Experimental Study on Partial Replacement of Water Hyacinth Ash with Cement in Concrete

Anindita Acharjee[1], Rishikesh Duarah[2]

[1]Student, Dept. of Civil Engineering, The Assam Royal Global University, Assam, India
[2]Assistant Professor, Dept. of Civil Engineering, The Assam Royal Global University, Assam, India

---***---

Abstract - *Water hyacinth is a freshwater weed that grows in most frost-free regions of the world. Although it is often used as a water ornamental due to its beautiful flowers, it is considered to be one of the most problematic aquatic plants due to its negative impacts. In Assam, it is seen in abundance in almost every river body of the state. Concrete is a widely used artificial material made up of aggregates that are bonded together with a fluid cement. Once the cement solidifies, it forms a solid mass that resembles rock. It is the second most commonly used building material worldwide, following water. This project has been done to test the compressive, flexural, and split tensile strength of concrete by partially replacing cement with water hyacinth. Concrete was casted in the form of a beam, cube, and cylinder with varying percentages of water hyacinth ash (WHA), i.e. 0%, 5%, 10%, and 15% for 7, 14, and 28 days. The prepared samples were tested in a Universal Testing Machine(UTM) in the laboratory. The final results of the test were compared to those of conventional concrete. It was found that the highest strength was achieved at a 5% WHA replacement for M30 grade. After comparing the concrete and WHA replacement concrete, it was concluded that using a 5% ratio of WHA to replace cement in concrete is the optimal solution.*

Key Words: **Water Hyacinth Ash, Cement, Concrete, Compressive strength, Flexural strength, Split tensile strength, Universal Testing Machine.**

1.INTRODUCTION

The aquatic weed water hyacinth produces roughly two tons of material per acre and grows very quickly. Waterway destruction, fish habitat degradation that results in fish death, decreased oxygen dissolved in water, increased water loss from evapotranspiration, preventing mosquitoes from having a place to breed, and deterioration of swimming and fishing water quality are just a few of its detrimental effects on the environment. However, it harms the ecosystem in a number of ways. It can destroy waterways, harm fish by deteriorating their habitat and reducing the oxygen dissolved in water. India has implemented several strategies to manage and mitigate the spread of water hyacinth. These measures include physically removing the plant by hand, introducing insects that feed on the plant for biological control, and in some cases, using herbicides. Despite the progress made, water hyacinth remains a significant problem in many regions. Water hyacinth is a fascinating aquatic plant. However, it's important to note that water hyacinth can be considered an invasive species in certain areas. Due to its fast growth rate, it can quickly cover water bodies, blocking sunlight and depleting oxygen levels, which can harm native plants and aquatic life. Despite its invasive nature, water hyacinth has some potential uses. It can be utilized in the field of construction.

Concrete is a vital construction material known for its strength, durability and versatility. It is widely used in building foundations, floors, walls, highways, and bridges due to its reliability and cost-effectiveness in construction projects. As compared to the other materials in concrete, cement is the most costly material. Enormous amount of carbon dioxide are released during the cement manufacturing process which causes harm to the ecosystem in various ways. Studies and research projects have demonstrated that using locally accessible materials, like fly ash and egg shell etc. can replace cement in whole or in part, and this approach has been effective in satisfying the demand for concrete in construction projects. This research work studies the impact of water hyacinth ash in concrete mixes, which determines the optimal proportions that enhance the performance of concrete while reducing the environmental footprint.

1.1 Objective

- To develop more environmental friendly construction methods by making better use of leftover resources and raising the standards of concrete structures.
- To partially replace cement mixture with water hyacinth ash which is produced by oven drying of the material
- To understand how water hyacinth ash can effect the durability, strength and other attributes of concrete.

1.2 Scope

- Environmental cleanup by removing water hyacinth.
- Utilizing it as a resource instead of waste.
- Promoting sustainable construction practices.
- Enhancing concrete properties with water hyacinth ash.

- Potentially reducing production costs and offering an eco-friendly alternative.

2. Materials

Portland Pozzolana Cement 43 grade, confirming to IS 1489(Part1): 1991 was used. Coarse aggregates of size 20 mm are adopted for the study. For fine aggregates, river sand was used which confirms to grading zone II of nominal size. Potable and colourless water has been used to mix the prepared concrete. Water Hyacinth Ash has been prepared and used accordingly.

