

Effect of Sawdust as Fine Aggregate in Concrete Mixture for Building Construction

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Abstract

This experimental study aimed to develop an acceptable concrete mixture with sawdust particles as substitute to fine aggregate that can be used for building construction particularly in residential class concrete slab and analyze the effect of sawdust concrete mixture in terms of adhesion of aggregates, thermal insulation, workability and surface quality. This also aims to determine the factors affecting the performance of sawdust concrete mixture in terms of humidity and temperature and design a sawdust concrete mixture as an alternative fine aggregates for residential class concrete slab that will meet the (American Society for Testing and Materials (ASTM) requirements in order to help contribute to the industry in saving the environment, to provide new knowledge to the contractors and developers on how to improve the construction industry methods and services by using sawdust concrete mixture, and sustain good product performance. A conventional concrete product was compared to sawdust concrete mixture with recycled bottles of the same proportion in terms of economic performance. Observations from the tests performed were conducted in the laboratory where precise data were gathered and completely attained.

Keywords: *Building construction, fine aggregate, sand, sawdust concrete mixture*

1. Introduction

The development in the construction industry all over the world is progressing [1]. Many structures are being built, both residential and non-residential. Just like many countries, the demand for new structures in the Philippines is highly increasing [2].

Attempts have also been made by various researchers to reduce the cost of its constituent and hence total construction cost by investigating and ascertaining the usefulness of material which could be classified as local materials. Some of these local materials are agricultural or industrial waste which includes sawdust, concrete debris, fly ash, coconut shells among others which are produced from milling stations, thermal power station, waste treatment plant and so on As a result of the increase in the cost of construction materials, especially cement, crushed stone (coarse aggregate), fine sand (fine aggregate); there is the need to investigate the use of alternate building materials which are locally available [3]. Since most building construction works consist of concrete work; therefore, reduction in cost of concrete production will reduce the cost of building construction.

Globally, there is a resurgence of interest in this era of information revolution and environmental awareness. However, modern applications are being discovered and several are based on wood's unique physical and mechanical properties like strength

and its ease in shaping. In this changing time, sawdust particles might just be one of an infinite number of solutions for low cost housing.

High cost of building material has affected many Filipinos who engage in cutting corners to achieve building production leading to failure in the buildings. It is therefore necessary to use alternative available local material for concrete production. The aim of this study, therefore, is to examine the use of locally available construction materials such as sawdust as substitutes for fine aggregate in concrete.

Concrete is a construction material which consists of the mixture of fine, coarse aggregate, cement which proportionally mixed with certain percentage of water. The importance of concrete as construction material is increasing every day. Surfaces of sawdust concrete hollow bricks have outstanding adhesion which guarantees a successful coating with various paints and varnishes, or other finishing materials.

Sand as a primary fine aggregate possesses superior adhesion of components in concrete. It provides strength by serving as small fillers in a mixture. Cement binds sand particles together forming one solid sand mix.

This study will also explore the possibility of creating wood fiber adhesion which can mimic that of the trees by synthesizing its bond using cement. This will also cite its impact on cost of structures compared when using its reigning counterpart that applies sand as fine aggregate.

In view of the rising costs of construction materials, the study paves the way for the recognition and acceptance of using waste building materials for low cost housing construction. It proposes alternative materials specifically sawdust as fine aggregate substitute. In its entirety, the research addresses the concern of the poor and marginalized sector of society on affordable shelter and recycling waste parts of construction materials.

This study will help in reducing construction waste materials. Thus, aiding the campaign of environmental consideration and promoting the optimum the use of every lumber taken from nature. It will provide additional income for lumber companies while disposing their waste materials. At the same time opening up a new business venture for others to take advantage. It will point out new paths and options to further advance this development and others alike. It also encourages the future researchers in recycling of other waste materials and making them a part of new composite materials and encourages the general public to more environmentally aware, broadening their horizons towards recycling and conservation. Emphasizing gluttony, which the over consumption of one good thing, as a bad thing and should be controlled.

