ANALYSIS OF THE EFFECT OF COMPRESSIVE STRENGTH OF MORTAR USINGCANE WASTE ASH AND LIME

Asri Mulyadi[1)], Saloma[2)], Siti Aisyah Nurjannah,[3)]

Palembang University[1)], Sriwijaya University[2), 3)]

asrimulyadi@unpal.ac.id[1)], saloma@ft.unsri.ac.id[2)], sanurjannah@gmail.com[3)]

ABSTRACT

From the results of research and testing of mortar with a variety of bagasse ash mixtures as a substitute for fine aggregate and limestone, it can be concluded that the compressive strength of normal mortar without bagasse ash waste but using limestone water is 1.90 kg/cm2, the compressive strength of mortar with Bagasse ash waste is 6% of the weight of cement and limestone is 2.29 kg/cm2 which is the optimum mixture content in this mixture. The compressive strength of mortar with sugarcane bagasse ash waste is 9% of the weight of cement and limestone has a compressive strength of 2.08 kg /cm2, the compressive strength of mortar with bagasse ash waste is 12% of the cement weight, the compressive strength is 2.12 kg/cm2, mortar mixed with bagasse ash and limestone will increase compared to normal mortar.

Keywords: Aggregate, Cement, Compressive strength, Limestone, Compressive strength, Mortar, Sugarcane bagasse ash

INTRODUCTION

a. Background

Bagasse is waste produced from the process of milling sugar cane 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[1].

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%[2].

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[3].

Planning high quality mortar requires planning in the form of mortar mix design. The mortar mixture must be planned as economically as possible with the right composition of ingredients, so that it is easy to work with when the mortar is still wet (not yet formed) and produces good quality when it has hardened (formed). The quality and strength of mortar is greatly influenced by the composition of the mortar mixture and its treatment (curing), water content, the presence of additional materials used for certain purposes and so on[4]. Therefore the author tried an alternative to use sugarcane bagasse ash waste and limestone which was used as a mortarmixture.

b. Research Objectives

1. Utilizing sugarcane bagasse ash waste to make mortar which is useful for reducing environmentalpollution.
2. Knowing the optimum composition of bagasse ash and limestone for forming mortar.

Can understand mortar mixtures, so that they can design mortar mixtures according to the planned quality.

c. Benefits of research

The use of bagasse ash and limestone waste which is processed into raw materials for making mortar, is expected to be useful in everyday life, apart from improving the community's economy, it can also reduce the impact of environmental pollution due to waste from bagasse ash. As well as providing information to the public about the effect of bagasse ash and limestone as a cement substitute on the quality of mortar.

d. Formulation of the problem

The problem that will be discussed in this research is that it is hoped that using bagasse ash as a substitute for cement and limestone as an adhesive in the mortar mixture can improve the quality of the mortar itself. This research was carried out on a laboratory scale with stages adapted to the literature so that results could be obtained that could improve the quality of the mortar itself.

1. Utilization of bagasse ash waste as a cement substitute for mortar mixtures with mixed variations of 0%, 6%, 9% and 12% by weight of cement and limestone.
2. Characterization tests on the mortar mixture which includes testing the compressive strength of themortar.

LITERATURE REVIEW

a. Mortar

Mortar is a paste made from a mixture of cement, sand and water which is useful for binding, filling and covering irregular gaps between building blocks such as stone, brick and concrete units. Has different percentages, ratios of cement, sand and waterAccording to SNI 03-6825-2002for 3 pieces of mortar 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 which can withstand the compressive force due to the load acting on it will not be destroyed (Concrete Technology, 2008)

Mortar can be used in the form of concrete cube paste (structural) or non-structural, for example in brick or molded stone wall masonry work, wall plastering work, wall ceramic masonry work, floor leveling work and even floor ceramic masonry work.

Mortar is classified according to its use, for example for joints, walls, waterproof, fireproof and so on. Joint mortar is used to join brick, stone and concrete blocks. Wall mortar used in various mixture ratios to meet work requirements. Work with wall mortar: base coating, smoothing, second coating and finishing.

Mortar and concrete are made from cement and aggregate mixed with water. What you need toknow about building materials is their density, porosity and compressive strength. In relation to heat, the properties of the mortar also need to be known, for example a wall made of concrete has a different conductivity compared to building materials, which is closely related to the use of building materials[5].

b. Mortar Specifications

Specifications for Proportions and Properties of Mortar

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.

