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Study of Gold Mine Tailings Utilization as Fine Aggregate Material for Producing Shotcrete Based on Concept of Green Technology

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Abstract - Shotcrete is concrete that is applied by spraying. The use of shotcrete from year-to-year increase. Because sand is a material for the manufacture of shotcrete, the volume of sand will increase as well. Sand excavation on a large scale can lead to disruption of the environment. Reuse of tailings for shotcrete can reduce the volume of sand used. In addition, utilize waste materials will reduce the contamination surrounding environment. This study is a continuation of previous studies, that the use of tailings as conventional concrete manufacture. The results showed that the optimum tailings substitution of 25% both for conventional concrete or shotcrete. Laboratory studies conducted at the Civil Engineering Laboratory of University of Bandar Lampung and PT Semen Baturaja. Research using a shotcrete equipment done in PT Natarang Mining, Way Linggo, Lampung. Type of admixture used is monomer composite material under the trade name Polcon. The compressive strength achieved in the laboratory was 32.7 MPa when not using Polcon as admixture. When using Polcon, the compressive strength reached 33.5 MPa. Crushing compressive strength of shotcrete in the field trial is 20.3 MPa. For studying the micro structure of tailings, cement, mortar with tailings 100%, 50% and without tailings, the Scanning Electron Microscopy micro photo are done.

Keyword : tailing shotcrete, composite monomer material, scanning electron microscopy of tailings

1. INTRODUCTION

The use of shotcrete from year to year increase. This is because the benefits, that does not require formwork, can be used to create an irregular shape, and the work can be done more quickly than for conventional concrete. In infrastructure, shotcrete widely used to repair slope retaining system, strengthening the walls of the tunnel and so on. Moreover, it also suitable for curved or thin concrete structure and shallow repairs, and can also can be used to make a thick concrete.

Due to the many construction materials include shotcrete require sand, then use the sand to rise sharply. Sand excavation on a large scale can lead to disruption of the environment.

The above is an issue that needs to be answered in the application of the concept of sustainable development that is to meet the needs of the present without compromising the ability of future generations.

Therefore, we need a construction material that: (1) efficient as possible using natural materials, (2) minimize the negative impact to the environment, (3) high performance, (4) utilizing waste materials. Reuse tailings for shotcrete can reduce the volume of sand used. Sand is more expensive price because of its availability becomes scarcer.

Previous studies showed that the tailings can be used for substitution of sand in the manufacture of concrete. So, it will be investigated the use of tailings for the manufacture of shotcrete. Shotcrete using the same material with mortar, but of a different nature, due to the use of different additives. Economic value generated is also different. Shotcrete has a higher economic value.

Shotcrete material was generally similar to that used for concrete in general, ie Portland cement, fine aggregate, water, admixture and additive. Retrofitting shotcrete is also the same as that used for the reinforcement of concrete in general, the deformed bars, wire mesh, or prestressing steel.

The difference is ordinary concrete was cast, shotcrete was pneumatically sprayed to the surface at high speed. Shotcrete is also known as "gunite" and " spraying concrete". See Figure 1.1. Because of differences in the implementation of the method, it require different types and amounts of admixture. So, shotcrete is different from ordinary concrete (Lagerblad et al.,2010) By simple it can be said that shotcrete is concrete with small aggregate, placed on horizontal and vertical surfaces.

Figure 1.1. Shotcrete aplication

2. LITERATURE REVIEW

Bhatty, 1984 reported that using cement that has been produced using anorthite from copper-nickel tailings and raw taconite tailings has better strength properties thn ordinary Type 1 Portland Cement and gave a stronger concrete when tested under identical curing condition. See Figure 2.1.

