International Journal of Research in Engineering, Science and Management
Volume 4, Issue 8, August 2021
https://www.ijresm.com | ISSN (Online): 2581-5792

Identification of Pozzolanic Activity Present in the Waste Material

Vetti Abhishek[1], Ellu Mani[2], Rellu Divakarsai Teja[3], Veluru Sadvik Sai[4], Kalavalapudi Deepika[5*]
[1,2,3,4]*Student, Department of Mechanical Engineering, Audiasankara College of Engineering and Technology, Gudur, India*
[5]*Faculty, Department of Mechanical Engineering, Audiasankara College of Engineering and Technology, Gudur, India*

***Abstract*: The consumption of cement is increasing recently due to the developing country. Many researchers working on the replacement of the cement with different agro-industrial ashes. In this paper, two tests have been performed to determine the pozzolanic property of Fly ash, Rice husk ash and Bagasse ash. The present paper investigated the physiochemical characteristics and the pozzolanic behaviour of bagasse ash (BA), rice husk ash (RHA) and fly ash (FA). From the performed tests, it is observed that the pozzolanic property present in fly ash is comparatively high than rice husk ash and bagasse ash.**

***Keywords*: Agro-industrial ashes, Pozzolanic behaviour, Pozzolanic property, Replacement.**

1. Introduction

In present time, there are large volumes of materials considered as wastes or by-products produced by industrial activities. These wastes not always have the possibility of reuse, or low economic value for the companies that generate it. Thus, it adds to the cost of its management and disposal. Current production models have associated some in sufficient practices as mentioned below:

1. Resource consumption.
2. Materials and energy.
3. Waste generation
4. Economic costs

In India, solid waste management is the major issue that demands attention. In only Asia, around 4.4 billion tons of solid wastes generate yearly. In India, alone agricultural sector has generated about 600 million tons of biomass waste [2]. Around 960 million tons of residual solid waste have been generated from agricultural, industrial and mining, yearly. Around 91.162 million tons of sugarcane biomass wastes generate yearly [3].

After industrial processing of raw sugarcane crop to obtain edible products, leaves the waste known as bagasse as a by Product. Similarly, Rice husk (RH) is a by-product of rice milling and rice husk ash (RHA) is generated by combustion in a separate boiler. Both RH and RHA are tremendously found in rice growing countries such as China, India, Brazil, the USA, and Southeast Asia. Thus, RH has been recycled by burning it for energy production [4].

In India, around 44,000 tons of SCBA is generated per day [4]. Thus, it gives around 4.4 million tons of RHA every year. This SCBA and RHA have negative impact on the environment and therefore, a proper technique should be adopted to overcome the disposal issues of ashes [5]. Similarly, Fly ash is the solid industrial waste generated from coal combustion process in thermal power plants. In India, around 120-150 million tons of coal fly ash is generated [28]. The behaviour of many metal pollutants present in fly ash may have hazardous effects on the environment and humans as well [32].

At present, the annual generation of fly ash is approximately 112 million tonnes Cement and Concrete Industry utilizes 50% Fly Ash of the total utilization of which at present is 28%. The Low-lying area fill utilizes 17%, 15% by Roads & Embankments, 4% by Dyke Raising, 2% by Brick manufacturing, etc. [34]. It contributes to air pollution and also acts like cumulative poisons since the fine particles remains in lungs for longer period of time [36].

Since, these industrial solid waste ashes have deleterious effects on both environment and human health and also dumping cause pollution of soil, it is required to utilize them in some harmless manner. Nowadays, due to the higher rate of infrastructure development, the requirement of concrete is increasing and thus increases the demand for concrete which results in the increase in consumption of their ingredients such as cement, sand, and aggregates for concrete.

Due to Carbon dioxide emissions, Cement industry is highly responsible for pollution [5]. Thus, it becomes important to find out the substitutes for cement. The findings of the literature study give an effective solution about the pozzolanic property in the above selected wastes by performing various tests.

2. Pozzolanic Activity

The measure for the of degree of reaction rate between a pozzolan and Ca2+ or calcium hydroxide (CA(OH)2) in the presence of water is known as pozzolanic property. The rate of the pozzolanic reaction is dependent on the intrinsic characteristics of the pozzolan. Since no irreversible molecular bonds are formed in the process, physical surface adsorption is

*Corresponding author: venkyvenkateshreddy0@gmail.com

not considered as being part of the pozzolanic activity [12].

