2nd Conference on Sustainability in Civil Engineering (CSCE'20)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

ONE-PART GEO-POLYMER CONCRETE USING WHEAT STRAW ASH AND BENTONITE

Asfandyar khan[a], Najmul Hassan[b], Muhammad Faisal Javed[c], Mir Hamza[d], Tamim Yousafzai[e].

a. Corresponding Author. BS student, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus. Email: Asfand3415@gmail.com
b. BS student, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus Email: najmulhassan823@gmail.com
c. Assistant Professor, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus. Email: arbabfaisal@cuiatd.edu.pk
d. BS student, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus.
e. BS student, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus.

Abstract Geopolymer concrete (GC) is considered as environmentally friendly concrete as compared to traditional concrete. As the formation of GC involves the addition of liquid Alkali Activated Materials (AAM) which is hazardous to the human skin. Hence, this research has been conducted to use activators (sodium silicate and sodium aluminate) in powder form along with Wheat Straw Ash (WSA) and bentonite for making GC. Different combinations were used for making mortar as 100% Bentonite, 20% WSA, and 80% Bentonite, 30% WSA, and 70% Bentonite. In all these ratios 10% sodium silicate in each sample with w/b of 0.4. Bentonite and WSA are used because these materials are pozzolanic in nature and can replace cement. Samples containing 80% WSA and 20% bentonite with a w/b ratio of 0.3, 0.4 and 0.5. 0.4 yields the highest compressive strength of 26 MPa. Hence, this ratio can be used in the future to further explore the behavior of GPC.

Keywords- Ordinary Portland Cement (OPC), Geo-Polymer Concrete (GC), Alkali Activated Materials (AAM), Wheat Straw Ash (WSA), Carbon Dioxide (CO_2), Super plasticizer (SP), Sodium Silicate (Na_2SiO_3).

1 INTRODUCTION

Construction industries are increasing day by day due to an increase in the demand for the development of infrastructure. In today's world concrete is widely used as a construction material due to its low cost, high strength, mouldability and high-temperature resistance which requires low or no maintenance. During the formation of concrete, the essential component (cement) is added in it which affects our environment by emitting CO_2 and Nitrogen oxides [1]. From previous studies, it can be concluded that by the production of 1 ton of cement release approximately 1 ton of CO_2 to the atmosphere [2], this amount adds up to 7% of CO_2 which is contributed towards global warming. Another major issue that contributes towards global warming is the burning of crop's waste into ashes. So, to tackle this issue the researchers have worked and suggested that instead of disposing of the waste it shall be incorporated into concrete that could reduce the negative impact of CO_2 on the environment. Besides, it could add to the internal properties of concrete (micro-structure properties) [3]. To minimize the usage of cement, alternatives solution is founded by researchers such as Geo-Polymers are introduced. It is formed by utilizing the waste materials**.** The main constituents of Geopolymer are Silicon and Aluminum which are provided by thermally activated natural materials (kaolinite) or industrial by-products such as Fly Ash, Rice-Husk Ash, Wheat-Straw Ash and alkaline activating solutions which polymerize these materials into molecular chains and network to create a hardened binder. Wheat straw is a byproduct of wheat that is commonly disposed of on a large scale. Even only in Pakistan for every 4 tons of wheat grain, 6 tons of wheat straw is produced [4]. The global estimated production of wheat from 2016 to 2017 was about 750 million tons [5]. WSA possess pozzolanic properties which is found by performing X-Ray Fluorescence (XRF) test that shows that WSA contain amorphous Silica and Alumina and has the potential to be used as a pozzolanic material, which is capable to replace cement partially [6]. Beside that it gives high compressive strength. So controlled burning of wheat straw is preferred at 600°C and at this temperature it showed best pozzolanic performance [6].

Figure 1: Flow chart of Wheat-Straw Ash

Bentonite is the commercial name of a whole range of natural clays with a high-water absorption capacity. Bentonite may contain a variety of accessory minerals in addition to montmorillonite due to its pozzolanic property [7], it can also be used in addition to WSA.

