ANALYSIS OF THE UTILIZATION OF SUGAR CANE ASH WASTE AS A CEMENT SUBSTITUTION IN MORTAR MIXTURE WITH NaCl AS A SUBSTITUTE FOR WATER

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ABSTRACT

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. The limitation of the problem in this research is the use of bagasse ash waste as a cement substitute for mortar mixtures with mixed variations of 0%, 6%, 9% and 12% of the weight of cement, NaCl as a substitute for water, characterization of tests on the mortar mixture which includes testing the compressive strength of the mortar. From the results of research and testing of mortar with various mixtures of bagasse ash as a substitute for fine aggregate and NaCl as a substitute for water, it can be concluded that the compressive strength of normal mortar without bagasse ash waste but using water from NaCl is 1.75 kg/cm^2., strong press mortar with waste bagasse ash 6% of the weight of cement and NaCl is 1.44 kg/cm^2, the compressive strength of mortar with waste bagasse ash 9% of the weight of cement and NaCl compressive strength is 1.39 kg/cm^2, compressive strength of mortar with bagasse ash waste 12% of the cement weight, the compressive strength is 1.55 kg/cm^2 which is the optimum mixture content in this mixture. Mortar mixed with bagasse ash and NaCl results in a lower compressive strength than normal mortar.

Keywords: Aggregate, Cement, Compressive strength, Mortar, NaCl, Sugarcane bagasse ash waste

INTRODUCTION

a. Background

The concept of environmentally friendly technology has inspired researchers to do more to protect the environment. According to research by Sugianto (2017), waste as an alternative building material has become a popular way to overcome environmental problems in most developing countries because the waste bagasse ash is directly disposed of on land or land around the sugar cane processing site. Sugarcane bagasse ash is one of the wastes that has the potential to be used as a mixture in building materials.

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%, SiO_2 (silica) in the range of 20% -24% and Al_2O_3 (aluminum oxide) in the range of 4% -8% (Raya ayu Sati, 2019). 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.

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 curing, water content, the presence of additional materials used for certain purposes, and so on. Therefore, the author tries an alternative for using bagasse ash as a substitute for cement and NaCl as a substitute for water. which is used as a mortar mixture.

b. Research Objectives

1. To determine the optimum composition of bagasse ash and NaCl for forming mortar.
2. Can understand mortar mixtures, so that you can design mortar mixtures according to the planned quality.
3. Utilizing sugarcane bagasse ash waste to make mortar which is useful for reducing environmental pollution.

c. Benefits of Research

The use of bagasse ash and NaCL 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. Problem Formulation

Issue to be discussed in this research is that it is hoped that using bagasse ash as a cement substitute and NaCl as a substitute for AR 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.

LITERATURE REVIEW

a. Mortar

Mortar is a paste made from a mixture of cement, sand, and water that is useful for binding, filling, and covering irregular gaps between building blocks such as stone, brick, and concrete units. Has different percentages and ratios of cement, sand, and water. According to SNI 03-6825-2002 for 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 that 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 is 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 to know 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.

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	Couple Cement	**M**	1	---		1	2.25-3 times the volume of cementitious material
2		**M**	---	1		---	
3		**S**	½	---		1	
4		**S**	---	---	1	---	
5		**N**	---	---		1	
6		**O**	---	---		1	

Source: SNI 03-6882-2002

From the table above, the types of mortar are as follows:

1. Type M mortar is a mortar that has a strength of 17.2 MPa according to Table 2, which is made using type N masonry cement or lime cement by adding portland cement and quenched lime to the composition.
2. Type S mortar is a mortar that has a strength of 12.4 MPa according to Table 2, which is made using type S cement or lime cement by adding portland cement and quenched lime with the composition according.
3. Mortar Type N is a mortar that has a strength of 5.2 MPa according to Table 2, which is made using type N masonry cement or lime cement by adding portland cement and quenched lime to the composition.
4. Mortar Type O is a mortar that has a strength of 2.4 MPa according to Table 2, which is made using type N masonry cement or lime cement by adding portland cement and quenched lime to the composition.