3. Material Selected

There are various waste materials i.e., Industrial waste and agricultural waste available all over India. The use of Cement is tremendously high and cement is the second mostly consumed material after water [50]. In order to control this high consumption of cement, these waste materials can be used as a replacement of cement. Different waste materials show different properties. In this paper, three waste products namely; Fly ash, Rice husk Ash and Bagasse Ash have been selected.

A. Fly ash

India is the third largest producer of coal and contribute about 70% of the total installed capacity for power generation [27]. This coals usually contain over 40% ash content [28]. Fly ash is an industrial waste generated in thermal power plant from coal combustion process. Fly ash is generally fine powdered ferro aluminium silicate material with Al, Ca, Mg, Fe, Na and Si as its elements. Large quantities of coal fly ash cause a serious threat to the environment as a major source of inorganic pollution. It causes deleterious effects on the environment as well as on human health [32].

Chemical Composition of fly ash is ash shown in the table below:

Table 1
Chemical Composition for Fly Ash (Expressed as Percent by Weight)

Components	Content (% by WT)
Silicon dioxide	57
Aluminium oxide	20
Iron oxide	2.5
Carbon oxide	5.8
Magnesium oxide	2.4
Sulphur trioxide	2.0
Sodium carbonate	1.5
Potassium oxide	2.8

B. Rice husk and rice husk ash

The natural covering that forms around rice grains during their growth is known as Rice husk. This rice husk is widely in the rice-producing countries. This rice husk is considered as agricultural waste material. It is important in some countries, like China, India, Indonesia, Malaysia and Bangladesh [46, 47]. The production rice produces a high volume of rice husk, which is a low-density residue [48]. Dumping this waste causes significant environmental problems. A huge amount of RHA is produced all over the world and found to be growing at more behaviour. Physical properties include particle size, specific gravity and density.

The chemical composition of sugarcane bagasse ash includes silicon dioxide, aluminium oxide, iron oxide, calcium oxide, and the potassium oxide). The sugarcane bagasse composed of approximately 50% of cellulose, 25% of hemicellulose and 25% of lignin [52].

Table 2
Chemical composition of rice husk ash

Particulars	Proportions
Silicon Dioxide	80.45%
Aluminium Dioxide	0.25%
Iron Oxide	0.95%
Calcium Oxide	1.25%
Magnesium Oxide	0.4%
Sodium Oxide	0.5%
Potassium Oxide	2.18%

Table 3
Physical properties of SCBA

Physical properties	SCBA
Particle size	5.56 micro meter
Specific gravity	2.12
Density	2340kg/m^3

Table 4
Chemical properties of SCBA

Oxide composition	SCBA
Sio_2	51.35%
Al_2O_3	12.45%
Fe_2O_3	1.2%
MgO	7.43%
K_2O	1.84%
SO_3	2.74

Chemical composition of husk ash consists of the following:

- Cellulose (C5H10O5)
- Lignin (C7H10O3)
- Hemicellulose
- SiO2
- Holocellulose

The chemical composition of rice husk ash includes silicon dioxide, Aluminium dioxide, Iron Oxide, Calcium Oxide, Magnesium Oxide, Sodium Oxide, Potassium Oxide.

C. Bagasse Ash or Sugarcane Bagasse Ash (SCBA)

Bagasse ash is the agricultural waste generated from sugarcane. The pozzolanic property of sugarcane bagasse ash depends on the physical properties and the chemical composition of bagasse ash [51].

Physical properties and chemical composition of SCBA plays an important role in its pozzolanic hours. After 6 hours, allow this oven dried ashes to pass through 90micron sieve and perform the tests on the sample passing through sieve.

4. Types of Tests Performed on the Selected Ashes

1. Electrical conductivity test
2. Chapelle Activity test

The ashes collected from industries or factories possess carbon content in it. The samples containing carbon content cannot be directly tested. In order to remove the carbon content.

There are certain ranges of Electrical conductivity which determines the pozzolanic property present in a particular ash. The table given below shows those ranges of electrical conductivity.

A. Electrical conductivity test

The instrument used in this test is known as Electric

conductivity meter. This instrument consists of electrical meter, electrode and magnetic stirrer. Readings are measured by electrical meter and are in micro-sec/meter. The pozzolanic activity of the material can be investigated by measuring its electrical conductivity in aqueous suspensions of Calcium hydroxide. The influence of the calcium hydroxide concentration in the suspension by calcium hydroxide solution.