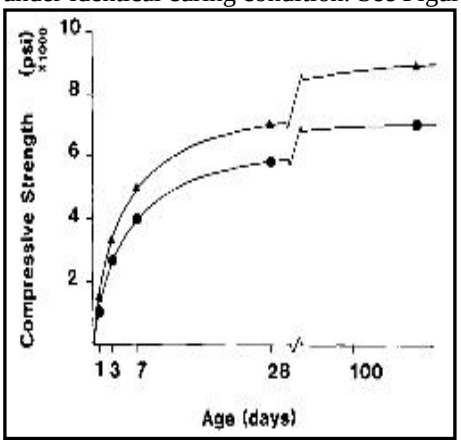

Figure 2.1. Development of compressive strength of concrete made from tailings cement and type 1 Portland Cement

Based on the research of Lationo, et al. (1997) tailings in Papua (PT Freeport) can be used in the mortar-making process. Tailings can be fastened with cement, but because the tailings contain magnesium which can cause cracking of the mortar, it is necessary to add chemical admixture in process. Based on the research that has been done by Lationo, et al., mixture composition using 10% cement and 90% tailings can reach compressive strength of 20 MPa , whereas the composition of 30% cement and 70% tailings can reach about 30-40 MPa compressive strength.

Tianhu, S., (2010) conduct an experiment to compare graphite tailings concrete and river sand concrete. His experiment shown that graphite tailing concrete strength slow formation in first 7 days, strength significantly increases after 7 days to 28 days. The strength slowly increased trend after 28 days. See Figure 2.2.

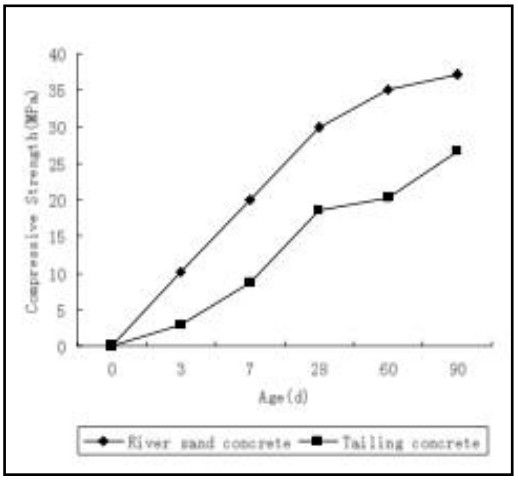

Figure 2.2. Curve about the compressive strength and tailing content

3. METHODOLOGY

3.1. Physical and chemical characteristics of the material.

The study began by testing the physical and chemical properties

of the tailings. Then performed testing the physical properties of sand. Tailings testing done in accordance with the objectives of the study.Tailings grain size gradation are expressed in the table can be seen in Table 3.1. Based on the results of the testing that has been done, saturated surface dry specific gravity ranging from 2.48 to 2.86 and loose density ranging from 1.23 to 1.79 ton/m^3 (Widojoko, 2012). While the physical characteristics of the tailings which is to make specimens can be seen in Table 3.2

Table 3.1 Gradient of tailings (SNI 03-1968-1990 Method)

Sieve size		Result	
ASTM	mm	% Passing	% Retained
3/4”	19	100	0
½”	12,5	100	0
3/8”	9,5	100	0
No. 4	4,75	100	0
No. 8	2,36	92.6	7.4
No. 16	1,18	83.3	16.7
No. 30	0,600	63	37
N0. 50	0,300	30	70
No. 100	0,150	7.3	92.7
No. 200	0,075	2	-
		FM =	2.238

Table 3.2 Characteristics of the tailings are used for the manufacture of test specimens

Description	Tailings		Method
	Value	Unit	
Specific Gravity (SSD) (((SSD)	2,5	-	SNI 03-1970-1990
Absorbtion	1,79	%	SNI 03-1970-1990
Water Content	32,13	%	SNI 03-1971-1990
Loss Unit Weight	1,277	t/m3	SNI 03-4804-1998
Dense Unit Weight	1,424	t/m3	SNI 03-4804-1998
Soundness (Na2SO4)	8	(%)	SNI 03-3407-1994 Na<10% Mg<12%
Organic Level (NaOH)	No.1		SNI 03-2816-1992

Metal content in tailings can be seen in Table 3.3. Before tailings thrown into the reservoir, its was "neutralize" at the factory, so its presence does not pollute the ground water. From testing results, it found that the metal content meets the quality standard requirements. Thus, the tailings safe to use as construction material. Sand grain size grading can be seen in Table 3.4. While the physical characteristics of the sand used for the manufacture of test

specimens can be seen in Table 3.5.

