ANALYSIS OF THE IMPACT OF SUGAR CANE ASH WASTE AS A REPLACEMENT FOR FINE AGGREGATE IN MORTAR MIXTURE

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Abstract

One of the challenges faced by concrete technology experts is how to use industrial waste as an additive or partial substitute for mortar. In this case, experts study and research the use of existing industrial waste so that it can be utilized, especially the sugar factory industry's bagasse ash waste material. This is one of the many solutions for handling waste in the community. Bagasse is waste produced from the sugar cane milling process after the juice is extracted. In the sugar cane milling process, there are 5 grinding processes from the sugar cane stalks until they become bagasse. The compressive strength value of normal mortar without bagasse ash waste is 1.28 kg/cm². The compressive strength value of mortar with bagasse ash waste 10% of the weight of sand is 1.57 kg/cm² which is the optimum mixture content in this mixture. The compressive strength value of mortar with 15% of bagasse ash waste from the weight of sand has a compressive strength of 0.90 kg/cm². The compressive strength value of mortar with 20% bagasse ash waste of the weight of sand has a compressive strength of 1.61 kg/cm². Mortar mixed with bagasse ash 10% of the weight of sand will increase from normal mortar. Meanwhile, mortar mixed with 15% or 20% bagasse ash tends to decrease compared to mortar mixed with 10% bagasse ash.

Keywords : mortar, bagasse ash, sugarcane, mortar compressive strength

1. INTRODUCTION

Mortar is a mixture of adhesive (Portland cement), fine aggregate (sand) and water with a certain composition. Mortar as an adhesive for structural construction is used for crushed stone masonry on foundations. Mortar for nonstructural construction is used in masonry for wall filling. The compressive strength of mortar is influenced by several factors, namely density, age of mortar, type of cement, and aggregate properties (SNI 03-6825-2002). One of the challenges faced by concrete technology experts is how to use industrial waste as an additive or partial substitute for mortar. In this case, experts study and research the use of existing industrial waste so that it can be utilized, especially the sugar factory industry's bagasse ash waste material. This is one of the many solutions for handling waste in the community. To answer this challenge scientifically and at the same time help society in dealing with this problem appropriately, we as researchers will analyze and develop this technology so that it can be useful for the wider community, especially among mortar users for building structures and industries that produce waste, specifically sugarcane bagasse ash waste. resulting from sugar production.

Cement is an adhesive material that is smooth in shape. If water is added, a hydration reaction will occur and can bind solid materials into one solid mass. The largest percentage of cement content is CaO (calcium oxide) in the range of 60% -65%, SiO2 (silica) in the range of 20% -24% and Al2O3 (aluminum oxide) in the range of 4% -8% (Marzuki, 2009). Bagasse is waste produced from the sugar cane milling process after the juice is extracted. In the sugar cane milling process, there are 5 grinding processes from the sugar cane stalks until they become bagasse. After the final grinding it produces dry bagasse. The abundant bagasse has been used as fuel for steam boilers (a machine that produces steam in a certain amount every hour at a certain pressure and temperature) where the energy produced is used as a steam power plant (Prasetyo A., 2009)

Based on the description above, it is necessary to carry out research regarding the use of bagasse ash waste (bagasse) as a substitute for sand which is lightweight, does not seep water and does not break easily and meets the requirements of SNI (Indonesian National Standards) and General Requirements for Building Materials in Indonesia. (PUBLIC). The most important thing is to create environmentally friendly building materials. Therefore, this research is entitled " Analysis of the Impact of Sugar Cane Ash Waste as a Replacement for Fine Aggregate in Mortar Mixture".

