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An Investigation into Properties of Concrete by Partial Replacement of Sand with Wheat Straw Ash and Addition of Polypropylene Fiber

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Abstract

Concrete is the more widely utilized construction material on the planet earth, particularly in evolving and developing nations. Concrete was created as a stronger and more resistant building material as it was worked upon over time. Gradually, the man figured out how to create it, transport it, and utilize it more efficiently. We know that concrete is made from cement, sand, aggregate, and water. Out of these, some of them may be replaced with some other material like wheat straw ash, rice husk ash, fly ash, etc. for various purposes, mostly to utilize waste material without affecting the important properties of concrete beyond acceptable limits. This study deals with an investigation into the properties of concrete by partial replacement of sand with wheat straw ash and the addition of polypropylene fiber in it. Wheat Straw is the portion of leftovers of the wheat crop after it is harvested. In most countries, it is a waste. People burn it and cause pollution and health hazards, good strength and high performance in concrete are very much required in future construction work. It is felt that fiber dispersion in concrete is one method to improve the structural characteristics of concrete.

Keywords

Polypropylene Fiber, wheat Straw Ash, rice husk ash, concrete

1. Introduction

Concrete is the more widely utilized construction material on the planet earth, particularly in evolving and developing nations. It is the world's most abundantly used building material and has a history that goes back to the Romans and ancient Egyptians. Considering that concrete is used twice the rate as all other building materials in construction, a focus on quality, performance, and sustainability is critical for the sector to expand and prosper. Concrete, and the technology that surrounds it, have gone a far way since its discovery and development.

Concrete has become a more efficient material throughout time. From the use of natural chemicals that resembled cement to the enhancement of natural materials through man-made procedures. As technology progressed, so did our ways of manufacturing concrete and cement. We know that concrete is made from cement, sand, aggregate and water. Some of these constituents may be partially replaced with some other material like with wheat straw ash, rice husk ash, fly ash, etc. Wheat and rice are from agro industry and agro industry is the basic need of all. A by-product of wheat crop is straw which is not very useful. Some people use it for animal fodder and at most of the times, people burn it, causing pollution and health hazard. Burning wheat straw out in the field leaves half of the Sulphur and Nitrogen and leaves the bare soil with Phosphorus and Potassium in the ash, which can risk soil erosion. Occasionally, is also used as a building material for insulation and in concrete also because it is a highly pozzolanic material. In concrete buildings, pozzolonic materials like Fly Ash, Silica Fume, as well as Blast Furnace Slag are commonly used. Supplementary cementitious ingredients have the potential to dramatically boost strength and durability of concrete.

Excellent strength and high performance in concrete is very much required in future construction work. Fiber dispersion in concrete is one method to improve structural characteristics of concrete. Fiber-reinforced concrete (FRC) is a type of concrete that contains fibrous material to improve structural stability. With different concrete fibre materials, geometries, distribution, orientation, and densities, the character of fiber-reinforced concrete changes. Polypropylene fibres are synthetic fibres that are a byproduct of the textile industry. Polypropylene fibre is a synthetic fibre that is low in weight. It inhibits fracture development and strengthens the concrete structure. Its application enables for the dependable and effective usage of the material's intrinsic tensile and flexural strength, also considerable decrease in plastic shrinkage cracking and a reduction in heat cracking. It offers strength, protects the concrete structure from damage, and avoids spalling in the case of fire.

2. Literature Survey

Extensive research has been conducted on a variety of relatively novel additional cementitious materials, including rice husk ash, sewage sludge ash, and oil shale ash. **Biricik et al.** have investigated ash of wheat straw as a potential additional cementitious material. A well-burned and ground wheat straw ash is a very active pozzolanic material. They also discovered that wheat straw contains 8.60 % ash with a silica concentration of 73.00%; and ash of wheat straw (WSA) possesses pozzolanic characteristics under typical curing conditions.

Nabil M. Al-Akhras, Bilal A. Abu-Alfoul in their research (the effect of ash of wheat straw on mechanical properties of autoclaved mortar) have replaced, in varying percentage 3.6, 7.3, 10.9 percent of sand with ash of wheat straw by weight of sand. And their study is successful. The replacement increases the mechanical strength. Replacing sand by 10.9% in mortar led to increase in 87% of compressive strength, 67% of tensile strength and 71% of flexural strength.

