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EFFECT OF SAWDUST ASH ON FLEXURAL STRENGTH OF RECYCLED AGGREGATE CONCRETE

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Abstract
In this paper, the flexural strength of recycled aggregate concrete that used saw dust ash instead of some part of cement is studied. Recycled aggregates are taken from broken construction waste and mixed in same amount like normal aggregates. Saw dust ash was made by burning wood at 1200°C. A 1:2:4 mixture and water-cement ratio of 0.5 was taken to make the prism shapes (100mm x 100mm x 500mm). Cement was changed from 0% to 10% slowly by 1% each time. Another set using only normal aggregates was also made so we can see the difference with the new concrete. How easy the mix was to work with was checked using slump test. There were 33 prisms in total and flexural test was done using central point loading. Central deflection at maximum sustained load was also recorded. The results showed that when 5% saw dust ash is used, the leftover flexural strength is 91% and deflection comes down by 74%. Also, when more saw dust ash was added, it helped to control the beam bending better.

INTRODUCTION

Modern infrastructure development not only require increased use of the conventional ingredients of concrete but also in many cases poses the waste management issues in case when development is done by demolishing the old infrastructure. Both factors pose serious management and environmental issues. Excessive use of concrete ingredients requires more working of production line of the concrete ingredients which in turn create environmental problems because of CO_2 emission and consumption of energy. Earlier demolishing waste was generally dumped in landfills but due to scarcity of the space it is left over or dumped in or around the agricultural lands. Second option is more harmful as it disturbs the important land. Transporting of it to far distances create overburden on the project. Therefore, to deal with management of the waste and to conserve conventional sources of concrete ingredients and environment a possible way is to make use of this waste in new concrete. If it does not nullify the above-mentioned issues, then reduce them to good extent. Although good quantum of time and effort is devoted for the research on the use of the demolishing waste as one or other ingredient of the concrete, but still there are several issues associated with it. Memon[0] reviewed the use of the waste as coarse aggregates in new concrete and highlighted its benefits and problems. Consequently, the paper also summarized the recommendations of different scholars for better utilization of the waste.

Demolishing waste is not the only waste which creates problems for the environment but there are several other byproducts of some primary processes responsible for the environmental issues. Sawdust is one among them. It is the result of sawing of wood used for different purposes. It is generated in huge quantum and generally goes to dumping places and finally burned in open areas making smoke and bad gases. People tried to reduce this waste by using it with normal concrete as a replacement for some of its parts [12]. Using this waste in new concrete helps to make sustainable material and also supports the environment. Many researchers, like Mangi et al., studied how sawdust can be used with regular concrete to replace cement and make low-cost useful material. Fapohunda et al[4]. also studied how sawdust can take the place of cement and sand. They also explored use of waste wood pieces as coarse aggregates. Based on their study authors insisted that uncontrolled burning of the waste should be avoided to keep loss on ignition within specified limits.

Wood ash has also been attempted as wood mixed concrete to study the strength of the product by Chowdhury et. al.[5] The authors from testing concrete made with different amounts of the wood ash observed that at early age strength decreased but it marginally increased at later age. They also developed numerical expression to predict strength based on vector machine theory. In another separate attempt Marthong[6] used sawdust ash from 0 – 40% with three different grades of cement to study the strength, shrinkage, and durability of the concrete. The author observed that low calcium content of the waste material give rise to the shrinkage. Considering the strength of the product the author concluded 10% as the optimum dosage for all considered grades of cement. Dhull[7], Claudiu[8], and Dadzie et. al.[9], Adebakin et. al.[10] also concluded 10% as the optimum dosage based on strength results of concrete using sawdust ash instead of cement, mortar containing sawdust ash, blocks made with sawdust used as some replacement for sand, and hollow sandcrete blocks respectively.

In separate studies Aqib et. al.0, Raheem et. al.0, Cheng et. al.[0], and Auta et. al.0 on other concluded 5% as the optimum dosage of sawdust ash. Sawdust ash has also been attempted in concrete for rigid pavement with tyre and jute waste0, Woodcrete building material0, low-cost construction material0, Rich-mix with sawdust as fine aggregates0, post cracking behavior of mortar[0], composite bricks0, and block making0.

It may be observed from above discussion that use of demolishing waste as recycled aggregates and using waste wood ash as fractional alternate of cement or fine aggregates has been addressed in literature separately. But the scatter of results least with respect to optimum values is not even established. Also, the combined use of two waste materials is not evident from available state of art. Therefore, this research work proposed laboratory investigations of the combined effect of both wastes on flexural strength of concrete.