The temperature of suspension influences the chemical reaction between pozzolanic material and the calcium hydroxide, which ultimately affects the degree of reaction. The readings are observed at the beginning and at the end. The difference between the first and the final reading noted during the process is known as Electrical conductivity.

Table 5
Range of electrical conductivity for pozzolanic property

Range of Electrical conductivity	Pozzolanic property
< 1.2	Not pozzolanic
1.2 – 1.4	Good pozzolanic
> 1.4	High pozzolanic

Fig. 1. 150ml of Calcium hydroxide + fly ash

Fig. 2. 150ml of Calcium hydroxide + Rice husk

Fig. 3. 150ml of Calcium hydroxide + Bagasse ash

Observation:

From the observations, it is found that fly ash is having highest pozzolanic property, whereas Rice husk ash and Bagasse ash possess average that is good pozzolanic property.

Table 6
Testing reading of electrical conductivity test

S.No.	Type of sample	Initial reading	Final reading	Electrical conductivity	Pozzolanic property of the sample
1	Fly ash	3.350	5.30	1.95	High pozzolanic
2	Rice husk ash	1.705	0.363	1.342	Good pozzolanic
3	Bagasse ash	1.051	0.227	1.274	Good pozzolanic

B. Chapelle activity test

This method is lime-pozzolana reaction-based method and it quantifies the pozzolanic reactivity of any material. This test depends on the physical properties and chemical characteristics of any material. C-S-H is the product obtained by the reaction with lime, which improves the mechanical properties. According to this method, the consumption of lime by pozzolana is made with the proportion of lime: pozzolana - 1:1.

Here, the tests are carried out with one gram of lime. It is added in order to eliminate all the virtuous phase present in materials. The calcium hydroxide is also called as hydrated lime, on reaction with pozzolan forms CSH phase. In method involves acid-base titration, thus in order to achieve end point of titration Phenolphthalein indicator is used. The reactions occur during titration process are as follows:

$$CAO + 2HCL = CaCl_2 + H_2O$$
$$CA(OH)_2 + 2HCL = CaCl_2 + H_2O$$

The result obtained from this test is expressed in reacted milligrams of $CA(OH)_2$ reacted or fixed per gram of pozzolana.

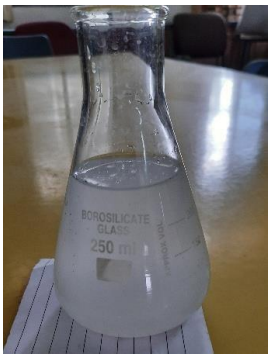

Fig. 4. 250ml of distilled water + 1gm CAO + 1gm Fly ash

Fig. 5. 250ml of distilled water + 1gm CAO + 1gm Rice husk ash

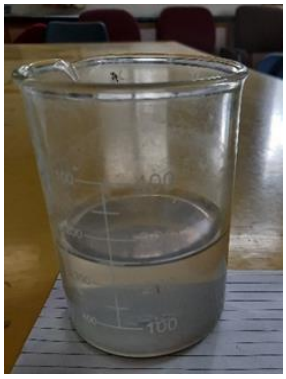

Fig. 6. 250ml of distilled water + 1gm CAO + 1gm Bagasse ash

Fig. 7. Sample in oven for 8 hours

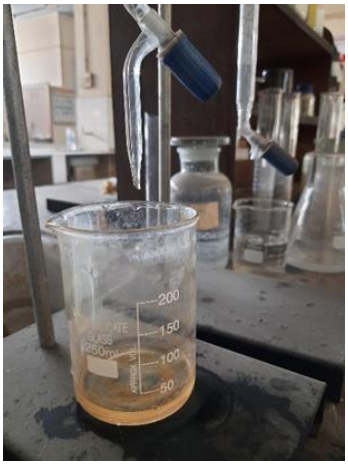

Fig. 8. Sample After adding phenolphthalein indicator

Fig. 9. After titration

Observation:

Table 7
Testing reading of Chapelle test

S. No.	Type of sample	Initial reading (V_1)	Final reading (V_2)
1	Fly ash	0.8	0.5
2	Rice husk ash	0.8	0.6
3	Bagasse ash	0.8	0.7

Calculations:

Mg of CA(OH)2 Fixed = 2(V1 - V2) /V1 × 74/56 ×1000

Fly ash 2(0.8-0.5/0.8) × 74/56 × 1000
= 991.0714 Mg

Rice husk ash 2(0.8-0.6/0.8) ×74/56 × 1000
= 660.7142 Mg

Bagasse ash 2(0.8-0.7/0.8) ×74/56 × 1000
= 330.3571 Mg

From the Chapelle Activity test, it is observed that, among fly ash, rice husk ash and bagasse ash; fly ash is having maximum pozzolanic property.