Divya S, Dharan and Aswathy Lal in their research (Study the effect of polypropylene fiber in concrete) have added 05, 1, 1.5, 2 percent of polypropylene fibre in concrete. They experienced a good result, at 1.5 percent of fibre the increase in compressive strength is 17%, tensile strength is 22%, 24% flexural strength and 11% elasticity compared to general or ideal sample.

As per research by **Abdul Qudoos, Zahid Ullah, Atta-ur-Rehman, and Zafar Baloch** on Performance evaluation of fiber reinforced cement composites blended with wheat straw ash, they have replaced the wheat straw ash with cement in fiber reinforced concrete. They have replaced 20% of ash of wheat straw by binder weight and added 0.5, 1 and 2 percent of polypropylene fiber in it by cement weight. The result of this study indicates that the compressive strength decreases and tensile and flexural strength increases

As per the PhD thesis of **Jennifer Ruth Dodson** (Wheat straw ash and its use as a silica source, university of York sep 2011) wheat straw has SiO2, Al2O3, Fe2O3, CaO, MgO, Na2O, K2O, SO3, P2O5, Cl (ref. chapter 1 table 1.2 pg 35, reproduced below). All these compounds play a vital role in enhancing various properties of concrete

Chapter 1 Introduction

Table 1.2: Ash content, elemental composition and calorific value data for a variety of biomass materials and coal

	Residue type	Ash (wt% dry basis)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	P_2O_5	Cl	HHV (MJ / kg dry basis)	Alkali index (kg M_2O / GJ)	Ref
Wheat straw	Imperial Valley (USA)	12.8	35.8	2.5	1.0	4.7	2.5	10.5	18.4	5.5	1.5	14.7	17.2	2.15	2
	(China)	10.0	36.9	8.0	6.3	8.1	3.0	9.2	17.4	4.5	2.0	5.2	16.2	1.64	32
	2000 (Denmark)	4.8	35.3	1.1	0.1	10.2	2.4	0.5	30.1	6.2	2.6	3.4	16.8	0.88	33
	Soisson (Spain)	5.7	64.0	0.3	0.2	5.4	1.8	0.1	17.0	1.8	1.6	2.8	16.3	0.60	33
	2001 (Denmark)	4.8	67.0	0.2	0.2	8.7	2.2	0.1	14.0	2.2	2.4	2.1	17.4	0.39	33
	Marius (Spain)	4.9	65.0	0.8	0.6	11.0	1.7	0.1	9.1	2.5	2.3	1.2	17.1	0.26	33
Other agricultural straws available in UK	Winter barley	6.9	25.2	0.2	0.1	6.9	2.2	5.1	40.2	5.1	1.9	6.9	16.5	1.89	33
	Spring barley	5.7	37.2	nd	nd	12.5	1.0	0.9	17.8	2.7	1.4	1.4	nd		33
	Oat straw	3.8	15.2	0.3	0.1	26.5	3.3	4.5	17.4	6.4	6.7	0.8	17.4	0.48	33
	Rape straw	2.7	2.4	4.2	1.6	48.7	3.1	0.2	15.2	3.8	1.4	0.5	17.0	0.24	33
Agricultural residues around the world	Rice straw	20.9	72.3	0.1	0.3	2.1	2.1	2.7	11.8	1.1	1.8	4.1	14.7	2.05	2
	Cotton straw	7.4	17.7	10.8	2.4	9.0	7.3	6.8	30.2	5.8	4.3	4.9	15.9	1.73	32
	Maize	7.1	33.0	3.7	1.6	17.0	4.4	0.4	22.0	1.7	1.9	5.4	16.4	0.97	33
	Sugarcane bagasse	8.5	42.6	23.2	16.2	3.0	2.0	0.6	3.0	0.5	1.3	0.1	17.7	0.17	2
	Switchgrass	3.8	62.8	0.3	0.9	6.2	1.7	0.4	11.7	1.5	4.2	0.1	18.7	0.24	2
Wood	Wood fuel	4.5	37.5	14.1	0.6	7.6	17.0	3.6	1.4	2.2	6.0	2.2	18.7	0.12	2
	Red Oak	1.2	38.3	8.1	7.6	12.8	1.0	0.4	8.6	1.8	1.0	<0.01	19.0	0.06	34
Macroalgae	*Laminara digitata*	25.8	0.4	0.1	1.0	5.0	5.2	19.6	14.8	-	6.7	-	17.6	3.23	35
Coal	Eastern Kentucky	7.6	51.6	32.5	4.5	1.1	0.4	0.2	1.3	1.3	0.3	2.3	31.0	0.04	34