2.1 Preparation of Water Hyacinth Ash

The water hyacinth plants have been accumulated from Deepor Beel, a lake located in Guwahati, Assam. The plants were thoroughly cleaned with fresh tap water to remove all impurities, trash and contaminants. After that, they were cut into small pieces with the help of a knife. Subsequently, they were dried in sunlight for over a week, resulting in a significant reduction in weight compared to their original state. To completely dry the samples, they were kept in an oven for 6 hours at 800°C. With the help of this procedure, the organic matter has changed into an inorganic matter. After that, a 150-micron sieve was used to filter the materials. The materials that made it beyond the 150-micron filter were utilized to partially substitute cement.

Fig-1: Water Hyacinth Plants

Fig-2: Oven drying of water Hyacinth

Fig-3: Burning of Oven dried water hyacinth plants

Fig-4: Ashes of Water Hyacinth after Burning

3. Methodology

Tests such as the specific gravity, sieve analysis, slump test etc. were performed to examine the characteristics of the coarse aggregate, fine aggregate, and cement. Concrete was manufactured by batching following the numerous tests conducted on the components. The water-cement ratio used was 0.432 kg/m^3, and the chosen materials were accurately weighed and combined in accordance with the design mix proportion of 1:1.55:2.70 for M30 grade of concrete. Concrete mixture was cast into cubes, beams, and cylinders mould with water hyacinth ash replacing 0%, 5%, 10%, and 15% of the cement. The slump test was performed in the new concrete mix to determine the workability of the concrete. The specimens were demoulded after 24 hours and were allowed to cure. Universal testing machine (UTM) was used for testing of the compressive, flexural and split tensile strength in 7th, 14th, and 28th day. Split tensile strength=2PπLD, flexural strength=PL/(bd^2), and compressive strength = Load in (N) and area in (SQ.MM).

Fig-5: Casting of the specimens

Fig-6: Curing of specimens

3.1 Equipment

- Universal testing Machine
- Measuring Tube
- Mixing Tray
- Slump Cone
- Tampering Rod
- Weighing Machine

3.2 Mix Design

Mix	Composition
Cement	450 kg/m³
Water	150.92766 kg/m³
Coarse Aggregate	1218.140588 kg/m³
Fine Aggregate	699.03354 kg/m³
Water Cement Ratio	0.432
Mix Ratio	1:1.55:2.70

4. Test Performed on Concrete

4.1 Compressive Strength Test

The test was done as per IS 156. After 7, 14 and 28 days of curing, specimens measuring 150x150x150mm were made and tested using a universal testing machine. Figure 7 shows compression testing of concrete cube.

Fig-7: Compression testing of cubes

4.2 Flexural Strength Test

Specimens of beam measuring 150x150x700mm dimensions were made. After 28 days of curing, testing has been done by using a universal testing machine. Flexural testing on a concrete beam is shown in Figure 8.

Fig-8: Flexural testing of beams

4.3 Split Tensile Test

According to IS: 5816, the test was carried out. After 28 days of curing, the samples were tested. Figure 9, shows split tensile strength test.

Fig-9: Split Tensile Test of cylinders

4.4 Slump Test

The slump test was done on freshly prepared concrete. The test was performed at various mix proportions. Figure 10 shows slump test on concrete.

Fig-10: Slump Test on freshly prepared concrete

5. Results

5.1 Compressive Strength Test Results

The compressive strength test was performed. Chart 1 shows the results for various mixes tested after 7th, 14th and 28th day of curing period.

Table-1: Compressive Strength Test Results

Mix %	Compressive Strength		
	7 Days (N/mm^2)	14 days (N/mm^2)	28 Days (N/mm^2)
0	16.53	25.38	28.85
5	19.25	26.16	29.46
10	18.35	25.33	28.14
15	12.31	20.24	24.34

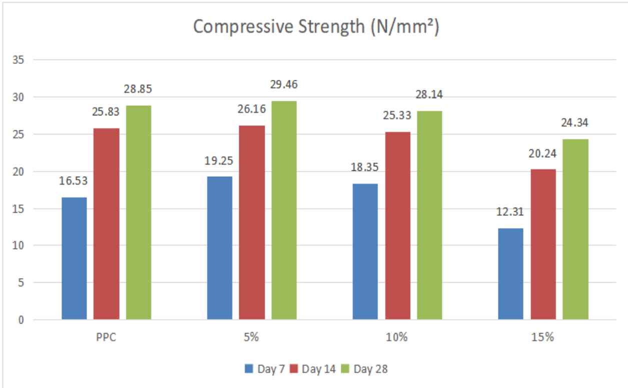


Chart-1: Compressive Strength Test of Concrete

The strength of the concrete cube after 7th, 14th, and 28th days is displayed in the above chart for both regular concrete and concrete that has had varied ratios of water hyacinth ash added to the cement. It has been noted that as the curing time grows, so does the concrete's strength. Nonetheless, the WHA replacement increases strength by 5% compared to regular concrete.