Figure 2: Bentonite

One-part Geo-polymer concrete is new technique in Geopolymer field in which activators are used in powder form. In our research work geopolymer is formed by using waste of agricultural material such as WSA with the combination of Bentonite in order to replace cement fully.
Research significance of our research work are:

- To contribute in reducing the CO_2 emissions by cement production.
- To achieve durable and workable geopolymer concrete based upon WSA and Bentonite.
- To make the best use of waste material in concrete for an eco-friendly and sustainable environment.

Many researchers have worked on a one-part geopolymer by substituting different alumina-silicate activators partially with cement, however no detailed and systematic studies have been designed on WSA and Bentonite fully replacing cement. In this research work we are substituting WSA and Bentonite with cement fully.

2 EXPERIMENTAL PROCEDURES

2.1 Testing

Testing has been divided into two phases; the first phase included XRF while the second phase included compressive strength test.

2.1.1 First phase Testing

2.1.1.1 X-ray fluorescence (XRF)

XRF test will be performed to determine the qualitative and quantitative elemental composition of WSA. The WSA particles would be excited by the primary X-ray source and each element present in the WSA sample produces a set of characteristic fluorescent X-rays that are unique for a specific element.

2.1.2 Second Phase Testing

2.1.2.1 Compressive Strength Test

For assessment of the compressive strength of the mortar, samples were cast in cubes of the standard dimensions of 2in x 2in x 2in. The sample, after its desired curing period, was placed in a Universal testing machine with its hardened face-up, on the plates of the machine. The sample was placed align to the axis of the machine. The final load was recorded which was divided by the cross-sectional area to compute the compressive strength. Moreover, for a single test, an average of three samples was taken.

3 RESEARCH METHODOLOGY

3.1 Materials

The summary of all the materials that have been used throughout the testing has been given below:

3.1.1 Fine Aggregate

The fine aggregate that has been used was taken from a quarry near COMSATS University Islamabad, Abbottabad Campus. The sieve analysis was performed using ASTM C136-01. The sieve analysis gave a Fineness Modulus of 2.64.

3.1.2 Wheat Straw Ash:

The Wheat Straw Ash that has been used, as a replacement of Cement. Wheat Straw was acquired from Abbottabad, Khyber Pakhtunkhwa Pakistan. The Wheat Straw was burned at 600 ºC for 2 hours in Muffle furnace to obtain Ash then it was grinded for 2 hours in grinding mill.

Figure 3: Wheat Straw Ash at 600 ºC

3.1.3 Bentonite:

Along with Wheat Straw Ash, bentonite was also used as a replacer for Cement. Bentonite was acquired from Azakhel Waziristan Khyber Pakhtunkhwa Pakistan. Calcium Bentonite was used. Calcium Bentonite first was ground to powder form and then was passed from sieve no 200.

3.1.4 Mixing Water:

The water that has been incorporated into mortar was the ordinary tap water of COMSATS University Islamabad, Abbottabad Campus.

3.1.5 Sodium Silicate (Na_2SiO_3):

During the whole research, Na_2SiO_3 in dry powder form was used. The anhydrous form of Na_2SiO_3 was used. The Na_2SiO_3 is Alkali-Activated Activator which is used in sample preparation to activate the Silica and Alumina present in the WSA and Bentonite. The properties of Na_2SiO_3 are given below:

Table 1: Properties of sodium silicate (Na_2SiO_3)

Colour	white
Form	Powder (Anhydrous)
Molecular weight	122.063 g/mol

3.1.6 Super-plasticizer

After mixing all material along with water, the sample did not attain enough workability, so to enhance workability super-plasticizer was added.

