Sugarcane Bagasse as a Partial Replacement of Fine Aggregates in Concrete

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Abstract

This study was carried out partial replacement of aggregates in concrete by sugarcane bagasse in order to reduce the industrial waste by saving the aggregates that is more environmental friendly. The waste utilization can helps to reduce the pollution in the world. Due to the increase in consumption of sugarcane, the sugarcane bagasse waste was increase and the waste is disposed in the landfills and now becoming the environmental problem. Many agricultural waste materials are used as replacement alternative for cement, fine aggregate and coarse aggregate. Sugarcane bagasse is one of the wastes that can use in the construction. Aluminium ion and silica are the element that contain in the sugarcane bagasse that suitable to partially replace of aggregates in the concrete. By using this waste, it can control the adverse effect of pollution because of disposal waste. In addition, it also can reduce the economic cost of construction because use of the waste material from the sugar industry. The concrete more strength because, the silica that present in the bagasse react with the component of cement during the hydration and impart additional properties such as corrosion resistance and chloride resistance. In this study, the sugarcane bagasse has been partially replaced in the ratio of 5% and 8% by volume of fine aggregates in concrete. The concrete was taken a test such as compression test and water absorptivity test. The concrete was moulding in the size of 100mm cube size. The concrete was curing for 7, 14 and 28 days in the open area.

Keywords: Sugarcane Bagasse, concrete, workability, compressive strength

1. Introduction

Sugarcane or the other name is *Saccharum Officinarum* is one of the major crops grown all over the world which is over 110 countries and the total production of the sugarcane is about 150 million tons (Modani & Vyawahare, 2013). Malaysian also one of the country that produce sugarcane. The quantity production of sugarcane in Malaysia is about 1 million per tons and the area harvested is about 12,000 hectare. About 32% of sugarcane bagasse is generates as a solid waste from the sugarcane (Abu Talib, Yasufuku, & Ishikura, 2015). The serious problem was occurring when to dispose of solid waste generated from industrial production activity. The collection of solid wastes is not only a burden to the industry, but also affects the environment adversely (Srivastava, 2015). As increased the production of sugar, the quantity of the sugarcane bagasse also increased and the disposal will be a problem.

Bagasse also has many functions such as production of wood, animal food, compost and thermal insulation (Sayali, N Shubhangi, Y Anjali, S Rutuja, & Rahanea, 2017). Fibrous texture of bagasse is suitable for making paper and about 0.3 tons of paper can be made from one ton of bagasse (Amin, 2011). In Pakistan, bagasse is mainly used as an energy source and estimated that 14 million tons bagasse was used annually (Amin, 2011). In addition, because of the bagasse is rich in cellulose, the bagasse also was being carried out for its potential for commercial quantities of cellulosic ethanol. Xanita board or bagasse board also comes from the bagasse because it is considered a good addition for plywood that can be used for making boards. Despite variety usage of bagasse, statistic show that about one million tons extra of sugarcane bagasse remain in the country (Sayali et al., 2017).

Sugarcane bagasse can undergo pretreatment process under mild condition in the present of water (solvolysis) or aqueous orthophosphoric acid (phosphorolysis) was used in order to increase the nutritional value of sugarcane bagasse for cattle feeding. For the best pretreatment condition were achieved without using high energy consumption and production of inhibitory. The sugarcane bagasse was heated up to 197 around 13.5 atm at a 4 : 1 water ratio was shown to achieve the condition for solvolysis as the high temperature need more energy consumption without ding to much to the already high 60% ruminal degradability of the residue in relation to its dry weight. To further the enhanced almost 70% rates of degradability by adding 2.9% orthophosphoric acid as an acid catalyst.