5.2 Flexural Strength Test results

The flexural tests were conducted and the results obtained for different mixes tested after curing periods of 28 days are illustrated in chart 2.

Table-2: Flexural Strength Test Results

Mix %	Flexural Strength
	28 Days (N/mm^2)
0	3.61
5	4.27
10	3.84
15	2.01

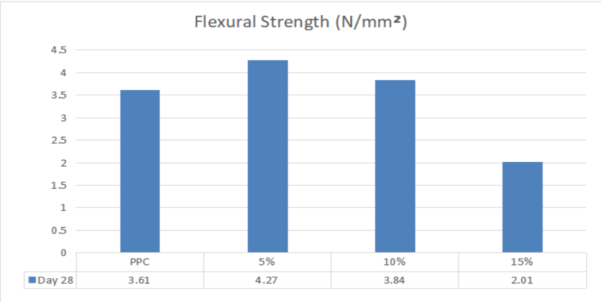


Chart-2: Flexural Strength Test of Concrete Beam

The strength of the beam in 28 days for both regular concrete and cement substituted with varying percentages of water hyacinth ash is shown in the following chart. It has been noted that the flexural strength of 0% mix is within an acceptable range.In comparison to the control, the flexural strength of the 5% WHA mix is the highest.

5.3 Split Tensile Test Results

Chart 3 shows the results of the split tensile test, which was performed on various mixes after a 28 day curing period.

Table-3: Split Tensile Test Results

Mix %	Split Tensile
	28 Days (N/mm²)
0	3.61
5	4.27
10	3.84
15	2.10

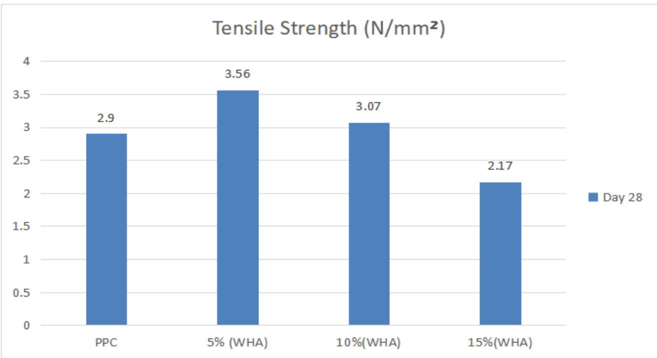


Chart-3: Split Tensile Strength Test for Concrete Cylinder

The split tensile strength of conventional concrete and water hyacinth-replaced concrete cylinders with different proportions are displayed in the following chart. The findings indicate that when water hyacinth ash is used in place of 5% cement, the ultimate strength is achieved.

5.4 Slump Cone Test

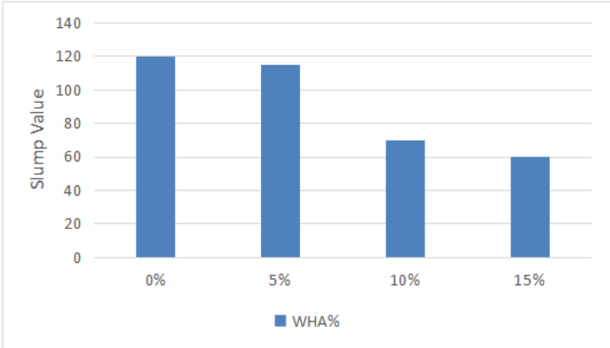


Chart-4: Slump Test

The concrete workability is determined by the slump test. This is an observation of the slump test on concrete that has been partially replaced with water hyacinth ash at 5%, 10%, and 15%.

6. Regression Graphs

Regression Analysis has been carried out for Flexural Strength with respect to compressive strength, split tensile strength and different percentages of water hyacinth ash. The graphs of regression analysis are shown below.