Table 3.3 Content of metals in tailings

No	Parameters	Unit	Test result	Specification
1	Lead (Pb)	mg/L	0,007	5
2	Copper (Cu)	mg/L	<0,01	10,0
3	Cadmium (Cd)	mg/L	<0,005	1,0
4	Chromium (Cr)	mg/L	<0,05	5,0
5	Zinc (Zn)	mg/L	0,037	50,0
6	Silver (Ag)	mg/L	< 0,004	5,0
7	Arsen (As)	mg/L	0,03	5000
9	Mercury (Hg)	mg/L	<0,00005	200
10	Nickel (Ni)	mg/L	0,06	20,0

Table 3.4. Gradation of Sand

Sieve size		Result	
ASTM	mm	% Passing	% Retained
3/4”	19	100	0
½”	12,5	100	0
3/8”	9,5	100	0
No. 4	4,75	100	0
No. 8	2,36	86,3	13,7
No. 16	1,18	63,9	36,1
No. 30	0,600	25,0	75,0
N0. 50	0,300	15,0	85,0
No. 100	0,150	11,5	88,5
No. 200	0,075	6,5	93,5
		FM =	2,98

Table 3.5. Characteristics of Kota Agung sand used for the manufacture of test specimens.

Description	Sand		Method
	Value	Unit	
Specific Gravity (SSD)	2,5	-	SNI 03-1970-1990
Absorbtion	2	%	SNI 03-1970-1990
Water Content	15	%	SNI 03-1971-1990
Loss Unit Weight	1,3	t/m3	SNI 03-4804-1998
Dense Unit Weight	1,46	t/m3	SNI 03-4804-1998
Soundness (Na2SO4)	8	(%)	SNI 03-3407-1994
Organic Level (NaOH)	No 1		SNI 03-2816-1992

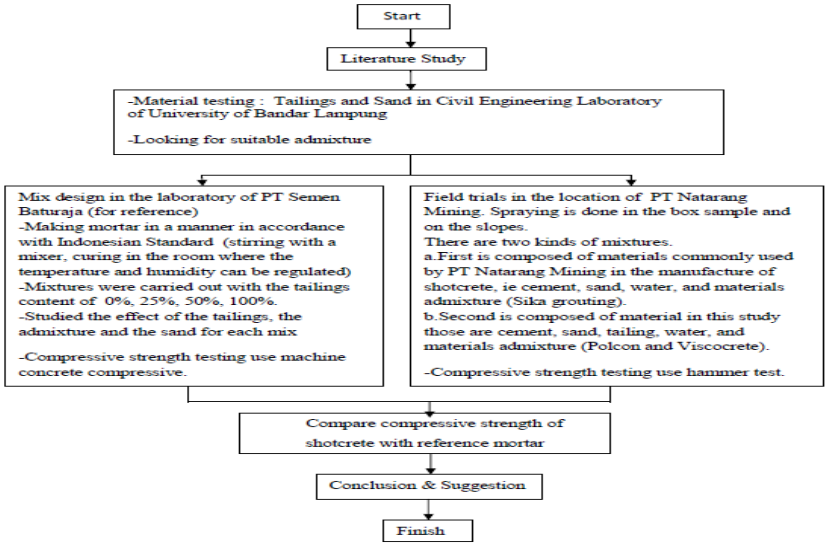

Figure 3.1 Method of study

4. DISCUSSION.

4.1 Result of the first year.

4.1.1 Compressive strength of mortar

In the first year chemical admixture materials used is Viscocrete 4100 as a high range water reducer and superplasticizer. Optimal mix is to use tailings as a substitute as much as 25%. Experiments were performed using the ratio of Water / Cement = 0.5, and cement 350 kg/m^3 produced compressive strength of mortar tailings at 28 days reached 307 kg/cm^2 See Table 4.1.