2. Related Literature

Sawdust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or other tool; it is composed of fine particles of wood. It is also the byproduct of certain animals, birds and insects which live in wood, such as the woodpecker and carpenter ant [4]. It can present a hazard in manufacturing industries, especially in terms of its flammability. Sawdust is the main component of particleboard. A major use of sawdust is for particleboard; coarse sawdust may be used for wood pulp.

Sawdust has a variety of other practical uses, including serving as mulch, as an alternative to clay cat litter, or as a fuel. Until the advent of refrigeration, it was often used in icehouses to keep ice frozen during the summer. It has been used in artistic displays, and as scatter [5]. It is also sometimes used to soak up liquid spills, allowing the spill to be easily collected or swept aside. As such, it was formerly common on

barroom floors. It is used to make Cutter's resin. Mixed with water and frozen, it forms pykrete, a slow-melting, much stronger form of ice. Sawdust is used in the manufacture of charcoal briquettes.

At sawmills, unless reprocessed into particleboard, burned in a sawdust burner or used to make heat for other milling operations, sawdust may collect in piles and add harmful leachates into local water systems, creating an environmental hazard. This has placed small sawyers and environmental agencies in a deadlock.

Questions about the science behind the determination of sawdust being an environmental hazard remain for sawmill operators (though this is mainly with finer particles), who compare wood residuals to dead trees in a forest. Technical advisors have reviewed some of the environmental studies, but say most lack standardized methodology or evidence of a direct impact on wildlife. They don't take into account large drainage areas so the amount of material that is getting into the water from the site in relation to the total drainage area is minuscule [6].

Other scientists have a different view, saying the "dilution is the solution to pollution" argument is no longer accepted in environmental science [7]. The decomposition of a tree in a forest is similar to the impact of sawdust, but the difference is of scale. Sawmills may be storing thousands of cubic metres of wood residues in one place, so the issue becomes one of concentration.

But of larger concern are substances such as lignins and fatty acids that protect trees from predators while they are alive, but can leach into water and poison wildlife. Those types of things remain in the tree and, as the tree decays, they slowly are broken down. But when sawyers are processing a large volume of wood and large concentrations of these materials permeate into the runoff, the toxicity they cause is harmful to a broad range of organisms.

Sawdust can be used as alternative substitute for fine aggregate in concrete production [8, 10]. Sawdust should be washed and cleaned before use as concrete constituent because of large amount of bark which can affect setting and hydration of cement. Concrete obtained from sawdust is a mixture of sawdust, gravel with certain percentage of water to entrance the workability and full hydration of the cement which help in bonding of the concrete. Sawdust concrete is light in weight and has satisfactory heat insulation and fire resisting values. Nails can be driven and firmly hold in sawdust concrete compare to other lightweight concrete which nail can also easily drive in but fail to hold [11]

According to [6], the flexural strength increased from 1.43 N/mm² at 7 days to 2.24 N/mm² at 28 days for control slab (i.e. about 57% increment). However, the strength of the 25% replacement by sawdust showed increased in flexural strength from 1.15N/mm² at 7 days to 1.67 N/mm² at 28days (45% increments). Similarly, the 50% replacement of sawdust showed an increase from 0.89 to 1.12N/mm² between 7 and 28 days. According to BS 1881, part 4 (1970), a grade 15 concrete should have acquired a flexural strength of 1.2N/mm² at 28days. In term of compressive strength, the 25% replacement slab gave a value of 15.9N/mm² which is equivalent to grade 15 concrete which a specified value of 15N/mm² for lightweight concrete (BS 8110, 1997) [12].

As the construction community might well be aware of, incorporating organic materials into solid concrete is not such a good idea to begin with. First of all, its loose molecular structure would cause the structure to fail at a certain stage and second, it would compete and retard the hydration process of cement [13].

