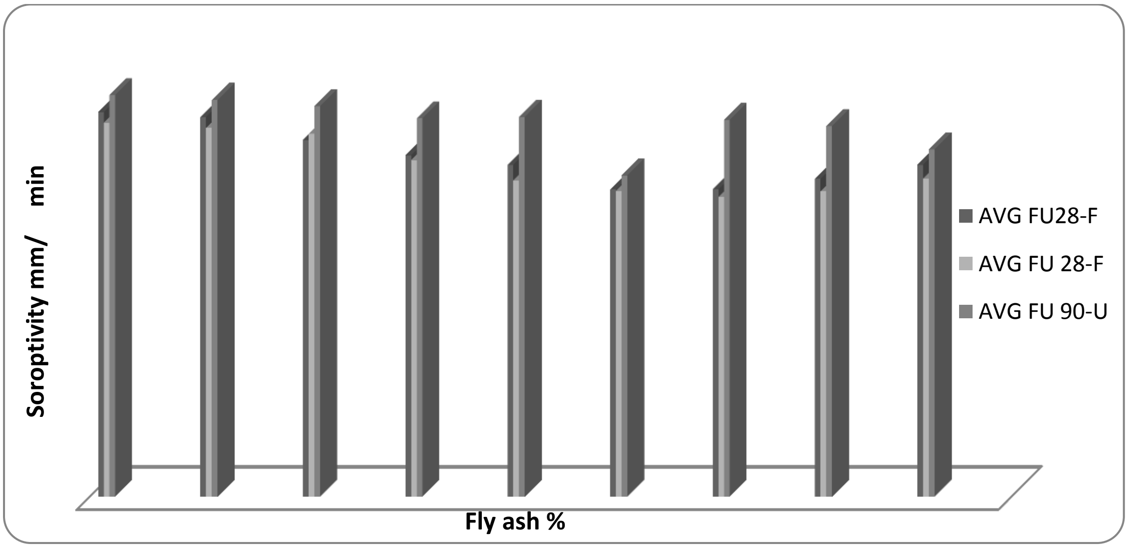

Fig.8. Variation in Soroptivity with Fly Ash Replacement.

Fig. 9 shows the bubble graph for the correlation coefficient test for SEM images. 12 images were taken for the analysis. The first 5 corresponded to images of fly ash with water curing and the next 7 belonged to images subjected to UEO soaking. First 3 images from both of these classes were used as pivot images which were later checked for correlation coefficient among other images in the database. X axis on the graph represents pivot images (3 for class A and 3 for class B samples) and the Y axis represents all the 12 images in the database. The diameter of the bubble depicts the correlation coefficient. Hence a larger diameter of a particular bubble can be attributed to a greater value of correlation coefficient. Hence it is evident from the figure that, the value of correlation coefficient is high for same images. In case of the rest images, the correlation coefficient is considerably low, even for images of the same class. This shows the ineffectiveness of the correlation coefficient to be used as a classifier. Also the time consumed in this case was considerably high. Hence SVM was used in this regard.

In a similar manner, the testing was carried on for larger dataset and similar results were obtained.

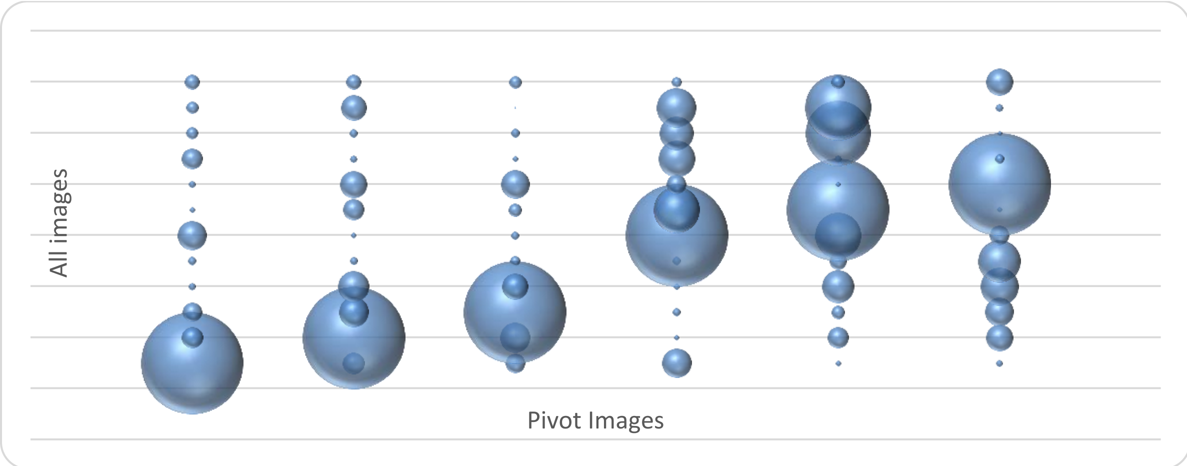

Fig.9. Correlation Coefficient Values for SEM Images.

In case of SVM, the classification was reliable with respect to the images under test. Accuracy of 100% was achieved for images already trained and 95 % accuracy for untrained images. The evaluation technique was found to be easier and fast.

6. Conclusions

The outcome of the study can be summarized as follows:

1) The degree of degradation of UEO on concrete with respect to compressive, flexural and splitting tensile strengths were assessed and found that the negative effect on strength properties were considerably less for fly ash mixed concrete .Reduction in soroptivity with fly ash indicates enhancement in durability at 25% and at 50% fly ash. Thus, it aids in the use of industrial waste product to reduce pollution.
2) The SEM data analysis was automated using SVM. Also, Pearson’s correlation coefficient was tested to accomplish this. The former yielded better and reliable results when compared to the latter.