Tabel 4.1 Average compressive strength of tailings mortar at 7,14 and 28 days.

Ages	Average compressive strength of mortar				
(days)	MT 0	MT 25	MT 50	MT 75	MT 100
7	15	197	183	186	12
14	21	265	232	224	16
28	24	307	275	255	18

4.1.2 Scanning Electron Microscopy (SEM) micro photo.

a. Micro photo of tailings

Tailings are the waste metal mining. In this study, tailings used was a gold mine waste. Its parent rock taken from quartz veins that hard, grayish white to gray and then milled. The nature of the parent rock and the mining process is causing the tailings form jagged polygons. See Figure 4.1.

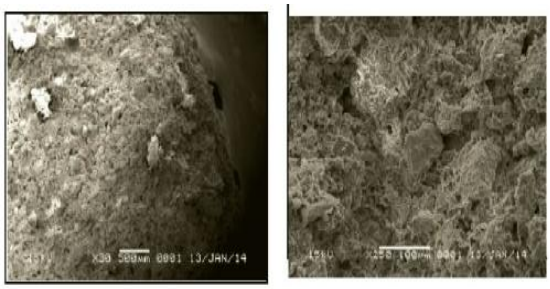

Figure 4.1. Scanning Electron Microscopy micro photo of tailings

b. Micro photo of tailings mortar.

Figure 4.2. SEM showed micro photo of tailing mortar with 100% tailings (MT 100), mortar with tailings 0% (MT 0), mortar with 50% tailings (MT 50), on the same scale.

In the MT 100 and MT 0, looked arrangement of tailings grain and sand grain alone. Tailings grain smaller than grain of sand. Around the two types of grain, there is a hardened cement paste as cement hydration results. Seen that the cement paste cover and bind the grain. Because tailings grain smaller than sand grain, the cement paste required MT 100 more than MT0. At the same cement content, the thickness of blanket of cement paste MT 100 is thinner than the MT 0. This is expected to result in the ability to hold stress MT100 lower than MT 0.

Being visible on MT 50, mixture of sand grain and tailings grain. Visible presence of grains that are large and small mixed and co-exist. Compression strength of MT 50 is greater than MT 0 and MT 100. This is expected due to the better aggregate gradation

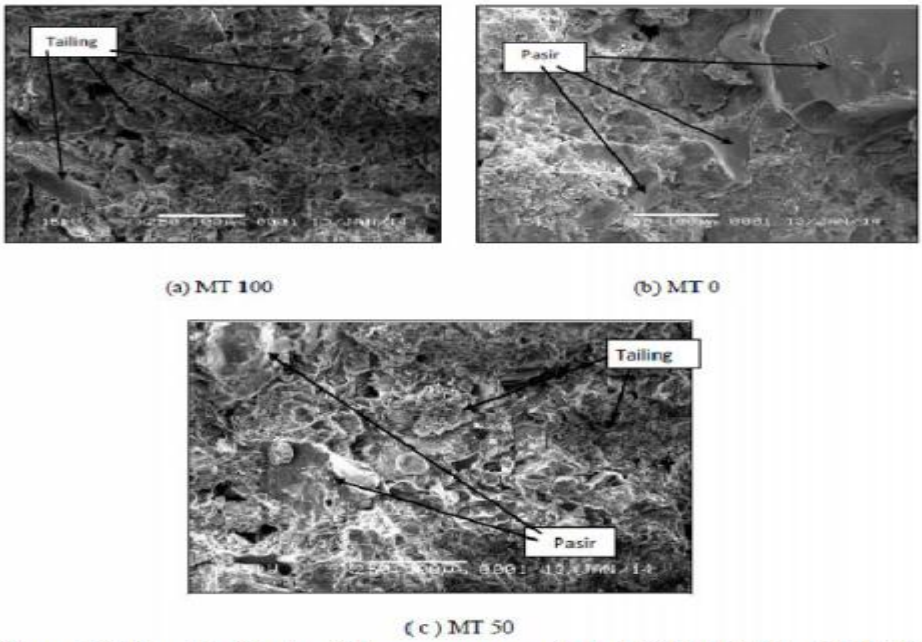

Figure 4.2. Scanning Electron Microscopy micro photo MT 100, MT 0 and MT 50.