2. LITERATURE REVIEW

2.1. Mortar

Mortar is a mixture of cement, sand and water which have different percentages. The ratio of cement, sand and water needed for 3 mortars that meet the requirements according to SNI 03-6825-2002 is 250 gr : 687.5 gr : 121 ml. As a binding agent, mortar must have a standard concentration/viscosity. This mortar concentration will later be useful in determining the strength of the mortar used as a plaster or wall plaster so that it is hoped that the mortar will withstand the compressive force due to the load acting on it will not be destroyed (Concrete Technology, 2008). Mortar and concrete are made from cement and aggregate mixed with water. What you need to know about building materials is their density, porosity and compressive strength. In relation to heat, the properties of mortar also need to be known, for example a wall made of concrete has a different conductivity to building materials, which is closely related to the use of building materials.

2.2. Mortar Spesification

Based on SNI 03-6882-2002, the proportion of mortar is specified in 4 types according to the strength of the mortar and the specifications for the proportion of materials consisting of cement, aggregate and water used. There are several types of mortar as follows:

- Type M mortar is a mortar that has a strength of 17.2 MPa according to Table 2.1, which is made using type N cement or lime cement by adding portland cement and quenched lime with the composition according to Table 2.1.
- Type N mortar is a mortar that has a strength of 5.2 MPa according to Table 2.1, which is made using type N mortar or lime cement by adding portland cement and quenched lime with the composition according to Table 2.1.
- Type O mortar is a mortar that has a strength of 2.4 MPa according to Table 2.1, which is made using type N mortar or lime cement by adding portland cement and quenched lime with the composition according to Table 2.1.

Table 2.1. Mortar Properties Specification Requirements

Mortar	Type	Average of Strength 28 days Min (Mpa)	Water Ratio Min (%)	Air Measurement Max (%)	Aggregates Ratio (Measurement)
Cement Setting	M	17.2	75	……….. b)	2.25 through 3.5 times of sigma cement characteristic volume
	S	12.4	75	……….. b)	
	N	5.2	75	……….. b)	
	O	2.4	75	……….. b)	

(source: SNI 03-6882)

Specifications for mortar properties must meet the requirements for materials and testing of mortar that has been prepared in the laboratory, where the material consists of a mixture of cement, aggregate and water binders that meet the requirements for mortar according to the test method issued by SNI 03-6882-2002 .

2.3. Cement

Cement is an industrial product from a mixture of raw materials: limestone/limestone as the main material, namely a natural material containing calcium oxide (CaO) compounds and clay/clay, namely a natural material containing compounds: silica oxide (SiO), aluminum oxide (AL2O3), iron oxide (Fe2O3) and magnesium oxide (MgO) or other substitute materials with the final result being a powdered solid (bulk), regardless of the manufacturing process, which hardens or petrifies when mixed with water. The cement factor greatly influences the characteristics of the mortar mixture. A high hydraulic cement content will provide many benefits, including making the mortar mixture stronger, denser, more water resistant, hardens faster and also provides better adhesion. The disadvantage is that the mixture hardens quickly, which can cause higher drying shrinkage. Mortar with a low hydraulic content will be weaker and easier to move. The chemical composition with characteristics contained in cement according to ASTM C 150 can be seen in table 2.2.

Table 2.2. Chemical Composition and Characteristics of Several Types of Cement

Cement	C_3S	C_2S	C_3A	C_4AF	CSH_2	Fineness (m^2/kg)	Compressive strength (1 hr, Mpa)	Heat of hydration (7 hr, J/kg)
Type I	50	25	12	8	5	350	7 (1000)	330
Type II	45	30	7	12	5	350	6 (900)	250
Type III	60	15	10	8	5	450	14 (2000)	500
Type IV	25	50	5	12	4	300	3 (450)	210
Type V	40	40	4	10	4	350	6 (900)	250

(source: ASTM C 150)

2.4. Agregate

In concrete structures, aggregates usually occupy approximately 70 to 75% of the volume of the hardened mass. The remainder consists of cement mortar that has hardened, water that has not yet reacted (that is, water that is not involved in the hydration process of the cement) and air voids. Unreacted water and air voids actually do not contribute to the strength of the concrete. In general, the denser the aggregates are arranged, the stronger the concrete produced, its resistance to weather and the economic value of the concrete. Aggregates must be strong, durable and clean. If there is dust and other particles, the dust and particles will reduce the bond between the cement paste and the aggregate. Aggregate strength has an important influence on the strength of concrete and the properties of aggregate greatly influence the durability of concrete.