Table 1 Proportion Requirements

No	Mortar	Type	Mix in volume				Aggregate Ratio (measurement of moist and loose conditions
			Portland Cement	Couple Cement			
				m	S	N	
1		**M** 1	---			1	
2 **M**	--- 1		---				
3 **S**	½ Coupl-e--		1				2.25-3 times the volume of cementitious material
4 **S**	--- Cemen-t--	1	---				

5	**N**	---	---		1			
6	**O**	---	---		1			

Source: SNI 03-6882-2002

The types of mortar are as follows:

a. Type M mortar is a mortar thatmehas a strength of 17.2 MPa according to Table 2.2, which is made using type N masonry cement or lime cement by adding portland cement and quenched lime with the composition according to Table 2.1.
b. Type S mortar is a mortar that has a strength of 12.5 MPa according to Table 2.2, which is made using type S cement or lime cement by adding portland cement and quenched lime with the composition according to Table 2.1.
c. Mortar Type N is a mortar that has a strength of 5.2 MPa according to Table 2.2, which is made using type N masonry cement or lime cement by adding portland cement and quenched lime with the composition according to Table 2.1.
d. Mortar Type O is a mortar that has a strength of 2.4 MPa according to Table 2.2, which is made using type N masonry cement or lime cement by adding portland cement and quenched lime with the composition according to Table 2.1.

Table 2 Characteristic Specification Requirements

Mortar	Type	Average strength 28day Min. (Mpa)	Water retention	Rate Air Max (%)	Aggregate Ratio (Measurement of moist
Cement Partner	M	17.2	75	…… b)	2.25-3.5 times the volume of cement
	S	12.4	75	…… b)	
	N	5.2	75	…… b)	
	O	2,4	75	…… b)	

Source: SNI 03-6882-2002

Information:

a. Only for mortars prepared in the laboratory.
b. When If there is structural reinforcement in the masonry cement mortar, the maximum air content must be 18%.

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 .

Test Method

a. Mixture proportions of ingredients for test specimens

Mortar made in the laboratory which is used to determine the properties according to this specification must contain construction materials in the mixture composition specified in the project specifications (SNI 03-6882-2002).

b. Mortar Mixing

All cement and aggregate materials must be mixed with sufficient water for 3 – 5 minutes using a mechanical mixer to produce a mortar that is easy to work with. Mixing mortar by hand is permitted if there is permission from the party that determines the requirements by providing the procedures for the intended mixing method (SNI 03-6882-2002).

c. Carelessness Maintenance

Mortar that has hardened must be stirred again by hand to maintain its smoothness, and mortar that has been mixed for more than 2.5 hours must not be used again (SNI 03-6882-2002).

Mortar Compressive Strength

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

c. Mortar Forming Material

a. Cement
b. Portland Cement
c. Pozzolan
d. Aggregate
e. Water.

d. Sugarcane Bagasse Ash

Sugarcane bagasse ash is the result of chemical changes from burning pure sugarcane bagasse. Sugarcane bagasse is used as fuel to heat boilers in sugar production with temperatures reaching 5500-6000˚C. Every 4-8 hours, the ash is removed from the boiler, because if it is left without cleaning, a buildup will occur which will disrupt the process of burning the next bagasse[6].

e. Limestone

Limestoneissedimentary rockwhich is composed ofmineralcalciteAndaragonite, which are two different variants of calcium carbonate (CaCO3). The main source of calcite ismarine organisms. These organisms form shells rich in lime, which then build up on the sea floor and are deposited on the floorOceanas oozepelagic.

f. Mortar Mix Planning

All materials for test objects are tested for characteristics in accordance with applicable standards. According to SNI 03-6825-2002for 3 pieces of mortar 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.