In some parts of the world, sugarcane bagasse has recently been tested for its use as an aggregates replacement material in concrete (Modani & Vyawahare, 2013). Sugarcane bagasse contains approximately 50% of cellulose, 25% of hemicellulose and 25% of lignin (Srinivasan & Sathiya, 2010). The sugarcane bagasse also contains high amount of un-burnt matter, aluminium, silicon and calcium oxides (Sayali et al., 2017). To improve some of the properties of the concrete including compressive strength and water absorptivity in certain replacement percentages and fineness, the sugar cane bagasse was found to improve some criteria of the concrete. It was suggested that the high content of silica in the bagasse can make the concrete more strength and it can be the main cause of these improvements (Patel & Raijiwala, 2015).

The concrete is produced from the mixture of cement, water and aggregates. The aggregates is comes from the natural sand and it was categorize as two different types, coarse and fine (Sekhar Reddy, 2015). Aggregates are commonly used to strength the concrete because it accounts 70% to 85% of the weight and 60% to 80% of the volume of the concrete. Aggregates also consider as inert filler and were be the components that needed to defines the concrete's elastic and thermal properties and dimensional stability. The size of the coarse aggregate is usually greater than 4.75 mm and it be retained on a no.4 sieve, while the fine aggregate is less than 4.75 mm and it passing the number four of sieve (Amin, 2011). The important characteristic in the selection of aggregate is the compressive of the aggregates strength. Based on the experimental, most concrete aggregates are few times stronger than the other components in concrete. In addition, may be lightweight aggregate concrete more significant by the compressive strength of the aggregates.

The first concrete that have been built by Nabataea Traders in the regions of southern Syria and Northern Jordon around 6500 BC (Nick Gromicko and Kenton Shepard,2006). Properties of the concrete the cement is invented in Britain on 1824. The cement has been named as Portland cement because the cement look like the stone quarried on the isle of Portland. The first usage of the Portland cement is in Civil Engineering project by Isambard Kingdom Brunel (1806-1859), as the lining of the Thames Tunnel. By mixing the ground limestone, clay or shale, sand and iron ore the Portland cement is produced. The mixture is heated to 1600°C in rotary kiln (America Cement Manufacture, 1916). The advantages of the concrete are the concrete has high compressive strength compared to other building materials. Concrete also can withstand good amount of tensile stress. The maintenance for the concrete is low because of the condition the concrete that can withstand any weather.

The environmental impact of concrete, its manufacture and applications, is complex. Some effects are harmful; others can bring beneficial to development of buildings. A major component of concrete is cement and aggregates which has its environmental and social impacts and contributes largely to those of concrete. A few experimental have been conduct by replacing partially the cement in the concrete to study pozzolanic activity and their suitability as holder (Srinivasan & Sathiya, 2010). The study was proven that the partially replacement of cement in the concrete can make the concrete more strength and it also can save the environmental because it can reduce the waste materials.

In the last decades, sources of natural sand is decrease as a result of ecological and environmental limitation and study was carried to research the use of sugarcane bagasse as a partial replacement of fine aggregate in concrete(Modani & Vyawahare, 2013). The experimental study the effect of replacement partially aggregates by bagasse on properties like 7 and 28 days compressive strength and sorptivity at 28 days coefficient with 5%, 10% and 15% replacement of fine aggregates with bagasse by weight.

2. Methodology

2.1 Preparation of sugarcane fine bagasse

Sugarcane bagasse was collected from the sugarcane juice stall. Then sugarcane bagasse need to be wash and clean. This process was carried out to make sure that the bagasse free from any contaminant such as sand, dust and etc. The next step was drying the bagasse in oven at temperature 150°C for 3 hours. This drying process was to make sure that the bagasse was dry and not contain any water. Then the bagasse was grind to get the fine sugarcane bagasse. The type of machine used to grind the bagasse is by using grinder with rotating metal blade at the bottom and connect with an electric.