Table 2. Characteristic Specification Requirements

Mortar	Type	Average strength 28day Min. (Mpa)	Water retention Min (%)	Rate Air Max (%)	Aggregate Ratio (Measurement of moist and loose conditions)
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. (Abdul Ghofur, 2010)

e. NaCl

NACL 0.9% is an infusion fluid containing NaCl 0.9%. This infusion is used to restore electrolyte balance in dehydration. Sodium ions are the main electrolyte in extracellular fluid which is needed in the distribution of fluids and other electrolytes. Chloride ions act as buffering agents in the lungs and tissues. This ion helps facilitate oxygen and carbon dioxide to bind to hemoglobin. Sodium ions and chloride ions are regulated by the kidneys which control homeostasis by absorption or excretion in the tubules.

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 METHODS

a. Place and time of research

This 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

The 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.. Tools and Research Materials

1. Scales with an accuracy of 0.1 gram
2. 1000 ml measuring cup
   Measuring cup, used to measure the amount of water used.
3. Pycnometer.
4. Sharpened cone

5. Corner rod
6. Aluminum pan
7. Glass plate
8. Cup
9. Oven equipped with temperature control.
10. Density spoons
11. Scales
12. Cylindrical tube
13. Vernier calipers are used to measure all dimensions of the test object.
14. Paintbrush
15. Plastic bucket
16. Cube mold measuring (5 x 5 x 5) cm
17. Cement spoon
18. Universal Testing Machine (Tokyo Testing Machine Inc.) capacity 1000 kN
19. Sieve, Pass sieve No. 200 (fine aggregate composition according to standards)
20. Wet cloth.

d. Material

The materials used in this research are:

1. Seme brand Type I Portland cement Baturaja
2. Fine aggregate
3. PDAM water
4. Sugarcane bagasse ash.
5. NaCl

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

1. 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%, 6%, 9%, and 12% of the sand weight.
2. 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.
3. 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. 3 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:

1. 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.
2. The test object is placed on the pressing machine.
3. A compressive load is applied slowly to the test object by operating the pump lever so that the test object collapses and is destroyed.
4. 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.
5. 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

Laboratory tests carried out for fine aggregate include loose bulk and solid bulk, sieve analysis, specific gravity and absorption of mud content and water content. The fine aggregate used is Musi river sand.

From the results of examinations carried out in the laboratory, the following data were obtained:

Examination of the Weight of Loose and Solid Contents of Fine Aggregate

Table 4. Weight of loose and dense fine aggregate content

Activity		I		II		III	
		Loose	Congested	Loose	Congested	Loose	Congested
A	Cylinder	1893,13	1893,13	1893,13	1893,13	1893,13	1893,13
B	Volume	855	855	855	855	855	855
C	Cylinder	2924	3258	2920	3230	2914	3288,5
	WeightWeight of Test Object						
Volume weight: $\frac{C-B}{A}$		1,093	1,269	1,091	1,255	1,088	1,285

Average Volume Weight:
- Loose weight = 1.091 gr/cm3
- Solid weight = 1.269 gr/cm3

Source: Research results

Fine Aggregate Sieve Analysis Examination

Table 5. Fine Aggregate Sieve Analysis

Filter (mm)	Suspended weight (gr)	The amount of weight retained	Total percent (%)	
			Stuck	Get away
4.75	0	0	0	100
4	2	0.4	0.4	99.6
2	4.5	0.9	1.3	98.7
1	33	6.6	7.9	92.1
0.5	30	6	13.9	86.1
0.25	262.5	52.5	66.4	33.6
0.125	153.5	30.7	97.1	2.9
0.063	10	2	99.1	0.9
pan	4.5	0.9	100	0
Total	500	100	386.1	

Source: Research results

$$\text{Fineness Number} = \frac{386,1}{100} = 3,861$$

Examination of Specific Gravity and Absorption of Fine Aggregate

Table 6. Specific Gravity and Absorption of Fine Aggregate

Activity		**Weight (grams)**	
		I	II
A B CDE	Weight of cupWeight of measuring cup (1000 ml)Weight of measuring cup + sand + waterWeight of measuring cup + waterWeight of cup + sand after oven (Dry Kerontang)	869 303 1592,5 1302 1367	881 303 1594 1302 1367
Dry specific gravity: $\frac{E-A}{D+500-C}$		2,387	2,337
SSD specific gravity: $\frac{500}{D+500-C}$		2,450	2,404
Water absorption percentage: $\frac{500-(E-A)}{E-A}$		2,669	2,881
Average dry specific gravity = Average SSD specific gravity = Average absorption percentage =		2,362 2,427 2,775%	