Certain predictions state that if sawdust is mixed with cement and gravel, it might simulate a synthetic wood fiber bond found in trees. Since trees exhibit great strength

and feats that manmade concrete structures cannot do without steel reinforcements, wood fiber bonding that could be more flexible and intricate in its own way might be adapted by most concrete structures allowing them to be shaped in more complicated forms. Also, presumptions indicate that if each sawdust particle took up enough water during hydration, they could aid the hydration process especially in the center parts of concrete that is impossible to cure with water thus eliminating the need of curing because water deposited in sawdust particles are being harvested by cement particles.

The most important aspect and main target of the experiment are proving that sawdust-cement-gravel mixtures can prove to be more lightweight and cost efficient [4],[14]. Since sawdust is already waste then the cost would go down as well as weight cause of its extremely light unit weight.

3. Methodology

In order to standardize our results, two sets (2) of samples were prepared as shown in Figure 1. One is made of a standard concrete mix and the other of the wood-concrete mix. This is necessary to able to compare the testing results to standard qualifications.

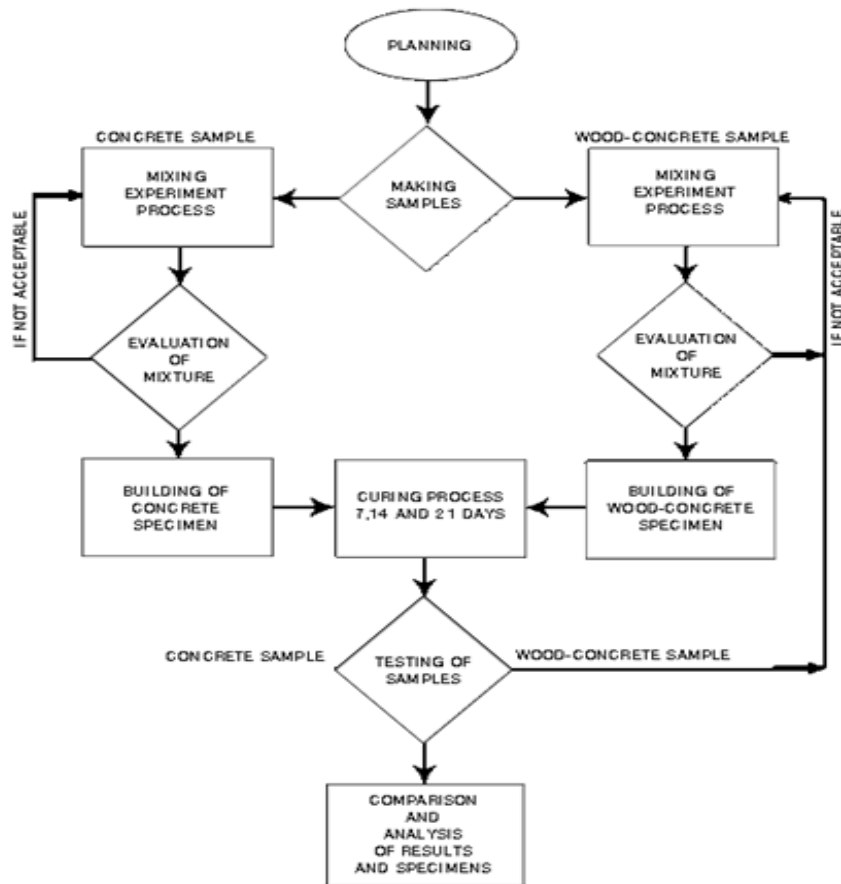


Figure 1. Project design

Each of the sample-making process will include: Optimum mix ratio, and the actual making of the specimens. For wood-concrete mix sample, experimentation was conducted

using different ratios until the proper combination will make it easier to handle and layout in molding containers.

Each specimen was paired according on their predetermined dry times which will range from seven (7), fourteen (14), and twenty-one (21) days. This is for the purpose of finding out the correct curing duration by using the results that will be obtained from a hydraulic press vertical stress test.

The data taken from the testing was utilized for finalization of the study. Comparison was done according to different criteria's namely: strength, texture, and cost of production.