RESEARCH METHODOLOGY

a. Place and time of research

PeThis research was carried out in the Structures 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 with a research period of two months.

b. Types of Research and Data Sources

PeThe research carried out was an experimental test, where the conditions were created and regulated by researchers by referring to SNI (Indonesian National Standards) regulations and related literature.

c. Research Tools and Materials

a. Scales with an accuracy of 0.1 gram
b. 1000 ml measuring cup

Measuring cup, used to measure the amount of water used.

c. Pycnometer.
d. Sharpened cone
e. Corner rod
f. Aluminum pan

g. Glass plate
h. Cup
i. Oven equipped with temperature control.
j. Density spoons
k. Scales
l. Cylindrical tube
m. Vernier calipers are used to measure all dimensions of the test object.
n. Paintbrush
o. Plastic bucket
p. Cube mold measuring (5 x 5 x 5) cm
q. Cement spoon
r. Universal Testing Machine (Tokyo Testing Machine Inc.) capacity 1000 kN
s. Sieve, Pass sieve No. 200 (fine aggregate composition according to standards)
t. Wet cloth.

d. Material

The materials used in this research are:

a. Seme brand Type I Portland cementn Baturaja
b. Fine aggregate
c. PDAM water
d. Sugarcane bagasse ash.
e. Limestone

Before buying these materials, you should first estimate how much is needed. For sand: It is best to increase the amount of sand, so that the aggregate inspection does not happen again, considering that the characteristics of the aggregate will not be the same for each purchase. Cement should be purchased as the day of printing approaches, because storing cement for too long will reduce the quality, if improper storage can cause the cement to harden and clots occur.

e. Procedure for Making Mortar Test Materials

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

b. Kneading
After all the ingredients are mixed, water is added to the middle of the mixture and left for 60 seconds so that the mixture binds together, then the mixture is stirred until the mixture is completely homogeneous.

c. Printing
After the kneading is complete, molding is carried out by inserting the mortar paste into a cube mold that has been smeared with Vaseline first by:

- Insert the paste as high as 1/3 of the height of the mold, then the mixture is shaken at least 25 times to ensure the density of the mixture.
- Put 1/3 of the mortar paste back into the mold then shake it again.
- Put the mortar paste back into the mold until it is full then shake it again.
- The surface of the mold is leveled and then covered with a wet cloth for ± 24 hours.

f. Mix Planning and Mortar Quality Test Procedures

Mortar Mix Planning

Mortar mixtures are guided by Standard ASTM C109-93, namely:

- Cube mold 5 x 5 x 5 cm
- Samples can be made with material details are:

Table 3. Three samples

	3 samples
Cement	250 grams
Sand	687.5 grams
Water	121 ml

Source: ASTM C109-93

Mortar Compressive Strength Testing Procedure

Mortar pressure strength testing is carried out to determine the crushing compressive strength of the test object. The test object used is a cube with side dimensions of (5 x 5 x 5) cm. Mortar pressure strength testing was carried out when the mortar was 28 days old. The amount of mortar tested consisted of 3 samples for each mixture.

Work procedures for testing compressive strength on mortar test specimens include:

a. Remove the test object after it reaches the planned age from the soaking tub, then dry it with a cloth and leave it for 24 hours.
b. The test object is placed on the pressing machine.
c. A compressive load is applied slowly to the test object by operating the pump lever so that the test object collapses and is destroyed.
d. 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.
e. This procedure is repeated for other compressive strength test specimens.

Compressive strength can be obtained using the following formula:

$$fc^{I} = \frac{F}{A}$$

With :

FCI = Compressive strengthtest object (kg/cm2)
F =Maximum compressive load (kg)
A = Field areasurface (cm2)

RESULTS AND DISCUSSION

a. Fine Aggregate Inspection

The fine aggregate (sand) used was Musi river sand. This test was carried out at the Civil Materials & Structure Test Laboratory, Faculty of Engineering, Palembang University and the Construction Materials Laboratory of the Public Works Department of Highways and Spatial Planning, South Sumatra Province. Tests carried out for fine aggregate include loose and solid density, sieve analysis, specific gravity and absorption, mud content and water content. From the results of the examination thathas been carried out, the following data were obtained:

Table 4. Loose weight Content Fine Aggregate (sand)

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

Source: Test Results

Table 5**.** Solid weight Content fine aggregate (sand)

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

Source: Test Results

Table 6. Fine Aggregate Water Content

Activity		Weight (grams)	
		I	II
A	Aggregate Weight	815	824.50
B	Cup Weight	3000	3000
C	Weight of Cup+aggregate before washing (dry)	3815	3824.50
D	Weight of Cup+aggregate before washing (in the oven)	3616	3624.50
Sludge levels : $\frac{(C-A)-(D-A)}{(D-A)}$		7.11%	7.14%
Average water content = 7.13%			