Source: Research results

Fine Aggregate Sludge Content Inspection

Table 7. Fine Aggregate Sludge Content

Activity		Weight (grams) I	Weight (grams) II
A	Aggregate Weight	736	987
B	Cup Weight	1000	1000
C	Weight of Cup+aggregate before washing (dry)	1736	1987
D	Weight of Cup+aggregate before washing (in oven)	1729	1978
Sludge levels ; $\frac{(C-B)-(D-B)}{(D-B)}$		0.705%	0.908%
Average sludge content = 0.807%			

Source: Research results

Fine Aggregate Water Content Inspection

Table 8.Fine Aggregate Water Content

Activity		Weight (grams) I	Weight (grams) 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%			

Source: Research results

From the examination carried out in the laboratory, the following data were obtained:

1. Fine Aggregate

Table 9. Sand data

No	Description	Information
1	Weight of loose contents	1.091 gr/cm^3
2	Solid Content Weight	1.269 gr/cm^3
3	SSD specific gravity	2,427
4	Dry specific gravity	2,362
5	Absorption	2.775 %
6	Sludge levels	0.807 %

7	Water content	7.13 %
8	Granule Gradation	Zone 4
9	Fineness Modulus	3,861

Source: Research results

b. Portlant Cement (PC) Inspection
Cement Specific Gravity Check

Table 10. Cement Specific Gravity

Activity		Weight (grams)	
		I	II
A	Weight of cement	64	64
B	Reading on a bottle scale (V^1)	0	0
C	Reading on a bottle scale (V^2)	21.4	21.5
D	Weight of water content at 4^o C	-	-
Cement Specific Gravity $\frac{Cement\ weight}{(V2 - V1)\ d}$		2.99	2.97
Average specific gravity of cement = 2,098 gr / cm^3			

Source: Research results

Cement Consistency Check

Table 11.Cement Consistency

Activity	Weight (g)
Weight of portlant cement	650
Water Weight	155
Consistency of portlant cement $\frac{Water\ weight}{Cement\ weight}$ x 100%	
Cement consistency	23.846 %

Source: Research Results

c. Water Inspection

The water used in this research is clean water , but in general the water used is: Water must be clean, must not contain mud,oil, acid, alkali, organic substances and other materials that can damage mortar.

d. Requirements for the Number of Research Test Objects

1. Normal Mortar (MN)
   According to SNI 03-6825-2002,The ratio of cement, sand, bagasse ash, NaCl needed for 3 pieces is:
   Cement : 250 gr
   Sand : 687.5 gr
   NaCl : 121 ml

2. *Mortar* using 6% sugarcane bagasse ash from the cement composition and NaCl as a substitute for water (MA6%NaCl).According to SNI 03-6825-2002 pThe ratio of cement, sand, bagasse ash, NaCl needed for 3 pieces is:
   Cement : 250 gr - 15 gr = 235 gr
   Sand : 687.5 gr
   NaCl : 121 ml
   Bagasse ash is 6% of the cement composition = 15 gr

3. *Mortar* by using sugarcane bagasse ash waste 9% of the cement composition and NaCl as a substitute for water (MA9%NaCl).According to SNI 03-6825-2002The ratio of cement, sand, bagasse ash, NaCl needed for 3 pieces is:
   Cement : 250 gr - 22.5 gr = 227.5 gr
   Sand : 687.5 gr
   NaCl : 121 ml
   Bagasse ash is 9% of the cement composition = 22.5 gr

4. *Mortar* using 12% sugarcane bagasse ash waste from the cement composition and NaCl as a substitute for water (MA12%NaCl).According to SNI 03-6825-2002The ratio of cement, sand, bagasse ash, NaCl needed for 3 pieces is:
   Cement : 250 gr - 30 gr = 220 gr
   Sand : 687.5 gr
   NaCl : 121 ml
   Bagasse ash is 12% of the cement composition = 30 gr

Table 12. Composition of a mixture of Normal Mortar (MN) and Mortar with sugarcane bagasse ash and NaCl waste.