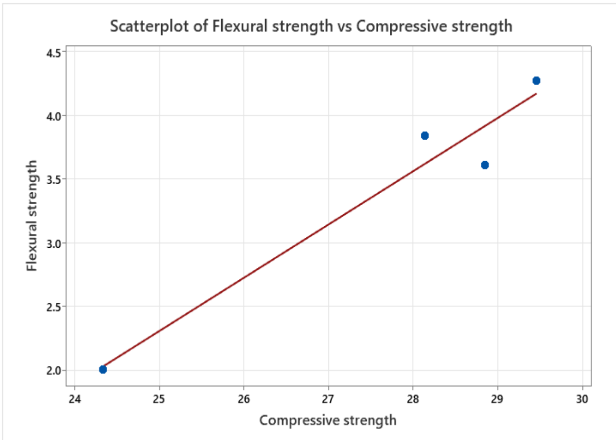


Chart-5: Scatterplot regression graph for Flexural Test vs Compressive Test

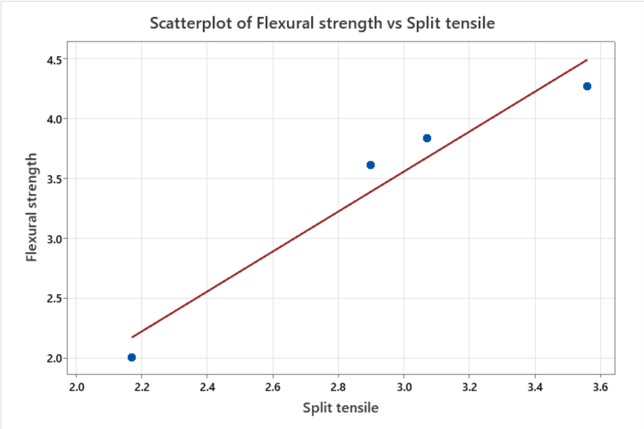


Chart-6: Scatterplot regression graph for Flexural Test vs Split Tensile Test

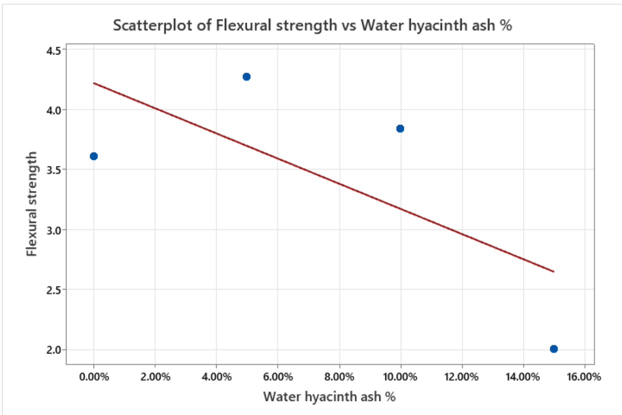
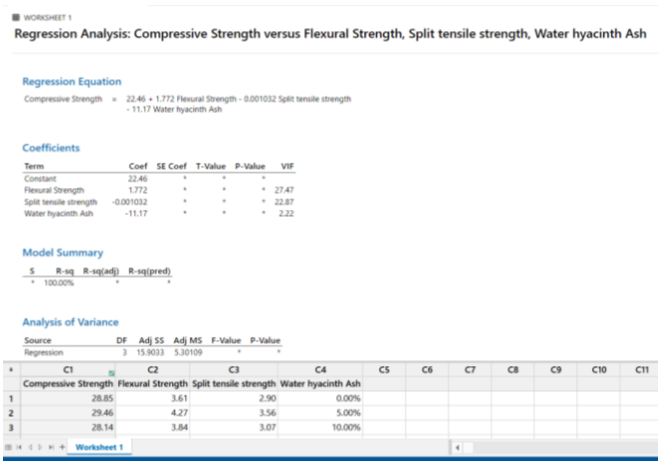


Chart-7: Scatterplot regression graph for Flexural Test vs different percentages of WHA



WORKSHEET 1

Regression Analysis: Compressive Strength versus Flexural Strength, Split tensile strength, Water hyacinth Ash

Regression Equation

Compressive Strength = 22.46 + 1.772 Flexural Strength - 0.001032 Split tensile strength - 11.17 Water hyacinth Ash

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	22.46	*	*	*	
Flexural Strength	1.772	*	*	*	27.47
Split tensile strength	-0.001032	*	*	*	22.87
Water hyacinth Ash	-11.17	*	*	*	2.22

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
*	100.00%	*	*

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	15.9033	5.30109	*	*

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
	Compressive Strength	Flexural Strength	Split tensile strength	Water hyacinth Ash							
1	28.85	3.61	2.90	0.00%							
2	29.46	4.27	3.56	5.00%							
3	28.14	3.84	3.07	10.00%							

Worksheet 1

Fig-11: Relationship of flexural strength vs compressive strength, split tensile strength and water hyacinth ash%

The relationship of flexural strength with respect to compressive strength, split tensile strength and different percentages of water hyacinth ash is shown in figure 11. the equation obtained is given below:

Flexural Strength = -12.68 + 0.5644 Compressive Strength + 0.000582 Split Tensile + 6.306 Water Hyacinth Ash.