Material and Testing

2.1 Recycled aggregates

Waste taken from breaking a house in Nawabshah, Pakistan was collected. Keeping in line with conventional aggregates having size up to 25 mm, these blocks (Figure 1) were hammered to obtain the required size. Obtained aggregates were cleaned from impurities and broken pieces before washing and drying (Figure 2). The aggregates were then sieved to ensure well graded aggregates in concrete mix as per ASTM provisions. The percentage passing of the aggregates on different sieves is listed in Table 1.


Figure 1: Demolished waste


Figure 2: Recycled aggregates

Table 1: Gradation of aggregates

Sieve	Passing (%)		ASTM Range %
	NCA	RCA	
1"	100.00	100.00	90-100
3/4"	68.20	69.40	35-70
1/2"	27.80	33.20	. . .
3/8"	15.60	18.40	. . .
#4	3.12	2.92	0-5
#8	1.32	0.80	. . .
Pan	0.00	0.00	. . .

2.2 Wood waste

Wood waste utilized in this specific work was collected from local wood processing shops (Figure 3). It was sorted for unwanted substances followed by burning in oven at about 1200°C. The burnt material after cooling was grinded to achieve the ash (Figure 4). This ash was sieved using #200 sieve to ensure its fineness in line with cement.

2.3 Conventional ingredients of concrete

The conventional aggregates taken for this study include ordinary Portland cement (Pak Land), coarse and fine aggregates taken from Noori Abad hills and potable water. Both cement and aggregates were taken from nearby market, whereas city water is collected from the city water supply scheme. The pH value measured for the water was noted as 6.7. The value falls in the range of potable water hence is fit for the concrete.

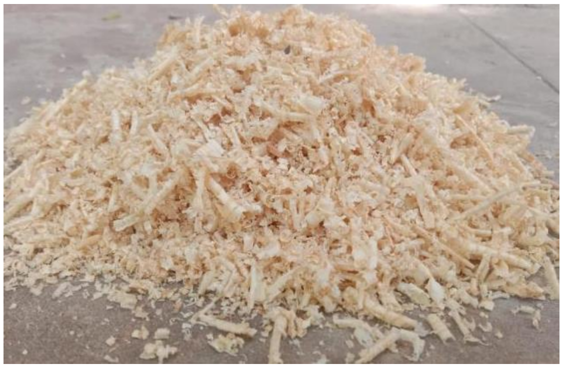
Figure 3: Wood waste

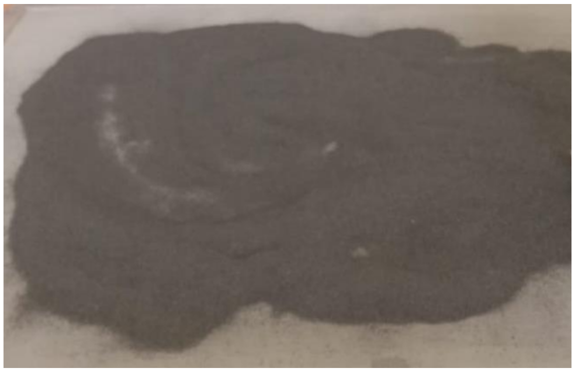
Figure 4: Saw dust ash

2.4 Sample preparation

To evaluate the flexural strength of proposed concrete, prism specimens of 100mm x 100mm x 500mm size were cast. While making the samples, both recycled and normal coarse aggregates were taken in same ratio as told by Oad and Memon[22] based on the compressive strength results. Sawdust ash used instead of cement by weight was used from 1% to 10% in increment of 1% (10 Batches). Additionally, one batch of specimen was prepared with 0% saw dust ash and all conventional aggregates. These specimens helped to check the difference between the new and regular concrete. The details of the specimens are listed in Table

Table 2: Details of specimens

Batch	No. of prisms	% replacement of cement with ash	Cement (kg)	Saw dust ash (grams)	Fine aggregate (kg)	NCA (kg)	RCA (kg)
CC	3	0%	6.00	0	13	21.0	0.0
B1	3	1%	5.94	60	13	10.5	10.5
B2	3	2%	5.88	120	13	10.5	10.5
B3	3	3%	5.82	180	13	10.5	10.5
B4	3	4%	5.76	240	13	10.5	10.5
B5	3	5%	5.70	300	13	10.5	10.5
B6	3	6%	5.64	360	13	10.5	10.5
B7	3	7%	5.58	420	13	10.5	10.5
B8	3	8%	5.52	480	13	10.5	10.5
B9	3	9%	5.46	540	13	10.5	10.5
B10	3	10%	5.40	600	13	10.5	10.5

For preparation of all specimens a 1:2:4 ratio mix was taken and water-cement ratio of 0.5 was kept. The ratio of water to cement was computed using DOE method of mix design. Batching of the ingredients was done by using weight batching. Mixing was done by concrete mixer. For each batch of the concrete, slump test was carried out to see how workable the mix is. Obtained values of slump can be seen in Table 3.