During specimen creation, the uses of six (6) sample molds were properly labeled by sets. Two mixes was made, one of sawdust-cement-gravel and the other of standard concrete. Both mixes have the same proportions of Class A mix or a 1:2:4 ratios of cement, sand or sawdust, and gravel respectively [15]. After mixes were laid and left to dry for a certain number of days, it will be tested under a hydraulic press machine for compressive strength tests. These tests help to show the strength of compressive force that can be withstood by the mixes.

4. Results and Discussion

4.1. Relative plasticity

The ratio of water to cement is termed as water cement ratio and is expressed as the ratio of the weight and volume of water to the weight or volume of cement in the concrete mixture, and generally, expressed as so many liters of water per bag of cement (50kg).

Table 1. Water-cement ratio

Cube No.	Water/cement Ratio	Compression strength (kg/sq.cm)	Water (liter)	Cement (kg)
1	0.8	2.10	0.8	1kg
2	0.5	220	0.5	1kg
3	0.4	320	0.4	1kg
4	0.3	160	0.3	1kg

As shown in Table 1 and Figure 1, findings seen that strength of sawdust concrete decrease as the water cement ratio less than 0.45 curves is dropping down, which shows that the sawdust concrete mix is not workable.

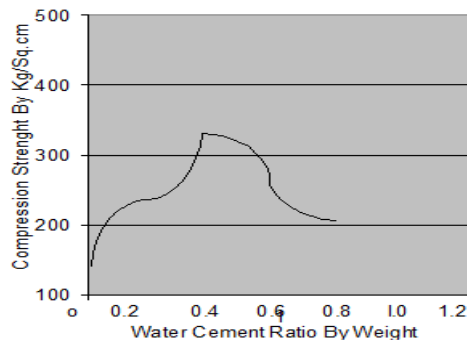


Figure 2. Water cement ratio with respect to strength

Due to less workability honeycomb structure is formed containing much voids if water cement ratio increases with water cement ratio lower than 0.45 (up to minimum of 0.3), Comparing to general concrete work 25 liters of water is required per bag of cement (50 kg) giving which ratio of 0.5

4.2. Weight and volume of the sample

As shown in Table 2, sawdust-cement-gravel mixtures tend to differ for almost 10% in weight making it a potential substitute fine aggregate for sand in terms of floor slab construction. Additional data also shows that standard concrete mixes and sawdust-cement-gravel mixtures can be designed in the same manner.

Table 2. Weight and volume of the sample

Sample	Weight (kg)	Volume (cu.cm.)
Sand-concrete	11.25	57.5
Sawdust-cement	10.5.	57.5

4.3. Sawdust as cost-efficient in labor and materials

Table 3 shows the difference in cost between sawdust and sand. Comparatively, sawdust only cost approximately 254.00php while sand cost around 450php, both are prices of the two materials at same quantities which was 3.5 m³. Already a difference of 686.00php is noticed, proving that sawdust is more cost efficient on its own by almost 56% cost reduction. The following table illustrates various price gaps in incremental amounts.

Table 3. Cost of sawdust and sand

Materials	Quantity	Unit (cu.m)	Unit cost Philippine peso (P)	Total cost Philippine peso (P)
Sand	3.5	cu. meter	450.00	1575
Sawdust	3.5	cu. meter	254.00	889

4.4. Compressive strength comparisons

Strength of concrete structures are often based upon sample testing facilitated by the Quality Control Engineer (QCE) directly on site whenever concrete pouring is scheduled. Simulating concrete testing being done on site, samples are subjected to compressive strength tests using a hydraulic press machine.

Specimens made underwent curing process for a certain number of days and were tested in standard intervals specified by the National Structural Code of the Philippines (NSCP) [11],[16]. Results indicated that sawdust-cement-gravel mix showed high early compressive strength and seem to degrade till it stabilized at around 3000 psi as shown in figure 3. In comparison, the standard mix began low and slowly increased in strength. According to NSCP standards, Class A concrete should attain a compressive strength of 2500 psi to 3000 psi over a period of 28 days. Based on the findings, sawdust-cement-gravel mixes passed the criteria classification standard by maintaining strength above 3000 psi on the 28th day after being laid out.