Figure 4.3. SEM micrograph showing mortars with 100% of tailings (MT 100), mortar with 0% of tailings (MT 0), mortar with 50% of tailings (MT 50), at a scale 10 times smaller than the Figure 4.2. In the photo, visible results of hydration of cement, namely Calsium Silicate Hidrat (C-S-H) and Ca OH_2. The spread of C-S-H and Ca OH_2 same for MT100, MT 0 and MT 50.

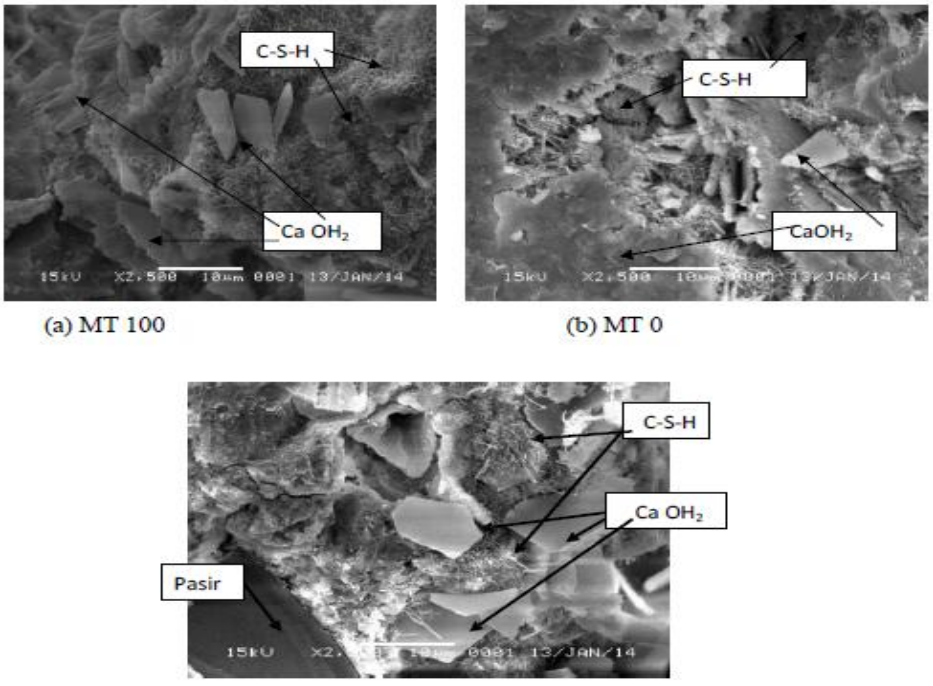

Figure 4.3. Scanning Electron Microscopy micro photo MT 100, MT 0 and MT 50.

c. Micro photo of cement

Micro photo of cement performed to determine the quality of the cement. The cement used in this study is Portland Composite Cement (PCC). PCC is a cement type 1 plus coal combustion products (fly ash). Poor semen quality contains many inactive fly ash, which will reduce the quality of the mortar or concrete.

SEM results of PCC can be seen in Figure 4.4. From these images it was found that the cement are clean. Therefore it can be concluded that the study have used a good cement, so that the hydration results obtained is already optimal results.

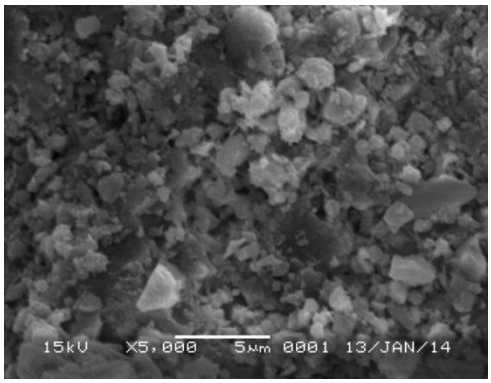

Figure 4.4. Scanning Electron Microscopy micro photo PCC

4.2. Result of the second year

In the second year, researchers made a mixture of mortar tailings experiments with the same composition with the first year, only added one more material admixture that is Polcon.