5. Conclusion

In India, due to the excessive consumption of coal, rice and sugar, there is millions of tons of fly ash, RHA and BA produced every year. At present, there are no efficient, harmless and economical technique available to recycle these materials. By recycling these materials, the natural raw materials can be conserved and will also create new revenues while protecting the environment.

In order to reduce the tremendous use of Cement and replacement of cement with selected waste materials two different tests are performed on these materials to determine their pozzolanic property. Electrode conductivity test concludes that; the range of electrical conductivity is greater than 1.4 (>1.4).

Therefore, according to this test, fly ash possess high pozzolanic property whereas Rice husk ash (RHA) and Bagasse

ash (SCBA) shows the range between 1.2 – 1.4 and thus they are considered as just good pozzolans. According the Chapelle test, mg of Calcium hydroxide in fly ash is far more as compared to RHA and BA, thus fly ash possess more pozzolanic property than RHA and BA. Overall, from the tests, it is concluded that Fly ash is highly pozzolanic.

On the other hand, RHA and BA possess less pozzolanic property as compared to that of fly ash.

References

[1] A. Seco, F. Ramirez, L. Miqueleiz, P. Umenta, types of waste for the production of pozzolanic materials, Research Gate publication, Spain, 2012 (141,142)

[2] S. Yoshizawa, M. Tanaka, A. V. Shekdar, Global trends in waste generation., Recycling, waste treatment and clean technology, TMS Mineral, Metals and Materials Publishers, Spain, 2004. 1541-52.

[3] A. Pappu, M. Saxena, S. R. Asolekar, Solid wastes generation in India and their recycling potential in building materials, Build. Environ. 42 (6) (2007) 2311– 2320.

[4] A. BAHURUDEEN, K. WANI, M.A. Basit, M. Santhanam, Assignment of pozzolanic performance of sugarcane bagasse ash, J. Mater. Civ. Eng. 28 (2), 2015.

[5] S. Mishra, N.A. Siddiqui, A review on environmental and health impacts of cement manufacturing emissions, Int. J. Geol. Agric. Environ. Sci. 2 (3) (2014) 26–31.

[6] U.S. Geological Survey. 2011. Mineral commodity summaries 2011: U.S. Geological Survey, 198 p.

[7] Daugherty, K.E. Cement as an indicator of economic development. Cement and Concrete Research. Volume 3, Issue 2, 1973. Pages 163-183

[8] Reddy, A.S., Pradhan, R.K., Chandra, S. Utilization of Basic Oxygen Furnace (BOF) slag in the production of a hydraulic cement binder. International journal of mineral processing. Volume 79 (2006) Pages 98105.

[9] O'Rourke, B., McNally, C., Richardson, M. G. Development of calcium SULAFATE–GGBS– Portland cement binders, Construction and Building Materials, Volume 23, Issue 1, January 2009, Pages 340-346,

[10] Juenger, M.C.G., Winnefeld, F., Provis, J. L., Ideker, J. H. Advances in alternative cementitious binders. Cement and concrete research. Volume 41, Issue 12, December 2011, Pages 1232-1243.

[11] Billong, N., Melo, U.C., Kamsew, E., Kinuthia, J. M., Njopwouo, D. Improving hydraulic properties of lime–rice husk ash (RHA) binders with metakaolin (MK), Construction and Building Materials, Volume 25, Issue 4, April 2011, pp. 2157-2161.

[12] Takemoto, K.; Uchikawa H. (1980). "Hydration of pozzolanic cements". Proceedings of the 7th International Congress on the Chemistry of Cement. IV-2: 1–29.

[13] Dermatas, D. Meng, X. Utilization of fly ash for stabilization/solidification of heavy metal contaminated soils, Engineering Geology, Volume 70, Issues 3-4, November 2003, Pages 377-394,

[14] Nalbantoglu Z., Effectiveness of Class C fly ash as an expansive soil stabilizer, Construction and Building Materials, Volume 18, Issue 6, July 2004, Pages 377-381.

[15] M. V Madurwar, R. V Ralegaonkar, And S. A. Mandavgane, "Application of AGRO-waste for sustainable construction materials A review," Constr. Build. Mater., vol. 38, pp. 872–878, 2013.