Table 7. Hasil Fine Aggregate Testing

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

Source: Test Results

b. Mortar Mix Design

The mortar mixture composition for the 3 test objects was made according to SNI 03-6825-2002 standards. The ratio of dry ingredients used is 1 part by weight of cement, 2.75 parts by weight of sand and the cement water factor is 0.484 for all types of portland cement.

a. Normal Mortar (MN)

The ratio of cement, sand, water and bagasse ash waste required is:

Cement : 250 gr
Sand : 687.5 gr
Water : 121 ml

b. *Mortar*by using 6% bagasse ash waste and limestone (MA6%K)

The ratio of cement, sand, water and bagasse ash waste required is:

Cement	: 250 gr – 15 gr	= 235 gr
Sand	: 687.5 gr	
Water	: 121 ml	

Sugarcane bagasse ash waste 6% of cement weight = 15 gr

c. *Mortar*by using 9% bagasse ash waste and limestone (MA9%K)
The ratio of cement, sand, water and bagasse ash waste needed for 3 pieces is:
Cement : 250 gr – 22.5 gr = 227.5 gr
Sand : 687.5 gr
Water : 121 ml
Sugarcane bagasse ash waste 9% of cement weight = 22.5 gr

d. *Mortar*by using 12% bagasse ash waste and limestone (MA12%K)
The ratio of cement, sand, water and bagasse ash waste needed for 3 pieces is:
Cement : 250 gr – 30 gr = 220 gr
Sand : 687.5 gr
Water : 121 ml
Sugarcane bagasse ash waste 12% of cement weight = 30 gr

Table 8. Composition of a mixture of Normal Mortar (MN) and Mortar with bagasse ash waste and limestone (MA K).

Description	M N	(MA6%K)	(MA9%K)	(MA12%K)
Cement (grams)	250	235	227.5	220
Sand (grams)	687.5	687.5	687.5	687.5
Water (ml) + limestone	121	121	121	121
Sugarcane bagasse ash waste	0	15	22.5	20

Source: Calculation Results

Information :
M N =*Mortar*Normal
(MA6%K) =*Mortar*with 6% bagasse ash waste and limestone
(MA9%K) =*Mortar*with 9% bagasse ash waste and limestone
(MA12%K) =*Mortar*with 12% bagasse ash waste and limestone

c. Mortar Compressive Strength Testing

Mortar compressive strength testing is carried out using a Compressor Machine. Data on compressive strength testing results for Normal Mortar, and Mortar with 6%, 9%, 12% bagasse ash waste and limestone, the results of the research can be shown in table 4.6 below:

Table 11. Mortar Compressive Strength Test Results Data at 28 Days

No	*Mortar*	Compression Area (A) (cm2)	Max Compressive Load Force (F) (kg)	Compressive Strength (fc') (kg/cm2)	Average Compressive Strength (kg/cm2)
1	M N	25	49.9 46.5 46.2	2.00 1.86 1.85	1.90
2	MA6%KG	25	60.0 58.1 53.7	2.40 2.32 2.15	2.29
3	MA9%KG	25	47.6 53.7 55.1	1.90 2.15 2.20	2.08