3.2 Mix Proportion:

To perform the whole experimentation, a mix of 2kg sample was prepared on a ratio of 1:1 (1 part of WSA and Bentonite and 1 part of sand). Initially, the water-binder (w/b) ratio was 0.3 and was increased gradually. The activator Na_2SiO_3 has been used as 10% of the total sample mix. The complete mix design has been summarized in Table below

Table 2: Mix Design of Geopolymer Concrete

Bentonite (%)	**WSA (%)**	**Activator (%)**	**WSA (g)**	**Bentonite (g)**	**Na_2SiO_3 (g)**	**Sand (g)**	**Water (g)**	**SP (%)**	**Water/Binder Ratio (w/b) (%)**
0.7	0.3	10	300	700	200	1000	300	3	0.3
0.2	0.8	10	800	200	200	1000	400	2	0.4
0.1	0.9	10	900	100	200	1000	500	2	0.5

3.3 Mixing

After adding all materials, they were dry mixed for 20 minutes in Mixer, after dry mixing water was added and again mixed for 5 minutes. After that it was found that the sample was not enough for work. So, to increase workability 2% super-plasticizer was added, and then the sample was mixed for 5 minutes to achieve desire workability

Figure 4: Sample of Mortar and Mixer Machine

3.4 Sample Curing

3.4.1 Heat Curing

After casting samples, moulds were placed in the oven-drying machine at 70 °C for 24 hours. After that samples were left in the open air.

Figure 5: Sample after heat curing

3.4.2 Exposed to Atmosphere

After heat curing samples were kept in the open atmosphere for 3, 7, and 14 days. After that samples were tested for compressive strength at 3, 7 and 14days.

4 RESULTS

4.1 X-ray fluorescence (XRF)

XRF was performed on the Wheat Straw Ash which was burned at 600 °C for 2 hours in Muffle furnace in order to obtain the chemical composition of the ash which is given in the table below. According to the standard ASTM C618, in order for a material to be classified as a pozzolana its (SiO_2 + Al_2O_3 + Fe_2O_3) should be equal to or greater than 70%.

Table 3: XRF test results

Chemical Compounds (%)	**WSA at 600 °C**
SiO_2	77.4
K_2O	5.4
Al_2O_3	1.5
Fe_2O_3	1.3
CaO	3.9
MgO	1.9
TiO_2	0.97
LOI	5.6
(SiO_2 + Al_2O_3 + Fe_2O_3)	80.2

4.2 Compressive Strength Test

The compressive strength results of the one-part geopolymer mortar samples at 3, 7, and 14 days are provided in Figures 6. The results reflected that the early age strength of a one-part geopolymer is greater and later on strength. It can be seen because a one-part geopolymer gains its maximum strength at 3 days after heat curing at 70 ºC in an oven. Moreover, the compressive strength of the samples formed by 80 % WSA and 20% Bentonite is higher than the samples formed by 90% WSA and 10% Bentonite, 30 % WSA, and 70 % bentonite because of the shrinkage cracks that were appeared on their surface. It was concluded that strength depends upon the percentage of activators that generate alkali base reactions in it and the initial heat curing after casting.

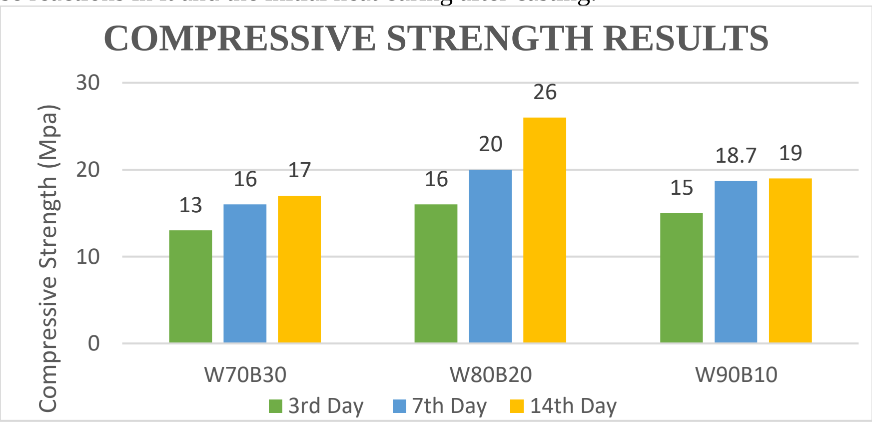

Figure 6: Compression strength results of mortar samples at 3[rd], 7[th] and14[th] days.