Table 3: Slump values

Batch	Slump (mm)
CC	62
B1	58
B2	55
B3	56
B4	54
B5	51
B6	49
B7	46
B8	39
B9	35
B10	28

Preparation of molds and pouring of concrete was done in standard way (Figure 5). After 24 hours the samples were taken out of the molds followed by putting them fully in clean water to be cured for 28-days (Figure 6).

Figure 5: Specimen castin

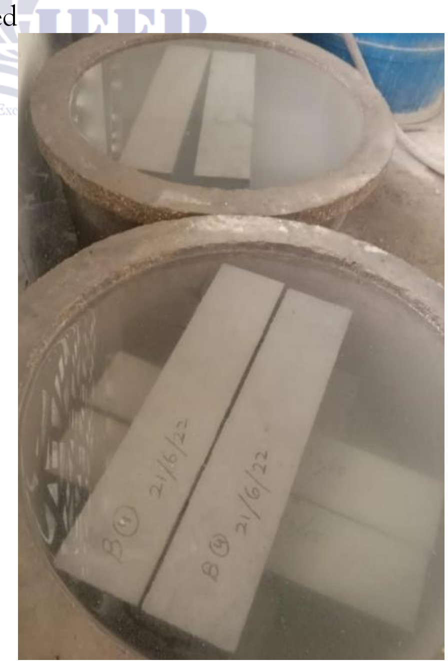

Figure 6:Curing of specimen

2.5 Testing

When curing period was finished, samples were removed from the water and kept in open air to dry for a day at room temperature. All prisms were checked using UTM where load was applied slowly under gradually increasing central point load (Figure 7). Crushing load and failure pattern was recorded. Flexural strength was computed using standard formula for the purpose. point deflection at maximum sustained load was also recorded. The recorded values of flexural strength, deflection, and average of both for all specimens are listed in Table 4.

Figure 7: Testing of specimens

Table 4: Flexural strength and deflection

Batch	Specimen 1		Specimen 2		Specimen 3		Average	
	Flexural Strength	Deflection	Flexural Strength	Deflection	Flexural Strength	Deflection	**Flexural Strength**	**Deflection**
	(MPa)	(mm)	(MPa)	(mm)	(MPa)	(mm)	**(MPa)**	**(mm)**
CC	5.29	2.00	5.57	1.70	4.52	1.28	**5.13**	**1.66**
B1	5.08	1.50	4.80	1.30	3.76	1.75	**4.55**	**1.52**
B2	4.61	1.38	4.55	1.37	4.34	1.60	**4.50**	**1.45**
B3	4.59	1.50	4.18	1.40	4.59	1.20	**4.46**	**1.37**
B4	4.61	1.40	4.49	1.30	4.46	1.35	**4.52**	**1.35**
B5	4.62	1.30	4.69	1.20	4.73	1.50	**4.68**	**1.33**
B6	4.48	1.38	4.51	0.90	4.60	1.20	**4.53**	**1.16**
B7	4.55	1.00	4.41	0.80	4.50	0.60	**4.49**	**0.80**
B8	4.43	0.68	4.40	0.70	4.51	0.78	**4.45**	**0.72**
B9	4.50	0.60	4.59	0.65	4.25	0.63	**4.45**	**0.63**
B10	3.55	0.50	4.32	0.58	3.90	0.62	**3.92**	**0.57**

Results and discussion

The sieve analysis results presented earlier and plotted in Figure 8 for comparison may be observed in good agreement to each other. Also, it is noted that passing percentage of both conventional and recycled aggregates on various sieved confirms with the specified ranges of ASTM standards. It shows proper recycling of the waste and ensures well graded aggregates in the mix design.

For each batch of the proposed concrete with different dosages of saw dust ash, slump test was performed. The reported results are plotted in Figure 9 for comparison. In this figure green bar shows the slump value of conventional concrete, whereas the blue bars show the slump value of all 10 batches of proposed concrete. It may be observed that with increase in dosage of fly ash, the slump of the mix decreases except for batch B3 where slump slightly increased than previous batch. But the different in the result is minimum. The decrease in slump ranged from 6.45% to 54.8%. Hence it is seen that higher doses of the ash B6 – B10 (6% - 10%) drastically decrease the slump from 20% - 58% leading to non-workable concrete unless additional measures; use of plasticizer; are not taken in consideration.