Table 1. Constituents of Wheat Straw

a) Polypropylene Fiber in Concrete

According to a study on Polypropylene fiber in concrete by N. Sohaib, Seemab, Sana G, R. Mamoon, because of the fibres ability to remove various faults in concrete, the usage of polypropylene fibres has expanded in recent years. Concrete's mechanical qualities are improved by the use of polypropylene fibres. The high tensile strength of fibres can enhance the capacity of concrete and regulate volume variations over time. According to the study findings, the addition of polypropylene fibres enhanced compressive strength by 20% and 16% after 7 days and 28 days, respectively, when compared to control samples, while split tensile strength rose by 11% and 17% after 7 days and 28 days, respectively. The optimal proportion of polypropylene fibres was obtained as 1.5 percent of cement contents in compressive split tensile strength. However, the reduction beyond 1.5 percent is moderate.

b) Wheat Straw Ash in Concrete

The study Incorporating Wheat Straw Ash as Partial Sand Replacement for Production of Eco-Friendly Concrete by Shazim Ali Memon, Usman Javed, Muhammad Haris, Rao Arsalan Khushnood, and Jong Kim proposed an environmentally friendly disposal of wheat straw ash by incorporating it as a partial substitute for fine aggregate in concrete. The studies considering the macrostructural and microstructural characterization of wheat straw ash indicated that it is pozzolanic in nature. With increasing volumes of ash of wheat straw replacement, slump values rose. This tendency was predicted due to the lubricating effect of additional water absorbed by wheat straw ash, which improved the fluidity of ash of wheat straw concrete mixtures.

4. Material

We used Ordinary Portland Cement, wheat straw ash (wheat straw is collected from the local shop in Chinhat, Lucknow, India, which was burnt in open ground and left for cooling for a night, later on it was collected), polypropylene fibers, sand, aggregate and water

a) **Wheat Straw Ash -** A well-burned and ground ash of wheat straw is an extremely active pozzolanic substance. Pozzolans are alumina and siliceous material that have little or no cement value in them but, when finely split and in the presence of moisture, chemically react with Ca (OH)2 at room temperature to generate compounds having cementitious qualities. When these minerals are added to Portland cement, they generally enhance the mechanical strength and longevity of concrete constructions.

b) **Polypropylene Fiber -** Polypropylene fibres are synthetic fibres that are produced as a byproduct of the textile industry. Polypropylene fibres are not hydrophilic, meaning they do not absorb water and are hence non-destructive. Furthermore, these fibres are resistant to alkalis, chemicals, and chloride, and have poor heat transmission properties. Its application enables dependable and effective usage of the material's intrinsic tensile and flexural strength, and also a considerable decrease in plastic shrinkage cracking and a reduction in heat cracking. It offers strength, protects the concrete structure from damage, and avoids spalling in the case of fire. Because of the qualities of polypropylene fibres, they do not require new concrete water and do not require cement to be mixed with water.

Figure 1. Polypropylene Fibre.