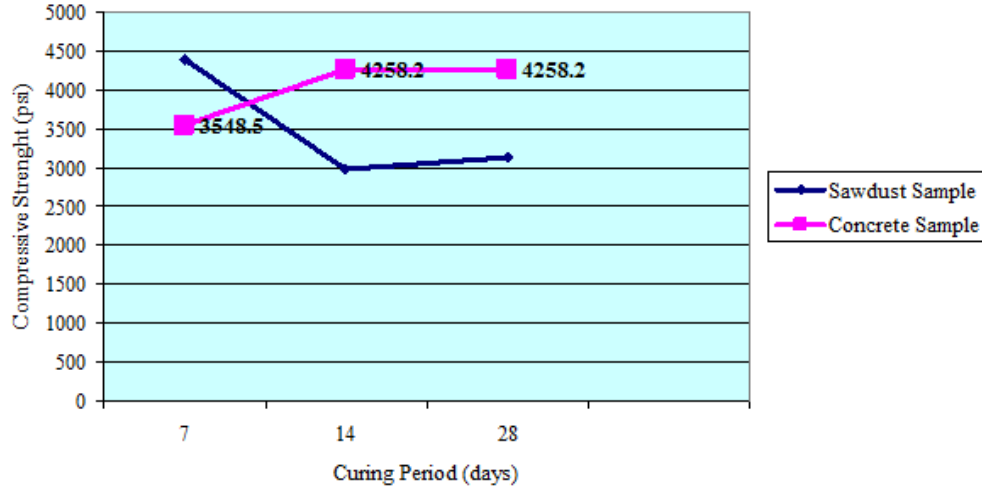


Figure 3. Compressive strength comparisons

After each test, both samples of standard concrete and sawdust-cement-gravel were compared. Physical characteristics were observed and listed including texture, color, and failure types. Texture property difference exhibited unique differences. The experiment describes the sawdust sample resembles building boards but still maintained its concrete rigidity. Color also changed, displaying a light brown color texture that was like recycled paper but isn't. Failure description however presented an unexpected outcome. Instead of breaking apart like normal concrete, sawdust sample tend to stay together much like tree trunks or wooden piles being driven by a pile driver. Closer inspection of the phenomenon revealed that tiny bits of sawdust particles held the said collapsing body intact preventing total failure. This might just prove useful when trying to apply safety precautions in strictures

5. Summary of Findings

This experimental research tries to implicate that sawdust-cement-gravel mix has an equal advantage than the standard mix of cement-sand-gravel. Both mixed in proportions classified as Class A mix with the proportions of 1:2:4 of cement, a fine aggregate, and a coarse aggregate respectively. Two sets of sample with three sample of each were made for a total of 6 specimens to be tested. The first set of three samples consists of the sawdust-cement-gravel mix, the second set of the ordinary concrete mix. Each set were mixed and molded in the same way and with the same volume proportions. After placement in molds, both sets were left to cure for a number of days. The curing samples will then be tested at a given period of days specified under the National Structural Code of the Philippines or NSCP (7, 14, and 28 days). The seven day specimen was not cured, the fourteen day specimen was soaked, and the twenty-eight day specimen was washed with a little bit of water every morning. The results of each period presented many peculiar findings.

During curing process, a decision was made to do different curing procedures. The seven day specimen, which was not cured at all, showed a high early strength yield. The fourteen day specimen, soaked in water, was lower by 100 kg/cm^3 or 1419.4 psi . The last sample cured every morning with water, stabled at about 220 kg/cm^3 or 3122.68 psi . Results indicated that the average strength of the sawdust-cement-gravel mix was

about 3000 psi which, according to NSCP standards is between 2500 psi – 3000 psi. This is still in accordance with minimum safety standards.