[16] Yong, R. N., Ouhadi, V.R., Experimental study on instability of bases on natural and lime/cement-stabilized clayey soils, Applied Clay Science, Volume 35, Issues 3-4, February 2007, Pages 238-249.

[17] Chen, L., Lin, D-F., Stabilization treatment of soft subgrade soil by sewage sludge ash and cement, Journal of Hazardous Materials, Volume 162, Issue 1, 15 February 2009, Pages 321-327.

[18] Higgins D. D., Kinuthia J.M., Wild, S. Soil stabilization using lime activated ground granulated blast furnace slag. Proc. 6th CANMET/ACI International Conference on fly ash, Silica Fume, slag and natural pozzolans in concrete, 1998, Thailand, ACI publication SP178-55

[19] Degirmenci N., Turabi, A., Application of Phosphogpsum in soil stabilization, Building and Environment, Volume 42, Issue 9, September 2007, Pages 3393-3398.

[20] Misra, A., Biswas, D., Upadhyaya, S., Physio-mechanical behaviour of self-cementing class C fly ash-clay mixtures, Fuel, Volume 84, Issue 11, 2003 International Ash Utilization Symposium, August 2005, Pages 1410-1422.

[21] Yarbasi, N., K E., Akbulut, S., Modification of the geotechnical properties, as influenced by freeze-thaw, of granular soils with waste additives, Cold Regions Science and Technology, Volume 48, Issue 1, April 2007, Pages 44-54

[22] Gokotope, A. B, Sezer, A., Sezer, G.I., Ramyar, K., Classification of time dependent unconfined strength of fly ash treated clay, Construction and Building Materials, Volume 22, Issue 4, April 2008, Pages 675-683.

[23] Mohamed, A.M.O. The role of clay minerals in marly soils on its stability, Engineering Geology, Volume 57, Issues 3-4, July 2000, Pages 193-203.

[24] Ouhadai. V.R, Yong.R.N. The role of clay fractions of marly soils on their post stabilization failure. Engineering Geology. Volume 70, 2003. Pages 365-375.

[25] Rajasekaran, G, Sulfate attack and ettringite formation in the lime and cement stabilized marine clays. Ocean Engineering Volume 32 (2005) Pages 1133-1159.

[26] Ouhadi. V.R, Yong.R.N. Ettringite formation and behaviour in clay soils. Applied clay science. Volume 42, 2008, Pages 258-256.

[27] Sahu, S. K., Bhangare, R.C., Ajmal, P.Y., Sharma, S., Pandit, G.G., and PURANIL, V.D., 2009, Characterization and quantification of persistent organic pollutants in fly ash from coal fuel thermal power stations in India., Journal of Microchemical, 92, 92-96.

[28] Lokesh B., and Dikshit, A.K., 2011, Disposal and management of coal fly ash, Proc. ICLST, 11-14

[29] Adriano, D. C., Page, A. L., Elsewi, A. A., Chang A. C., and I., 1980, Utilization and disposal of fly ash and other coal residues in terrestrial ecosystems: a, review., Journal of Environmental Quality, 9, 333–344.

[30] Aitken, R.L., and Bell, L.C., 1985, Plant uptake and Phyto-toxicity of boron in Australian fly ash., Journal of Plant and Soil, 84, 245-257.

[31] Matti god, S. V., Rai, D., Eary L. E., and Ainsworth, C. C., 1990, Geochemical factors controlling the mobilization of inorganic constituents from fossil fuel combustion residues: review of the major elements., Journal Environmental Qual-ity,19, 188–201.

[32] Yuan, C. C., Fang, W. C., Mui, D.T., and Chiang., H.L., 2009, Application of methods (sequential extraction procedures and high-pressure digestion method) to fly ash particles to determine the elements: a case study of BCR 176., Journal of Hazardous Materials, 163, 578-587.

[33] M. V Madurwar, S. A. Mandavgane, D, R. V Raleganokar, D, And M. Asce, "Development and Feasibility Analysis of Bagasse Ash Bricks," no. Tay 1987, pp. 1–9, 2013.

[34] ALAMI, J. and Akhtar, M. N., 2011 "Fly Ash Utilisation in Different Sectors in Indian Scenario", International journal of emerging trends in Engineering and Development on Issue1, Vol 1.

[35] Senapati, M. R., 2011, "Fly ash from thermal power plants – waste management and overview", Current Sc 1792 IENCE, Vol. 100, No. 12, 25.

[36] Matani, A. G., 1998, Res. J. Chem. Environ., 2.