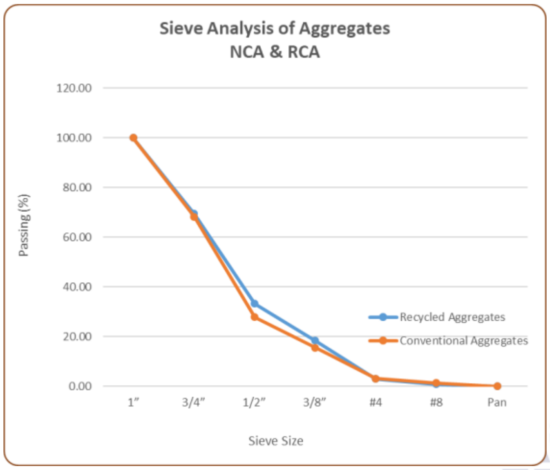

Figure 8: Sieve analysis of NCA and RCA

Figure 9: Slump test

Crushing load of the beams loaded at center was used to compute flexural strength by using standard formula (3PL/2bd²). Obtained results were listed in earlier part and are plotted in Figure 10 for all three samples of each batch. It may be observed that the control concrete had more flexural strength, whereas recycled aggregate concrete with saw dust ash followed the same kind of trend as in case of slump. The results within the batch are same with minor variation. The average strength of concrete in flexure is computed and can be seen in Figure 12. It may be observed that up to 4% of the ash flexural strength is approximately the same. It may be due to same action of the ash during hydration process. It increased with batch B5 (5% dosage), resulting in maximum average flexural strength among used ranges. Beyond 5% up to 9% again strength is observed in same range but decreased more at 10% replacement level. The difference in flexural strength in percent for different saw dust ash amounts compared to normal concrete is shown in Figure 13. It can be seen that minimum loss of power to hold load (about 9%) at 5% dosage of the ash. Hence it is concluded that 5% dosage is the optimum beyond which saw dust ash losses its bonding properties due to which required bonding strength lowers and the strength of concrete decreases.

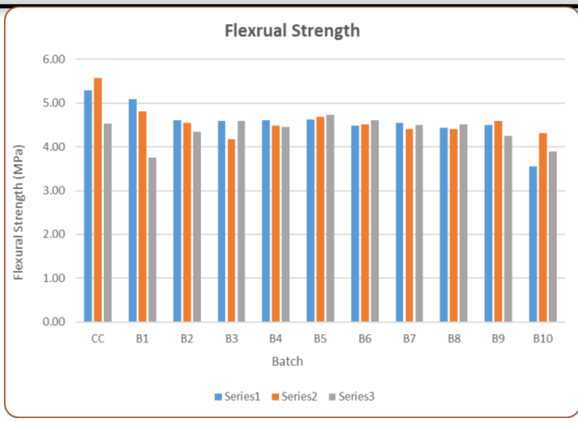

Figure 11: Flexural strength

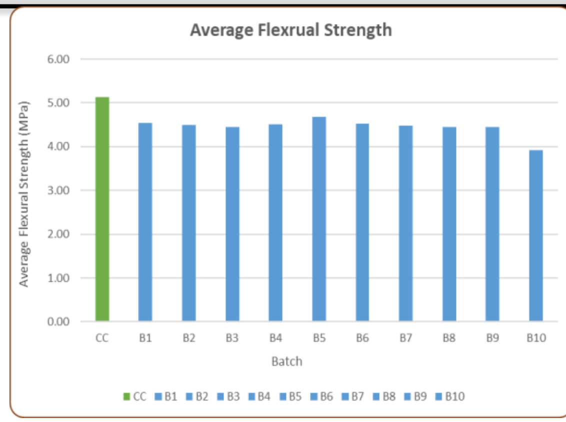

Figure 12: Average flexural strength

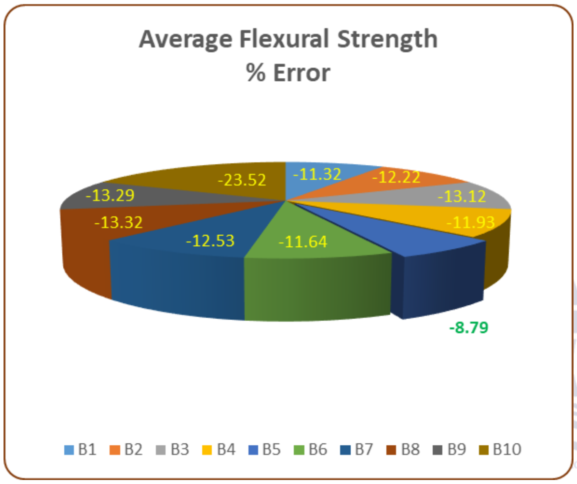

Figure 13: Flexural strength (% change)