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

Source: Calculation Results

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

e. 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% sugarcane bagasse ash waste and NaCl, the results of the research can be shown in table 13.below:

Table 13. 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	38.8 50.3 42.4	1.55 2.01 1.70	1.75
2	MA6%NaCl	25	40.4 32.9 34.8	1.62 1.32 1.39	1.44
3	MA9%NaCl	25	31.7 40.2 32.3	1.27 1.61 1.29	1.39
4	MA12%NaCl	25	36.5 45.6 34.5	1.46 1.82 1.38	1.55

Source: Test results

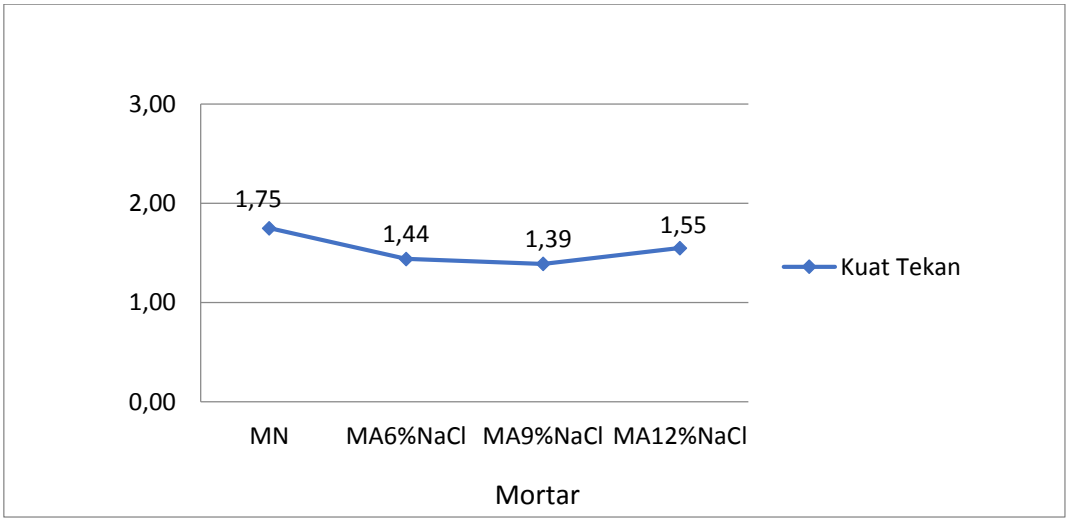

Figure 1. Mortar Compressive Strength Graph at 28 Days

From figure 1.. It can be seen that the compressive strength of Standard Mortar without waste bagasse ash and lime or normal lime is 1.75 kg/cm2, while the compressive strength of mortar with 6% bagasse ash waste and NaCl is 1.44 kg/cm2, and for mortar with 9% bagasse ash waste and NaCl has a compressive strength of 1.39 kg/cm2, then for mortar with 12% bagasse ash waste and NaCl a compressive strength of 1.55 kg/cm2.

CONCLUSIONS

a. Conclusion

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

1. The compressive strength of normal mortar without bagasse ash waste but using NaCl water is 1.75 kg/cm2.

2. The compressive strength of mortar with bagasse ash waste 6% of the weight of cement and NaCl is 1.44 kg/cm2.
3. The compressive strength of mortar with sugarcane bagasse ash waste is 9% of the cement weight and the compressive strength of NaCl is 1.39 kg/cm2
4. The compressive strength of mortar with bagasse ash waste is 12% of the cement weight, the compressive strength is 2.12 kg/cm2 which is the optimum mixture content in this mixture
5. *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] Sugianto, et al. (2017),*Experimental Study of Adding a Mixture of Sugarcane Bagasse Ash and Bamboo Fiber to Concrete Bond Strength*,Journal, Sebelas Maret University Surakarta.

[2] ....., Annual Book of ASTM Standard, Volume 04.02, Concrete and Aggregates, 1997

[3] ....., Indonesian National Standard SNI 03-2847-2002 "Procedures for Calculating Concrete Structures for Buildings.

[4] SNI–03-6825-2002, Testing Method for Compressive Strength of Cement Mortar*Portland For Civil Works*National Standardization Body ICS 27.180

[5] SNI–03-6882-2002, Mortar Specifications for Pair Work National Standardization Agency ICS 27.180

[6] Triaswati MN, Didik Harijanto., Boedi Wibowo., Wahyu Ismoyo.,*Use of Stone Ash to Reduce Natural Sand Aggregate in Concrete Mixes by Adding Type D Additives*.Journal of Infrastructure & Facilities Asset Management, (e)ISSN 2615-1847 (p)ISSN 2615-1839, Vol. 3, Special Issue 2, June 2019

[7] Nugraha P., Antoni, Concrete Technology, Andi offset, Yogyakarta, 2007

[8] Rara Ayu Sati, et al (2019). Effect of variations in the use of bagasse ash (AAT) and stone ash (AB) as partial replacement materials for cement on the compressive strength of mortar. (p)ISSN : 2086-9045, UNIB.

Biodata

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