[37] Z.T. Yao et al.,2015, "A comprehensive review on the application of coal fly ash", Earth-Science Reviews 141, 105–121

[38] www.tifac.org.in, Fly ash Mission, Technology Information Forecasting & Assessment Council (TIFAC), Department of Science & Technology, Ministry of Science & Technology, Government of India, Technology Bhawan, New Delhi.

[39] Fournier, B., Lu, D., Charland, J.P, and Li, J. (2004), "Evaluation of Indian Fly Ashes for Use in HVFA Concrete, Part 1: Characterization", The Indian Concrete Journal, November, 22-30.

[40] Zachariassen, W.J. (1932), "The Atomic Arrangement in Glass", J. Am. Ceram. Soc., 54, 3841 – 3951

[41] Surabhi, Udaya Bhanu G., Nikkam Suresh, "Characterization of Unburnt Carbon Recovered from Fly Ash by Froth Flotation", Proceedings of the international seminar on Mineral Processing Technology, 2006, Chennai, India, pp. 128-133.

[42] Md. Ghazali, O.P. Kaushal, 2015," Characteristics of fly ash from thermal power plants and its management along with settling pond design", vol-1, issue-4, 24-32

[43] Surabhi, Udaya Bhanu G., Nikkam Suresh, "Characterization and Beneficiation of carbonaceous material in Indian fly ash", Journal of Indian Chemical Society, vol.91, 2014 January,73-80

[44] Chatterjee, A.K. (2008), "Enhancing the Potential of Industrial use of the Indian Fly Ashes Through Mechano-Chemical Activation – Prospects and Problems", International Conference on Mechano-Chemistry and

Mechanical Alloys, National Metallurgical Laboratory, Jamshedpur, India.
[45] Mullick, A.K. (2005), "Use of Fly Ash in Structural Concrete: Part 1 – Why?", The Indian Concrete Journal, May, 13–22.
[46] Rice market monitor. FAO. FAO (accessed 19.05.14).
[47] Oil Palm market monitor. FAO (accessed 21.05.14).
[48] Khan R, Jabbar A, Ahmad I, Khan W, Khan AN, Mirza J. Reduction in environmental problems using rice husk ash in concrete. Construction Build Mater 2012; 30:360–5.
[49] M. V Madurwar, S. A. Mandavgane, And R. V Raleganokar, "Use of sugarcane bagasse ash as brick material," vol. 107, no. 6, 2014.
[50] C. M. Hanson, "Concrete: the advanced industrial material of the 21st century," Metallurgical & Materials Transactions A, vol. 26; 1995.
[51] Vasudha D. Katare, Mangesh V. Madurwar, "Experimental characterization of sugarcane biomass ash – A review"; (2017)
[52] V. S. Aigbodion, S. B. Hassan, T. Ause and G.B. Nyior, "Potential Utilization of Solid Waste (Bagasse Ash)"; Journal of Minerals & Materials", 2010.
[53] V. A. Quarcioni, F. F. Chotoli, A. C. V. Coelho, M. A. Cincotto; Indirect and direct Chapelle's methods for the determination of lime consumption in pozzolanic materials, Feb 2015.
[54] Eduardo Ferrazerraz, Slavaka Andrej Kovicovia Walid Haj Ana Luísa Velosa António Santos Silva and Fernando, Pozzolanic Activity of Metakaolin's by the French Standard of the Modified Chapelle Test: A Direct Methodology, 2015.
[55] M. Madurwr, V. Sakhare, and R. Ralegaonkar, "Multi objective optimization of mix proportion for a sustainable construction material," vol. 118, pp. 276–283, 2015.
[56] Sergio Velázquez, Josem. Monzo, María V. Borrchero and Jordi PAYA, "Assessment of the Pozzolanic Activity of a Spent Catalyst by Conductivity Measurement of Aqueous Suspensions with Calcium Hydroxide"; March 2014.
[57] Guney Y., Sari D., Cetin M., Tuncan M., Impact of cyclic wetting-drying on swelling behaviour of lime-stabilized soil, Building and Environment, Volume 42, Issue 2, February 2007, Pages 681-688.
[58] Carlson, C. L., And Andriano, D. C., 1993, Environmental impacts of coal combustion residues, Journal of Environmental Quality., 22, 227-247.
[59] R. Walker, S. Pavia, "Physical properties and reactivity of pozzolans, and their influence on the properties of lime–pozzolan pastes," Materials and Structures (2011) 44:1139–1150.