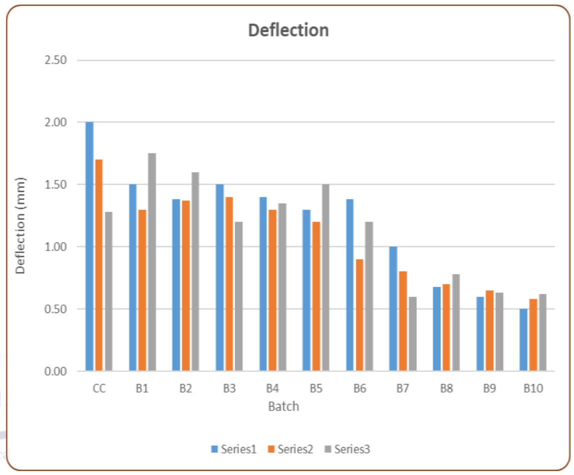

Figure 14: Deflection

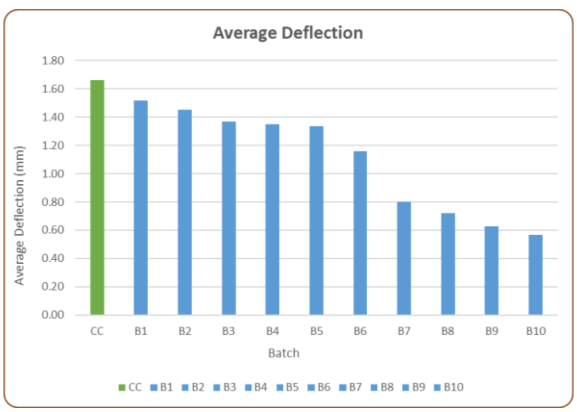

Figure 15: Average deflection

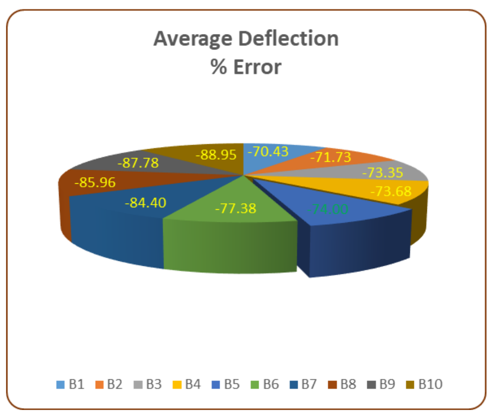

Figure 16: Average deflection (% change)

During testing of the specimens, deflection at maximum sustained load was recorded. The obtained values are plotted in Figure 14 for all specimens. Unlike flexural strength maximum deflection with increase in the dosage of saw dust ash decreased. The average of three samples in each batch of the concrete is computed and shown in Figure 15. The average deflection of conventional concrete beams is recorded equal to 1.66 mm, whereas the average deflection of saw dush ash recycled concrete beam is recorded in the range of 1.52 mm – 0.57 mm. The percentile difference of the deflection of various batches of beams is shown in Figure 16. The decrease in deflection with increase in dosage of saw dust ash shows that the material has capability to increase the stiffness of the concrete resulting in lesser deflection with increase in dosage. Maximum decrease in deflection was recorded at highest replacement percentage used. In all batches the deflection recorded was less compared to allowable deflection by ACI-318.

Although the maximum improvement in deflection value is at 10% replacement level but combining it with flexural strength 5% dosage is considered suitable as at this dosage the residual flexural strength is maximum and decrease in deflection is 74%, which is only 15% less than the deflection at 10% replacement level. Hence it is concluded that the saw dust ash has potential to replace the cement partially. It is helpful in improving the flexural strength in comparison to recycled aggregates when used along in concrete. It has also the capability to improve the deflection resistance of the beams.

Conclusion

Based on the outcome of this research study following are concluded.

Saw dust ash has potential to replace cement partially.

Improved flexural performance of recycled aggregate concrete beams with saw dust ash is observed.

Optimum dosage of saw dust ash is recorded equal to 5% as at this dosage level reduction in flexural strength is about 9%.

Saw dust ash has potential to control deflection in recycled aggregate concrete beams. With increased dosage of saw dust ash improvement in deflection control is observed.

At 5% dosage of saw dust ash, 74% decrease in deflection is recorded.

In all batches deflection recorded was less than allowable deflection by ACI-318.

Conflict of Interest

The authors declare no conflict on any interest at any level of this research work.

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