2.2 Material

2.2.1 Fine aggregates

Fine aggregate is easy to find, debris free and nearly riverbed sand is use as fine. The sand particles also pack to provide minimum void ratio, high void content that need for mixing more water. The specific gravity of the sand is 2.680. Fine aggregate is that passing from 4.750 mm to 150 micron and the density of fine aggregate is 1393.17 kg/m^3 (Prusty et al., 2016). Quantity for the fine aggregate was used in this experiment is 6.38kg per 10 sample.

2.2.2 Coarse aggregate

For the coarse aggregates. It have been catogerize in two size which is 10 mm and 20mm. The 10 mm minimun size of aggregates also was used. The specific gravity of coarse aggregate is 2.830, the density of coarse aggregate is 1692.32 kg/m3(Prusty et al., 2016). For this experiment, the quantity of 10 mm aggregates that was used is 14.22kg. This quantity was used for 10 sample.

2.2.3 Sugarcane bagasse

Sugarcane industry produce huge amount of sugarcane bagasse which is contain high amount of cellulose and hemicellulose. The bagasse contain 45 – 50% moisture content and has a mixture of hard fiber(Srinivasan & Sathiya, 2010). Chemical composition of sugarcane bagasse is 50% cellulose, 25% hemicellulose and 25% lignin(Kadir & Maasom, 2013).

Table 1: Chemical composition of Sugarcane Bagasse (Srinivasan & Sathiya, 2010)

Sr. No	Description of properties	Percentage (%)
1	Silica	65.43
2	Magnesium	0.753
3	Calcium	10.6
4	Iron	4.58
5	Sodium	1.07
6	Potassium	3.56
7	Alumina	11.47

2.2.4 Cement

Rapid hardening cement is very similar to ordinary portland cement (OPC). It contains higher compounds tricalcium silicate (C_3S) content and finer grinding(Sekhar Reddy, 2015). Therefore it gives greater strength development at an early stage than OPC. The strength of this cement at the age of 3 days is almost same as the 7 days strength of OPC with the same water-cement ratio. The main advantage of using rapid hardening cement is that the formwork can be removed earlier and reused in other areas which save the cost of formwork. This cement can be used in prefabricated concrete construction, road works and others.

Table 2: Physical properties of ordinary portland cement (OPC) are (Modani & Vyawahare, 2013) :

Physical Properties
Fineness
Soundness
Consistency
Setting time
Compressive strength
Heat of hydration
Loss on ignition
Specific gravity (relative density)

2.3 Experimental work

The experimental was carried out total of 10 sample of concrete specimens. In this study the proportions for concrete mix design of M30 were carried out according to British Standard BS: 12:1996(Amin, 2011).in formation of concrete, the concrete was done according to the percent of sugarcane bagasse which is 5% and 8% replacement by weight were estimated. By using the titling mixer machine, the ingredients of the concrete such as cement, coarse and fine aggregates and water were mixed together until achieved the uniform thoroughly consistency.

2.4 Performance of concrete

The concrete was analyzed at 7, 14 and 28 days, for compression test and water absorptivity strength. In 100 mm of the cube specimens, the compressive strength test was carried out. The strength test was conducted using a compression testing machine and compress meter. The test was conduct according to the British Standard. The next test that be conducted is water absorptivity strength to carried out the strength of concrete sample (Prusty et al., 2016). The sample was put into the water for 24 hours before make the compression test. All of the sample was test at the 7 days and 28 days.

3. Result and Discussion

The compression and water absorptivity strength test was carried out according to the British Standard BS: 12:1996. The 100mm size cubes of concrete mixtures were cast to test compressive strength and water absorptivity strength. The cube samples after de-moulding were stored in open area. The sample was stored for 7 and 28 days. In the first experiment, the chemical was used which is super plasticizer TecMult 400 in the dark brown colour and have the pH 7.5. This chemical is water reducer for the concrete. Although the experiment was conduct by using the chemical, the concrete also not achieve the target strength because of a few factors.