Figure 2. Wheat Straw Ash

5. Methodology

M25 grade of concrete is prepared for this study. Using a ratio of 1:1:2 sand, cement, and aggregate. Water cement ratio is 0.4 to 0.6. An ideal sample is so prepared for comparison with other samples. A total of four kind of samples are prepared in which first kind is ideal which is just only M25 grade of concrete; the second sample is M25 but 10 percent of sand is replaced with wheat straw ash and 1 percent of polypropylene fiber by weight of sand is added. The third and fourth samples are similar to the second one, but, polypropylene fiber in third and fourth is 2 and 3 percent of sand. The mixtures were labelled WSAX/PPY,

where X denotes the quantity of WSA (Wheat Straw Ash) and Y represents the PP (Polypropylene fibre dose). WSA10/PP1, for example, denotes a mortar mix containing 10% of Wheat Straw Ash and 1 percent Polypropylene fibres. The samples are prepared for compressive test and flexural test of concrete. In addition, workability test by slump cone test is also done.
The following samples were prepared

WSA10/PP1	10% replacement of sand with Wheat Straw Ash and 1% polypropylene fiber
WSA10/PP2	10% replacement of sand with Wheat Straw Ash and 2% polypropylene fiber
WSA10/PP3	10% replacement of sand with Wheat Straw Ash and 3% polypropylene fiber

Required material like cement, sand, and aggregate for this study is collected from the nearby building material shop and polypropylene fiber also known as engineer fiber is obtained from a local shop. Wheat Straw is collected from a local shop and converted to wheat straw ash by burning the wheat straw in open ground. After cooling, the ash it is taken to the laboratory

5.1 Digital Sample

a) **Cube for compression test.** Samples were cast in a shape of cube having dimension 150x150x150 mm, left for settlement of sample for 24 hrs, demoulded and put for curing for 28 days

Figure 3. Cubes cast and ready for testing

b) **Beam for flexural test.** Samples were cast in the shape of a beam having dimension 150x150x700 mm, left for settlement of sample for 24 hrs, demoulded and put for curing for 28 days

Figure 4. Beams cast and ready for testing

6. Test & Result

The following tests were performed on all the samples to investigate the impact of the replacement on the properties of concrete.

a) Workability Test – Workability was measured by slump cone test. The results of the slump cone test obtained for the different samples are given below in tabulated and graphical form:

Table 2. Results of Workability Test

Sample Type	Slump test Value (cm)
Ideal Sample	2.3
WSA10/PP1	2.4
WSA10/PP2	2.7
WSA10/PP3	2.4