5 CONCLUSION

Following conclusions can be drawn from the conducted study:

- The early age strength of a one-part geopolymer is greater than later strength.
- One-part geo-polymer gains its maximum strength at 3 days after heat curing at 70 ºC in an oven.
- Comparatively high compressive strength was of the samples formed by 80 % WSA and 20% Bentonite.
- Higher bentonite ratios cause shrinkage cracks that appeared on the surface.
- Strength depends upon the percentage of activators that generate alkali base reactions.

The above conclusions indicate that the One-Part Geopolymer Concrete can be used where early-stage strength is required because it gains its maximum strength in 3 days after heat curing in an oven. It also indicated that by using higher percentage ratios of either WSA or Bentonite reduces Strength.

6 PRACTICAL IMPLEMENTATION

The application of geopolymer is same as the cement concrete but leading the world towards sustainability geopolymer is preferred. Geopolymer concrete is used for construction of pavements, retaining walls, water tanks and precast bridge decks and in the structure which are prone to sulfate attack. Recently the four-story structural building for public use is constructed using geopolymer concrete by the University of Queensland's Global change Institute. Another example is the building of Toowoomba Well camp Airport in which Geopolymer concrete was used.

ACKNOWLEDGMENT

The authors would like to thank every person/department who helped thorough out the research work, particularly Engr. Dr. Muhammad Faisal Javed. His careful reviews and constructive suggestions are gratefully acknowledged.

REFERENCES

[1] Ali, N., Jaffar, A., Anwer, M., Khan, S., Anjum, M., Hussain, A., ... & Ming, X."The greenhouse gas emissions produced by cement production and its impact on environment: A review of global cement Processing". *International Journal of Research (IJR)*, vol. *2*(2), pp 1-13, 2015.

[2] Lee, Z. H., Sethupathi, S., Lee, K. T., Bhatia, S., & Mohamed, A. R. "An overview on global warming in Southeast Asia: CO2 emission status, efforts done, and barriers". *Renewable and Sustainable Energy Reviews*,vol. *28*, pp 71-81, 2013.

[3] Yasina, M., Bhuttob, A. W., Bazmia, A. A., & Karimb, S."Efficient utilization of rice-wheat straw to produce value–added composite products" *International Journal*, vol. *1*(2), pp 1-8, 2010.

[4] El-Sayed, T. A., Erfan, A. M., & Abd El-Naby, R. M. "Recycled rice & wheat straw ash as cement replacement materials". *Journal of Engineering Research and Reports*, vol. 5(2), pp 1-9, 2019.

[5] Brock, P., Madden, P., Schwenke, G., & Herridge, D."Greenhouse gas emissions profile for 1 tonne of wheat produced in Central Zone (East) New South Wales: a life cycle assessment approach". *Crop and Pasture Science*,vol. *63*(4), pp 319-329, 2012.

[6] Memon, S. A., Wahid, I., Khan, M. K., Tanoli, M. A., & Bimaganbetova, M. "Environmentally friendly utilization of wheat straw ash in cement-based composites". *Sustainability*, vol. *10*(5), pp, 1322, 2018.

[7] Akbar, J., Alam, B., Ashraf, M., Afzal, S., Ahmad, A., & Shahzada, K."Evaluating the Effect of Bentonite on Strength and Durability of High Performance Concrete". *Int. J. Adv. Struct. Geotech. Eng*, vol. *2*, pp 1-5, 2013.

[8] Ahmad, S., Barbhuiya, S. A., Elahi, A., & Iqbal, J."Effect of Pakistani bentonite on properties of mortar and concrete". *Clay Minerals*, vol. *46*(1), pp 85-92, 2011.

[9] Khan, M. S., Ali, F., & Zaib, M. A. "A Study of Properties of Wheat Straw Ash as a Partial Cement Replacement in the Production of Green Concrete". *University of Wah Journal of Science and Technology (UWJST)*, vol. *3*,pp 61-68, 2019.

[10] Mirza, J., Riaz, M., Naseer, A., Rehman, F., Khan, A. N., & Ali, Q."Pakistani bentonite in mortars and concrete as low cost construction material". *Applied Clay Science*,vol. *45*(4), pp 220-226, 2009.