Further analysis determines that during the hydration process of concrete, the water taken in by the sawdust particles during mixing help hydrate cement particles in places where it is impossible to cure, mainly the center. Since found that the hydration of the center of structural components like columns take most of the time in construction, sawdust particles might help lessen curing time in half and could also eliminate the need to using chemicals to cure. Henceforth, proves that sawdust can be used in concrete mixes for residential floor slabs. With regards to the weight of the two sets of samples, an equally small amount of each was made and weighed. The results were dramatic since the sawdust-cement-gravel mixture was almost half of the standard mix's weight then again proving its lightweight property. Another observation was that every sample tested to its failing point showed wood fiber bonding at work. Faces of the sample that were supposed to fall off once cracked didn't, instead were being held together by strands of sawdust. To make it short, rather than splitting apart like usual, it just bulked up making it a remarkable feat for a manmade object that rigid. This could prove helpful during structural collapses since concrete tend to fall right off in an event of a major crack occurring.

6. Conclusions

Analysis showed a difference in each specimen tested. Since the curing of specimens were altered in a way to be able to explore other aspects of the research. The curing processes were as follows: seven day specimen received no curing, fourteen day specimen was soaked in water, and the twenty-eight day specimen was splashed with water every morning. Of all the three specimens the sample that showed the highest early compressive strength was the seven day specimen which was not even cured. Initial conclusions described the curing process of the seven day specimen as if the sawdust particles within the concrete that pre-absorbed water during mixing helped hydrate the center part causing it to reach early high compressive strength at such early time period. Unit weights also varied since after weighing two control samples, the sawdust-cement-gravel mix showed an almost 10% reduction of weight and since floor slabs composed almost 40% of a structure's weight, it can help in reducing the weight of succeeding floors thus eliminating the need to design extremely thick columns on previous floors. With regards to costs, the price of sawdust per sack in comparison with sand was also lesser than usual since sawdust already is waste. Another observation made is during failure of specimens due to compressive flexural stresses. Specimens that were made using a standard concrete mix immediately cracked if not fell apart once their yield limits were reached. In contrast, the sawdust-cement-gravel specimens were being held together by tiny wood particles. This might present a bonus feature with regards to sawdust; it might help keep components in place during collapses giving people more time to escape. With regards to workability, consistency, and surface texture, integrating sawdust to the mix has increased workability because it becomes softer and compressed when wet, although might a bit toughened the consistency making it a bit harder to flatten since bits of sawdust tend to protrude out during smoothing. When it comes to surface texture, sawdust produces a light brown surface color that slightly resembles recycled paper. You can say that sawdust adds to the ambience of the room by giving the illusion of old wallpaper.

In addition to the conclusions based upon experimentation, some conclusions pre-released by previous researches were added in consideration. Its acoustic insulation and

buffering property can reduce sound penetration by 14 dB. If applied to floor panels, sound resonance and floor vibrations can be reduced for the occupants below the floor with sawdust-cement-gravel flooring, soundproofing using natural buffering so to speak. Its thermal disposition can retain heat or cold longer than its standard concrete counterpart. Air circulation and climate control device usage can be lowered as well as electric bills since floor panels have a higher absorption to changing temperatures. Of course, in any project, cost is always an issue. The more you reduce the cost, the more enticing the project is to occupants. With 1 sack of sawdust amounting only to roughly 6.00 php, it can be quite a sufficient cost reducing aggregate substitute.

The only downside to using sawdust as fine aggregate in concrete mixes is its weakness which is water. Experimentation and data analysis shows that the higher the saturation of water deposits in the sawdust particles during curing tend to weaken the sample, making it softer than it was designed for, thus explaining why the soaked and splashed sample appeared weak. It was because of over exposure to solvents, suggesting that sawdust-cement-gravel mixes should only be used on interior parts of the structure where natural elements cannot reach it. Although it can take in water in bursts, soaking it would be extremely unadvisable.

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