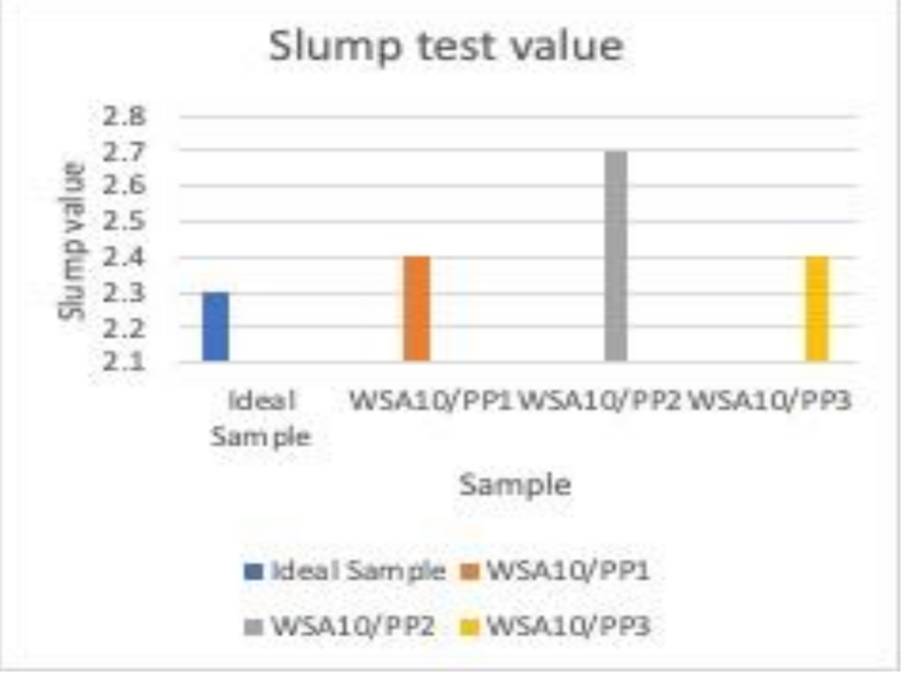

Figure 5. Results of Workability Test

In all samples the slump we got is true slump, in true slump, the concrete just subsides, remaining mostly intact. It was observed that the Slump value of the altered concrete first increases and then decreases. The ideal sample have value 2.3 cm means degree of workability is very low and compacting factor is 7.8. Concrete having 10% wheat straw ash replace and 1% polypropylene fiber (WSA10/PP1), concrete having 10% wheat straw ash and 3% polypropylene fiber (WSA10/PP3) have slump value 2.4 cm and 2.3 cm. This indicates very low workability. Concrete having 10% wheat straw ash and 2% polypropylene fiber (WSA10/PP2) has slump value 2.7 cm which indicates low workability.

b) Compression Test- After 28 days of curing, the samples are evaluated using a compressive testing equipment. Load was gradually applied at a rate of 140 kg/cm2 per minute until the samples failed. The compressive strength of the concrete was calculated by dividing the load at failure by the area of the sample.

Figure 6. Compressive Test being conducted

Compressive strength = compressive load on sample / cross sectional area of sample
Cross sectional area of sample = 150 X 150 mm = 22500 mm
Compressive strength = compressive load on sample / 22500 mm

The Compressive strength test result of the samples is indicated in tabular and graphical form as under

Table 3. Results of Compressive Test

Samples	Compressive Load KN	Compressive Strength N/mm²
Ideal Sample	711.7	31.63
WSA10/PP1	379.1	16.84
WSA10/PP2	398.2	17.69
WSA10/PP3	337.2	14.98

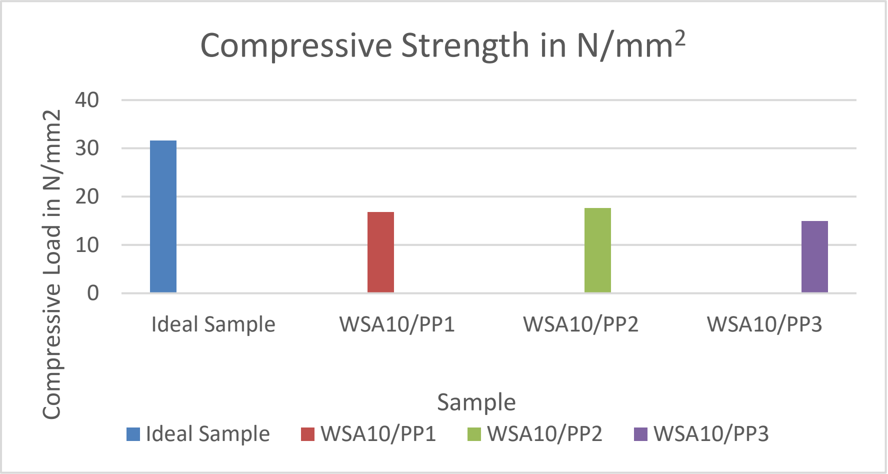

Figure 7. Results of Compressive Test

c) Compressive strength was found to reduce with the addition of fibres and the substitution of ash of wheat straw with sand, as predicted. WSA10/PP1, for example, demonstrated a drop in strength when compared to the ideal one. Samples containing 1%, 2% and 3%Polypropylene fibres showed a decrease of 61%, 56.5% and 71.4% at 28 days, respectively compared to the ideal one. The decrease in compressive strength appears caused by the inclusion of PP fibres. The discontinuity in the cement matrix induced by the fibres is probably responsible for the loss in compressive strength. Aside from that, the inclusion of ash of wheat straw particles also appears to have caused strength loss. The tiny wheat straw ash particles act as a filler and have pozzolanic properties.

d) Flexural Strength test. The flexural test indirectly measures the tensile strength of concrete. The flexural test determines the capacity of an unreinforced concrete beam or slab to survive bending failure. The maximum stress sustained within the material at the point of rupture is represented by flexural strength. The beams which were cast were laid horizontally over two points of contact (lower support span), and a force applied to the material's top through points of contact (upper loading span) until the sample fails. The greatest measured force represents the sample's flexural strength. The flexural strength of a specific concrete member was calculated using the load that caused the fracture and the pattern of the crack