3.1 Compression test

Based on the Table 3.1 and 3.2, the result show the compression test for 7 days of 5% bagasse used is 7.5 N/mm^2 and 8% bagasse used is below 4.0 N/mm^2. For the 28 days of concrete is 5% of bagasse used is 7.6 N/mm^2 and 8% of bagasse used is below 4.0 N/mm^2. For the ideal concrete the strength is 20 N/mm^2 for 7 days and 30 N/mm^2 for

28 days. Based on the result, the experiment does not achieve the ideal strength. This is because the experiment was conduct by using the sugarcane bagasse instead of sugarcane bagasse ash.

The characteristic of the sugarcane bagasse, it contain 45%-55% of cellulose that content of cotton fibre about 90%, wood about 40%-50% and dried hemp approximately 57%. The fibres of the bagasse absorb more water and this makes the water ratio for the concrete was absorb totally by the bagasse. The moisture content of the bagasse is 45%-50% and parenchymatous (pitch) tissue with high hygroscopic property which is attracting and holding the water molecules. This phenomena make the concrete less in water because the bagasse has absorb the water and makes the concrete dry and not enough water to mix well. The bagasse fibre also makes the concrete not strong to hold each other and the mixture of the concrete easy to rupture. The size of the bagasse also was bigger than the ash makes the concrete less bonding among the mixture of the concrete.

To make the concrete more strong the bagasse should have size about 10 micron meters. Smaller size can make the mixture among the substances of the concrete mix well and no pores will produce in the concrete. The molecules of the particles also will make a bonding to each other and will lead to the strong of the concrete. According to (Srivastava, 2015), the result shows that by using the sugarcane bagasse ash the compressive strength of 5% bagasse ash used is 15.84 N/mm^2 for 7 days and for 28 days is 30.12 N/mm^2. For the 28 days, the compressive strength is 30.12 N/mm^2 for the 5% of bagasse used (Srivastava, 2015). According to the ideal strength, **this experiment was achieved the target**. This is because the properties of the bagasse ash that has a few characteristics which is the relative fineness and the Pozzolonic activity of sugarcane bagasse ash and also the crystalline silica (SiO2) that exist in the ash (Sayali, N Shubangi, Y Anjali, S Rutuja, & Rahanea, 2017). In addition, the size of the sugarcane bagasse ash also was small and suitable to substitute partially in the concrete.

Table 3.1: Compression test for 7 days

Percentage of bagasse use	Com ression (kN)	Compressive strength N/mm^2)
5%	75	7.5
8%	Below 40	Below 4.0

Table 3.2: Com ression test for 28 days

Percentage of bagasse use	Com ression (kN	Com ressive strength N/mm^2)
5%	76	7.6
8%	Below 40	Below 4.0

3.2 Water absorption test

For this water absorptivity test, the concrete was put in the water about 24 hours and after that the concrete was tested in the compression test machine.

Based on the Table 3.3 and 3.4, the result show the absorptivity test for 7 days of 5% bagasse use is 4.0 N/mm^2 while for the 8% bagasse use is 0 N/mm^2. In the 7 days the concrete was store, the strength for the water absorptivity was not show the reading for the 8% of bagasse used. For the 28 days of concrete of 5% bagasse used is 6.4 N/mm^2 while for the 8% of bagasse used is below 4.0 N/mm^2. The experiment does not achieve the British standard due to the sugarcane properties itself. The sugarcane bagasse contains cellulose and hemicellulose. The cellulose itself has covered more than 50% in the sugarcane bagasse content. The cellulose has the ability to absorb water easily. It shows that the bagasse was absorbing more water than the concrete. The water ratio of the concrete was totally absorbed by the bagasse. While in the experiment, the sample was put into the water and a lot of bubble was produce from the concrete. It shows that, the concrete has more pores in the body surface. The more pores of the concrete will make the molecules of the concrete are not bond together and it will make the structure of the concrete easy to rupture and broke. Increase in the volume of water in the concrete also makes the concrete less flexible and fragile when the load was applied