4	MA12%KG	25	41.0 59.3 59.1	1.64 2.37 2.36	2.12

Source: Test results

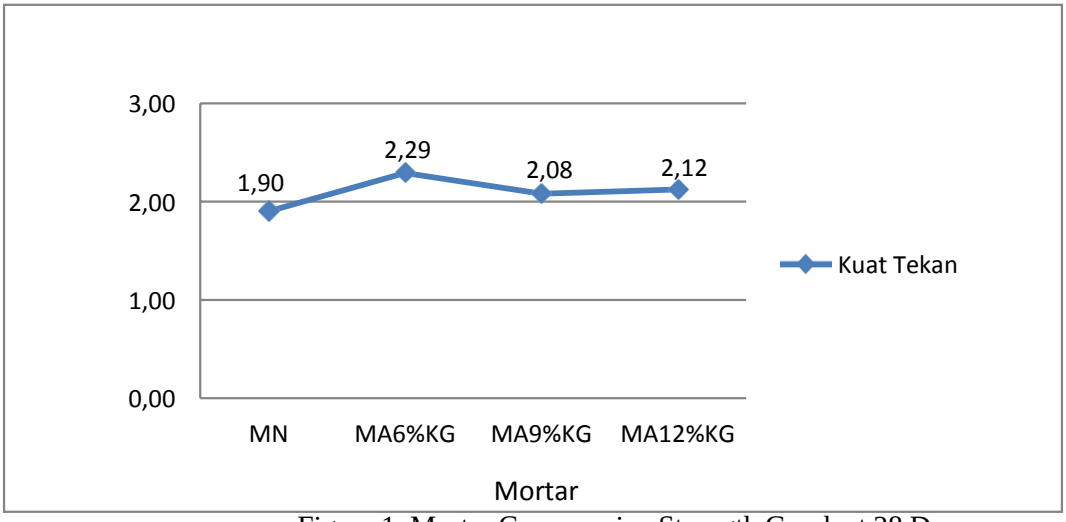

Figure 1. Mortar Compressive Strength Graph at 28 Days

From figure 1. It can be seen that the compressive strength of standard mortar without bagasse ash and lime or normal waste is 1.90 kg/cm2, while the compressive strength of mortar with 6% bagasse ash waste and limestone is 2.29 kg/cm2, and for mortar with 9% bagasse ash waste and lime lime the compressive strength is 2.08 kg/cm2, then for mortar with 12% bagasse ash waste and lime lime the compressive strength is 2.12 kg/cm2.

CONCLUSIONS AND RECOMMENDATIONS

a. Conclusion

From the results of research and testing of mortar with various mixtures of bagasse ash as a substitute for fine aggregate and limestone, it can be concluded that:

a. The compressive strength of normal mortar without bagasse ash waste but using lime water is 1.90 kg/cm2.
b. The compressive strength of mortar with bagasse ash waste 6% of the weight of cement andlimestone is 2.29 kg/cm2 which is the optimum mixture content in this mixture.
c. The compressive strength of mortar with bagasse ash waste 9% of the weight of cement andlimestone has a compressive strength of 2.08 kg/cm2
d. The compressive strength of mortar using bagasse ash waste is 12% of the cement weight, thecompressive strength is 2.12 kg/cm2
e. *Mortar*by mixing bagasse ash and limestone it will increase from normal mortar.

b. Suggestion

It is hoped that further research can be carried out using a mixture of bagasse ash with varying soaking (treatment) times.

REFERENCES

[1] D. D. Pranowo, E. Suryani, and C. P. Rahmadhani, "Pengaruh Penggunaan Abu Ampas Tebu sebagai Pengganti Sebagian Semen Ditinjau Terhadap Kuat Tekan Mortar," *J. Penelit. Inov.*, vol. 2, no. 3, pp. 477–484, 2023, doi: 10.54082/jupin.106.
[2] F. Batool, A. Masood, and M. Ali, "Characterization of Sugarcane Bagasse Ash as Pozzolan and Influence on Concrete Properties," *Arab. J. Sci. Eng.*, vol. 45, no. 5, pp. 3891–3900, 2020, doi: 10.1007/s13369-019-04301-y.
[3] G. L. Asri Mulyadi, "Pemanfaatan Limbah Abu Tempurung Kelapa Sawit Untuk Campuran

Mortar," vol. 9, no. 2, pp. 88–93, 2019.
[4] Saloma, Hanafiah, and K. Ilma Pratiwi, "Effect NaOH Concentration on Bagasse Ash Based Geopolymerization," *MATEC Web Conf.*, vol. 78, 2016, doi: 10.1051/matecconf/20167801025.
[5] Saloma, A. Nasution, I. Imran, and M. Abdullah, "Improvement of concrete durability by nanomaterials," *Procedia Eng.*, vol. 125, pp. 608–612, 2015, doi: 10.1016/j.proeng.2015.11.078.
[6] A. Mulyadi, "Pengaruh Penambahan Abu Ampas Tebu Terhadap Kuat Tekan Mortar," *Academia.Edu*, vol. 2, no. 3, pp. 1–12, 2012, [Online]. Available: https://www.academia.edu/download/49333206/Naskah.pdf.

Biodata

Asri Mulyadi is a lecturer of Civil Engineering, Faculty of Engineering, University of Palembang, South Sumatera. Email: asrimulyadi@unpal.ac.id