Figure 8. Flexural Test being conducted

The Flexural strength test result of the samples is indicated in tabular and graphical form-

Table 4. Results of Flexural Test

Samples	Peak Load KN	Flexural Strength N/mm2
Ideal Sample	19.5	3.47
WSA10/PP1	13.8	2.45
WSA10/PP2	12.7	2.26
WSA10/PP3	9.1	1.62

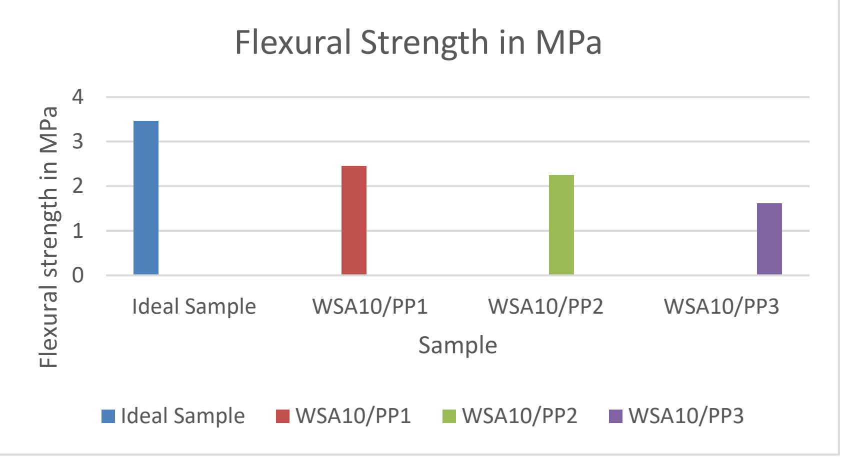

Figure 9. Results of Flexural Test

As we can observe, the ideal sample has flexural strength of 3.47 MPa. With variation in composition, i.e. replacement of sand with wheat straw ash and addition of polypropylene fiber, the flexural strength is found to reduce. WSA10/PP1 has flexural strength 2.45 MPa, WSA10/PP2 has 2.26 MPa and WSA10/PP3 has 1.62 MPa. As seen from the result the flexural strength is decreasing by increasing the amount of polypropylene fiber with constant replacement of sand with wheat straw ash

7. Conclusion

The efficacy of fibres on different mechanical and durability parameters was investigated using fiber-reinforced wheat straw ash mixed concrete. When wheat straw ash was added to Polypropylene fibre concrete, the compressive strength of the concrete dropped. The inclusion of wheat straw ash particles, on the other side, compensated for the unfavourable influence of polypropylene fibres. The tiny wheat straw ash particles contributed pozzolanic and filler effects, resulting in a densified microstructure of the cement composites. As a result, the addition of polypropylene fibres to wheat straw ash cannot improve the compressive strength of the concrete.

The decrease in compressive strength of concrete may be due to presence pozzolan in wheat straw ash, elements such as of Fe2O3, alkali like Na2O, K20 and P2O5. The concentration of Na2O and K2O in cement is referred to as its alkali content. Increased alkali content in cement probably slowed final setting time, reduced compressive strength, and increased rapid chloride ion permeability, drying shrinkage, and volume of permeable voids. It is also observed from the results that, increasing the amount of polypropylene fibre with continuous replacement of sand with wheat straw ash reduces flexural strength. It was expected that the flexural strength of the concrete would increase with the addition of polypropylene fibres, however, results were to the contrary. More detailed studies are possibly required to establish the exact effect

8. Future Work

As we can see by the result, the compressive strength and flexural strength decreases by the replacement of sand with 10 percent ash of wheat straw and addition of polypropylene fiber with variation of 1,2, and 3 percent. Further studies can be conducted by varying the composition, possibly, ash approx. 5 percent by weight of sand and fiber should may be 0.1, 0.5, and 1 percent in it. The effect on compressive and flexural strength can then be studied and recorded.

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