Sand is a natural aggregate that comes from volcanic eruptions, rivers, soil and beaches, therefore sand can be classified into three types, namely excavated sand, sea sand and river sand. According to (SK SNI – S – 04 – 1989 – F: 28) the requirements for good fine aggregate are as follows:

- Fine aggregate must consist of sharp and hard grains with a hardness index < 2.2.
- Permanent properties when tested with a saturated, such as sodium sulfate, a maximum of 12% disintegration. Meanwhile, if magnesium sulfate is used, the fine part is a maximum of 10%.
- It must not contain more than 5% mud and if the sand contains more than 5% mud then the sand must be washed.
- The sand should not contain too much organic material, which must be proven by a color experiment from Abrans–Harder with a saturated 3% NaOH solution.
- The large composition of sand grains has a fineness modulus between 1.5 and 3.8 and consists of various grains.
- For concrete with a high level of durability, the reaction of sand to alkali must be negative.
- Sea sand may not be used as a fine aggregate for any grade of concrete unless directed by an approved building materials government agency.
- Fine aggregates used for plastering and applied species must meet masonry sand requirements.

Table 2.3. Sand Gradation Boundary Requirements

Sieve Hole (mm)	Cumulative Breakthrough Weight (%)							
	Zone 1		Zone 2		Zone 3		Zone 4	
	Bottom	Upper	Bottom	Upper	Bottom	Upper	Bottom	Upper
10	100	100	100	100	100	100	100	100
4.8	90	100	90	100	90	100	95	100
2.4	60	95	75	100	85	100	95	100

1.2	30	70	55	100	75	100	90	100
0.6	15	34	35	59	60	79	80	100
0.3	5	20	8	30	12	40	15	50
0.15	0	10	0	10	0	10	0	15

(source: SNI-03-2834-2000)

Information:
Zone 1 is coarse sand, Zone 2 is rather coarse sand, Zone 3 is fine sand and Zone 4 is rather fine sand.

2.5. Water

Water is needed in making mortar to trigger the chemical process of cement, wet the aggregate and make mortar work easier. Drinkable water can generally be used as a mortar mixture. Water containing dangerous compounds, contaminated with salt, oil, sugar or other chemicals, when used in mortar mixtures will reduce the quality of the mortar, and can even change the properties of the resulting mortar.

Table 2.4. Water Limits and Permits for Mortar Mixtures (SNI 03-6825-2002)

	Permissible limits
Ph	4,5 – 8,5
Solid material	2000 ppm
Dissolved material	2000 ppm
Organic Material	2000 ppm
Oils	2% berat semen
Sulfur (SO_3)	10000 ppm
Chlor (C1)	10000 ppm

2.6. Sugarcane Bagasse

Bagasse is a residue from the process of milling sugar cane plants (Saccharum officinarum) after the juice is extracted or removed in the sugar refining industry so that a large amount of fibrous waste product is obtained as a by-product known as bagasse. The chemical composition of bagasse ash consists of several compounds which can be seen in the following table.

Table 2.5. Chemical Composition of Sugarcane Bagasse Ash

Chemical compounds	**Percentage(%)**
SiO_2	70,63
Fe_2O_3	3,96
Al_2O_3	3,48
K_2O	1,75
TiO_2	1,55
P_2O_5	0,927
CaO	0,728
MgO	0,706
SO_3	0,235
CL	0,134

ZrO_2	0,0906
MnO	0,0627
Cr_2O_3	0,0424
Na_2O	0,0308
V_2O_5	0,0141
ZnO	0,0051
CuO	0,0028
NiO	0,0027

2.7. Mortar Mix Planning

All materials for test objects are tested for characteristics in accordance with applicable standards. According to SNI 03-6825-2002 for 3 pieces of mortar it is 250 gr : 687.5 gr : 121 ml. The cement water factor (w/c) is 0.485 for all types of Portland cement with a flow of 110 ± 5. Mortar mixtures are guided by Standard ASTM C109-93.