7. Conclusions

The research on incorporating water hyacinth ash (WHA) as a partial replacement for cement in concrete has provided important insights into its impact on workability, compressive strength, flexural strength and split tensile strength. This study is focused on replacement levels of 5%, 10%, and 15% by weight. Here are the key conclusions drawn from the results:

- The optimum value for the partial substitute of cement by using water hyacinth ash is obtained as 5%.
- Concrete loses strength in the compressive, flexural, and split tensile domains when the amount of water hyacinth ash is increased above 5%.
- Compressive, flexural and split tensile strength for the above criteria sample is more than the normal concrete mix.
- The results shows that the strength of the concrete gets effected when 15% water hyacinth ash was replaced.
- It was found that water hyacinth ash have high absorptivity, hence the setting time of cement gets increased.
- Thus, it is feasible to introduce water hyacinth in the production of concrete.

8. References

[1] Ertie Abana, William Vega, Jaezel Gacias, Patrick John Rañon, John Denver Talattad, Herbert Orata, Jerone Perez, "Pulverized Water Hyacinth as an Admixture for Concrete" International Journal of Integrated Engineering, Vol. 13 NO. 4 (2021) 298-303

[2] Aadarsha Lamichhane, Gokarna Bahadur Motra, Thaman Bahadur Khadka, "Evaluation of Water Hyacinth Extract of Nepalese Lakes as an Admixture in Concrete Production", Proceedings of 8th IOE Graduate Conference Peer Reviewed ISSN: 2350-8914 (Online), vol.8, June, 2020

[3] Prang Subpa-ASA, Laemthong Laokongthavorn, Sheigeyuki Date, "The Study on Effect of Lightweight Concrete Block by Water Hyacinth Adding", 6th International Conference on Advanced Engineering and Technology (ICAET 2019)

[4] Geeja K George, Aswin Das A S, Breeze Joy K, Georgootty K Milson, Jeeva Varghese, "Effect of Using Water Hyacinth Extract and Glass Powder in Concrete", International Research Journal of Engineering and Technology (IRJET), Volume 09 Issue: 07, July 2022.

[5] Neelu Das, Shashikant Singh, "Evaluation of Water Hyacinth Stem Ash as Pozzolanic material for use in Blended Cement", Journal of Civil Engineering, Science and Technology Volume 7, Issue 1, April 2016.

[6] C.K.Kiptum, L.Rosasi, O. Joseph and E.Odhiambo, "Some Mechanical Characteristics of Concrete Reinforced with Dried water Hyacinth and Quarry Dust as Fine Aggregate" Journal of Civil Engineering, Science and Technology Volume 10, Issue 2, September 2019.

[7] M. Anwar, A. Makhlouf, "Durability of Water Hyacinth Ash Concrete", Engng.Res.Jour.,Vol.87.PP.C 156, June 2003.

[8] Tidarut Jirawattanasomkul, Haruna Minakawa, Suched Likitlersuang, Tamon Ueda, Jian-Guo Dai, Nattamet Wuttiwannasak , Nattapong Kongwang, "Use of water hyacinth waste to produce fibre reinforced polymer composites for concrete confinement: Mechanical performance and environmental assessment", Journal of cleaner production 292(2):126041, 2021

[9] Harshit Sharma and M.S. Chauhan, "Water Hyacinth: Control and Utilization. International Journal of Civil Engineering and Technology pp. 765–772.

[10] IS:383-1970: Specifications for Coarse and Fine Aggregates for Natural Sources of Concrete, Bureau of Indian Standards, New Delhi.

[11] IS:10262-20019: Concrete Mix Proportioning– Guidelines Bureau of Indian Standards, New Delhi.

[12] IS:516-1959: Methods of Tests for Strength of Concrete, Bureau of Indian Standards, New Delhi.

[13] IS:1489(Part1): 1991 Portland-Pozzolana Cement – Specification,Bureau of Indian Standards, New Delhi.