Acknowledgements

The authors are indebted to KLE Dr. M. S. Sheshagiri College of Engineering and Technology, Belgaum, and Shivaji University, Kolhapur; for all the crucial amenities provided for the experimentation.

References

[1] Nuruddin M.F.,et al(2008). Effect of Used Engine Oil on MIHRA Concrete, A New Material In The Construction Industry. United Kingdom Malaysia Engineering Conference, vol. 28, No. 3, pp. 398-11.

[2] Wasiu O. Ajagbe, Olusola S. Omokehinde, Gabriel A. Alade, Oluwole A. Agbede, (2012). Effect of Crude Oil Impacted Sand on compressive strength of concrete. Construction and Building Materials 26 (2012) 9–12, Elsevier. doi: 10.1016/j.conbuildmat.2011.06.028.

[3] M.A. Matti, (1983). Effect of oil soaking on the dynamic modulus of concrete. International Journal of Cement Composites and Lightweight Concrete, Volume 5, Issue 4, Pages 277–282, Elsevier. doi: 10.1016/0262-5075(83)90069-6.

[4] T.Z. Blaszczynski, 'Concrete in contact with crude oil', STATYBA-CIVIL ENGINEERING, No. 2(6), 1996, pp.13-17.

[5] J.L.Rodgers, W.A. Nicewander, "Thirteen Ways to Look at the Correlation Coefficient", *The American Statistician, February 1988, Vol. 42, No. 1, pp.59-66*

[6] Eugene K. Jen, Roger G.Johnston, "The Ineffectiveness of Correlation Coefficient for Image Comparisons", *Research Paper prepared by Vulnerability Assessment Team, Los Alamos National Laboratory, New Mexico.*

[7] Vapnik, Vladimir Naumovich, and Vlamimir Vapnik. *Statistical learning theory*. Vol. 2. New York: Wiley, 1998.

[8] Joachims, Thorsten. *Learning to classify text using support vector machines: Methods, theory and algorithms*. Kluwer Academic Publishers, 2002.

[9] Lin, Yuan-Pin, Chi-Hong Wang, Tien-Lin Wu, Shyh-Kang Jeng, and Jyh-Horng Chen. "Support vector machine for EEG signal classification during listening to emotional music." In *Multimedia Signal Processing, 2008 IEEE 10th Workshop on*, pp. 127-130. IEEE, 2008. Doi: 10.1109/MMSP.2008.4665061.

[10] Panda, R., P. S. Khobragade, P. D. Jambhule, S. N. Jengthe, P. R. Pal, and T. K. Gandhi. "Classification of EEG signal using wavelet transform and support vector machine for epileptic seizure diction." In *Systems in Medicine and Biology (ICSMB), 2010 International Conference on*, pp. 405-408. IEEE, 2010. Doi: 10.1109/ICSMB.2010.5735413.

[11] Guo, Guodong, Stan Z. Li, and Kap Luk Chan. "Support vector machines for face recognition." *Image and Vision computing* 19, no. 9 (2001): 631-638, Elsevier. DOI: 10.1016/S0262-8856(01)00046-4.

[12] Navalyal, Geeta U., and Rahul D. Gavas. "A dynamic attention assessment and enhancement tool using computer graphics." *Human-centric Computing and Information Sciences* 4.1 (2014): 1-7, Springer. doi:10.1186/s13673-014-0011-0.

[13] Shankar, Sheela. "Assessment of the effect of variations in Eye Blinks on a face recognition algorithm." *Advance Computing Conference (IACC), 2015 IEEE International*. IEEE, 2015.

[14] Sheela Shankar and V.R Udupi, "Achieving Robustness in Face Recognition by Effective Feature Acquisition", IJIGSP, Vol. 7, No. 9, MECS Publisher.

[15] Navalyal, Geeta U., and Rahul D. Gavas, "Enhanced learning with abacus and its analysis using BCI technology", International Journal of Modern Education and Computer Science 6.9 (2014): 22.

Authors' Profiles

Prof. Nandini M Naik has graduated in Chemical Engineering from SIT, Tumkur and completed her post-graduation in Chemical Engineering from Shivaji University, Kolhapur. She is currently working as Associate Professor in Chemical Engineering Department, KLE DR. M.S.Shesagiri College of Engineering and Technology, Belgaum, Karnataka. She is having a teaching experience of 15 years, and is a research scholar in Environmental Science and Technology, Department of Technology, Shivaji University, Kolhapur.

Girish.S.Kulkarni, has graduated in Civil Engineering and post graduated in Environmental Engineering from Shivaji University, Kolhapur and Ph. D in Environmental Engineering and Technology from Walchand College of Engineering, Sangli. He is currently working as Professor in Environmental Science and Technology, Department of Technology, Shivaji University Kolhapur, Maharashtra. He has published and presented many technical papers in international and national conference.

Dr. K. B. Prakash, has graduated in Civil Engineering from National Institute of Engineering Mysore and post graduated in Structural Engineering and Ph. D degree from Walchand College of Engineering, Sangli. He is currently working as Professor and Head in Civil Engineering Department and Principal of Government Engineering College, Haveri, Karnataka. He has 27 years of teaching experience and 2 years of industrial experience. He has published around 200 technical papers in International/National Journals and proceedings of International/ National conferences.

How to cite this paper: Nandini M.Naik, Girish S.Kulkarni, K.B.Prakash,"Assessment of the Deterioration of used Engine Oil Soaked Fly ash Concrete and its Analysis using Automated SEM Analysis", International Journal of Engineering and Manufacturing(IJEM), Vol.6, No.3, pp.1-11, 2016.DOI: 10.5815/ijem.2016.03.01