2.8. Mortar Compressive Strength

Compressive strength is a very important factor in testing the results of a mixture of mortar materials as a component for making building materials. Compressive strength is the amount of load that mortar can withstand per unit area. The compressive strength test used is the ASTM C109-93 standard.

In calculating continuously distributed forces, it is necessary to know the intensity of the force, namely the magnitude of the force per unit area. The resultant force will work through the center of gravity of the cross section. Compressive strength is calculated using the following formula:

$$Fc = \frac{P}{A} \quad (1)$$

Where: Fc is the compressive strength of the test object (kg/cm2)
P is the maximum compressive load (kg)
A is the area of compression (cm2)

2.9. Specific Gravity

Mortar specific gravity is the specific gravity per unit content. The formula used to calculate the specific gravity of mortar is:

$$\text{Specific Gravity} = \frac{W}{V} \quad (2)$$

Where: W is mortar weight (kg)
V is a volume (m3)

3. Research Methodology

Step I
Mixing where materials such as cement, sand and water needed for 3 pieces of mortar are weighed in the ratio according to SNI 03-6825-2002 is 250 gr : 687.5 : 121 ml and bagasse ash as much as 0%, 10%, 15% , and 20% of the sand weight.

Step II
Doughing where after all the ingredients are mixed, water is added to the middle of the dough and left for 60 seconds so that the mixture binds together, then the mixture is stirred until the mixture is completely homogeneous.

Step III
Printing where, after the mixing is complete, printing is carried out by inserting the mortar paste into a cube mold that has been smeared with Vaseline first in a manner such as inserting the paste at a height of 1/3 of the height of the mold, then the mixture is shaken at least 25 times to ensure the density of the mixture. Then, put 1/3 of the mortar paste back into the mold and then compact it again. Next, put the mortar paste

back into the mold until it is full and then compact it again. Finally, the surface of the mold is leveled and then covered with a wet cloth for ± 24 hours.

Step IV

In this step, it is continued with testing the compressive strength of the mortar, such as removing the test object after it reaches the planned age from the soaking tub, then drying it with a cloth and leaving it for 24 hours. Next, the test object is placed on the pressing machine, then a compressive load is slowly applied to the test object by operating the pump lever so that the test object collapses and is destroyed. Finally, when the needle on the load scale no longer moves or increases, the scale indicated by the needle is recorded as the maximum load that can be carried by the test object and this test is carried out repeatedly for other samples of mortar compressive strength test objects.

4. Results and Discussion

The materials used in this research were fine aggregate (sand) and composite portland cement. This aggregate testing refers to SNI (Indonesian National Standards). This testing was carried out in the Structure and Materials Laboratory of the Civil Engineering Study Program, Faculty of Engineering, Palembang University and the Construction Materials Laboratory of the Public Works Department of Highways and Spatial Planning of South Sumatra Province. The results of the fine aggregate (sand) inspection carried out before making the test objects can be seen in the table.

4.1. Calculation of Fine Aggregate Sieve Analysis

Data from the calculation results of fine aggregate sieve analysis can be seen in table 4.1.

Table 4.1. Fine Aggregate Sieve Analysis Calculation

Sieve/Strainer Size		Retained Aggregate		Aggregate Passed
Inch	**MM**	**Gram**	**%**	**(%)**
1”	25,40	-	-	100,00
¾”	19,91	-	-	100,00
½”	12,70	-	-	100,00
3/8”	9,52	-	-	100,00
No. 04	4,76	2,40	0,48	99,52
No. 08	2,38	15,50	3,09	96,91
No. 16	1,19	124,00	24,70	75,30
No. 30	0,60	339,00	67,53	32,47
No. 50	0,30	453,00	90,24	9,76
No. 100	0,15	500,50	99,70	0,30
Total			285,74	
Fineness Number = $\frac{Total\% \mathrm{Re}\, rstrauned}{100} = \frac{285,74}{100} = 2,86$				

4.2. Calculation of Specific Gravity and Absorption of Fine Aggregate

Calculation data for specific gravity and absorption of fine aggregate can be seen in table 4.2. the following :

From the results of calculating the specific gravity and absorption of fine aggregate, it is obtained:

1. Specific Gravity (Bulk) = 2.50
2. Saturated Surface Dry Specific Gravity (SSD) = 2.52
3. Apparent Apparent Specific Gravity = 2.55
4. Absorption = 0.83%

Table 4.2. Calculation of Specific Gravity and Absorption of Fine Aggregate

No.	Analysis	Sample I	Sample II	Averrage	Unit
1.	Dry Object Weight	500,00	500,00	500,00	Gram
2.	Dry Test Object Weight – Oven (B2)	496,00	495,80	495,90	Gram
3.	Pycnometer Weight in Water (25ºC) (B3)	732,40	740,10	736,25	Gram
4.	Pycnometer Weight + SSD Test Object + Water (25ºC) (B1)	1.033,50	1.041,80	1.037,65	Gram
*	Specific Gravity (Bulk) = B2 / (B3 + 500 – B1)	2,49	2,50	2,50	-
*	Dry Specific Gravity Saturated Surface = 500 / (B3 + 500 – B1)	2,51	2,52	2,52	-
*	Apparent Specific Gravity Apparent = B2 / (B3 + B2 – B1)	2,54	2,55	2,55	-
*	Absorption (Absorption) = (500 – B2) / B2	0,81	0,85	0,83	%

4.1. Calculation of Fine Aggregate Mud and Clay Content

Calculation data for fine aggregate silt and clay content can be seen in table 4.3. below this :

Table 4.3. Calculation of Fine Aggregate Mud and Clay Content

No.	Analysis	Sample I	Sample II	Averrage	Unit
1.	Dry Weight (original) + Cup (W2)	500,00	500,00	500,00	Gram
2.	Weight of Dry Test Object (Final) + Cup (W4)	494,00	493,00	493,50	Gram
3.	Cup Weight (W1)	15,00	15,00	15,00	Gram

4.	Dry Object Weight (original) (W3 = W2 – W1)	485,00	485,00	485,00	Gram
5.	Dry Weight (final) (W5 = W4 – W1)	479,00	478,00	478,50	Gram
	Mud and Clay Content = $\frac{(W_3 - W_5)}{(W_3)} x100\%$	1,24	1,44	1,34	%

Table 4.4. Weight of Loose Content of Fine Aggregate (sand)

No	Information	I	II
1	A. Weight of place + test object (kg)	5,620	5,624
2	B. Pan weight (kg)	1,887	1,887
3	C. Test object weight (kg)	3,733	3,737
4	D. Fill the container (litres)	2,722	2,722
5	E. Weight of test object (kg/liter)	1,371	1,373
6	F. Average weight of test object (kg/liter)	1,372	

Table 4.5. Solid Content Weight of fine aggregate (sand)

No	Information	I	II
1	A. Weight of place + test object (kg)	5,975	5,970
2	B. Pan weight (kg)	1,887	1,887
3	C. Test object weight (kg)	4,088	4,083
4	D. Fill the container (litres)	2,722	2,722
5	E. Weight of test object (kg/liter)	1,501	1,500
6	F. Average weight of the test object (kg/liter)	1,501	

Table 4.6. Fine Aggregate Water Content

Activity		Weight (gram)	
		I	II
A	Aggregate Weight	815	824,50
B	Cup WeightBerat	3000	3000
C	Cup+aggregate before washing (dry)	3815	3824,50
D	Weight of cup+aggregate before washing (in oven)	3616	3624,50
Sludge levels : $\frac{(C-A)-(D-A)}{(D-A)}$		7,11%	7,14%
Average of w/c = 7,13%			

Table. 4.7. Fine Aggregate Test Results

No.	Checking type	Test result
1	Weight of loose contents	1,372 kg/liter
2	Solid Content Weight	1,501 kg/liter
3	SSD specific gravity	2,53
4	Dry specific gravity	2,48
5	Absorption	1,85 %
6	Organic Impurities	No. 2
7	Granule Gradation	Zone 4
8	Fineness Modulus	2,53

4.4. Design Mortar Mixtures

Table 4.8. Mixed composition of Normal Mortar (MN) and Mortar mixed with bagasse ash waste (MA).

Analysis	MN%	MA-10%	MA-15%	MA-20%
Ash waste Sugarcane bagasse (grams)	0	68,75	103,13	137,5
Cement (gram)	250	250	250	250
Sand (grams)	687,5	618,75	584,37	550
Water (ml)	121	121	121	121

4.5. Mortar Compressive Strength Testing

Mortar compressive strength testing is carried out using a Compressor Machine.

Table 4.9. Mortar Compressive Strength Test Results Data at 28 days.

No	Mixed Variations (%)	Compression Area (A) (cm2)	Max Compressive Load Force (F) (kg)	Compressive Strength (fc') (kg/cm2)	Average Compressive Strength (kg/cm2)
1	0	25	28,3 35,7 31,9	1,13 1,43 1,28	1,28
2	10	25	39,6 37,2 40,9	1,58 1,49 1,64	1,57
3	15	25	22,7 19,9 24,9	0,91 0,80 1,00	0,90
4	20	25	26,7 27,1 33,0	1,07 1,08 1,32	1,16

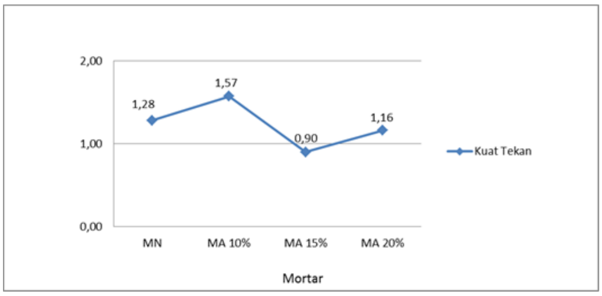

Figure 2. The effect of mixed variations on Compressive Strength of Mortar at 28 Days

From figure 2. It can be seen that the compressive strength of mortar without a mixture of bagasse ash or normal is 1.28 kg/cm, while the average compressive strength of mortar mixed with bagasse ash is 10%, 15% and 20% respectively. are 1.57 kg/cm2, 0.90 kg/cm2, and 1.16 kg/cm2.

5. Conclusions and recommendations

From the results of research and testing of mortar with variations in the mixture of bagasse ash as a substitute for fine aggregate, it can be concluded that the compressive strength value of Normal mortar without bagasse ash waste is 1.28 kg/cm2. The compressive strength value of mortar with 10% sugarcane bagasse ash waste by weight of sand is 1.57 kg/cm2, which is the optimum mixture content in this mixture. The compressive strength value of mortar with 15% of bagasse ash waste from the weight of sand has a compressive strength of 0.90 kg/cm2. The compressive strength value of mortar with 20% bagasse ash waste of the weight of sand has a compressive strength of 1.61 kg/cm2. Mortar mixed with bagasse ash 10% of the weight of sand will increase from normal mortar. Meanwhile, mortar mixed with 15% or 20% bagasse ash tends to decrease compared to mortar mixed with 10% bagasse ash. It is hoped that further research can be carried out using a mixture of bagasse ash with varying soaking (treatment) times.

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