Table 4.2 Mortar composition to study effect of tailings

Tailing (%)	Name of Sample	Cement (gram)	Water (gram)	Silica sand (gram)	Tailing (gram)
0	Reference	500	242	1375.0	0.0
25	T-25			1031.3	343.8
50	T-50			687.5	687.5
75	T-75	500	242	343.8	1031.3
100	T-100			0.0	1375.0

Table 4.3 Compressive strength of tailings silica sand mortar

Polcon is composite monomer material to form a polymer composite-concrete or polymer composites-mortar with the aim to modify material properties and mechanical properties of concrete or mortar in order to have high performance.

4.2.1. Test results of mortar in the laboratory of PT Semen Baturaja.

A set of laboratory tests conducted to determine the strength of the mortar to be used for reference. Mortar is made according to Indonesian Standard method, ie using a mixture of water, cement and silica sand. The weight of water, cement and silica sand each is 242 grams, 500 grams and 1375 grams. Crushing compressive strength obtained at the age of 3 days, 7 days and 28 days respectively is 19 MPa, 21.9 MPa and 30 MPa.

a. Effect of tailings

The study was conducted with the substitute of silica sand with tailings gradually. To study the effect of tailings, one set of specimens made using 100% silica sand. Furthermore, the use of silica sand is reduced 25%, while the use of tailings is increased 25%. Mortar composition and test results of 3 days, 7 days and 28 days can be seen in Table 4.2 and Table 4.3. Ratio of water and cement used was 0.48. Samples are named according to the content of the tailings. Mortar with 25% content of the tailings, is named T-25 and soon.

Tailing	Name of sample	Ages (days)		
(%)		3	7	28
		Stress		
		(MPa)	(MPa)	(MPa)
0	Reference	19.0	21.9	30.0
25	T-25	25.8	29.2	32.7
50	T-50	12.3	14.2	16.6
75	T-75	15.3	17.6	23.4
100	T-100	5.6	8.4	11.1

This study shows that tailings substitution of 25% can raise the compressive strength at 3 days, 7 days and 24 days as many as 36%, 33% and 9%. Using of tailings more than 25% will decrease the compressive strength of mortar. See Figure 4.5. Judging from the value of the resulting compressive strength, 25% content of tailings produced the highest average compressive strength is 36.8 MPa.

See Table 5.2, Table 5.3 and Figure 5.2. A research "Study on the sprayed Concrete with Iron Tailing" conduct by Liu, (2012) indicated that the performance of 20% iron tailing to replace nature sand is the best. Study by MA.L.,(2012) about Concrete mix design of Tailings sand and gravel, using Water/Cement ratio of 0.5, tailing 744 kg/m^3, admixture

0.5%, the compressive strength of concrete can reach 48.3 Mpa

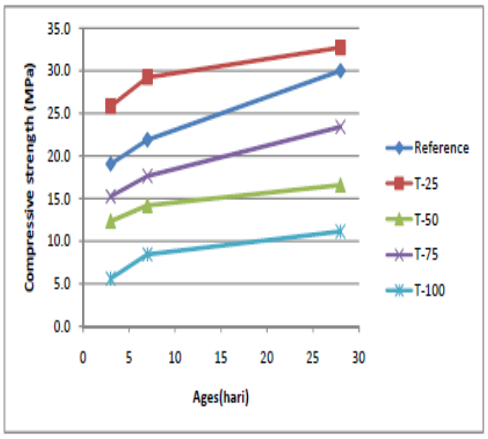

Figure 4.5. Effect of tailings in mortar compressive strength

b. Effect of admixture Polcon

Tabel 4.4 Composition mortar and concrete using Polcon.

Composition		
Material	Concrete	Mortar
Cement Type I	1 zak (50 Kg)	1zak (50 kg)
Sand	150 Kg	150 Kg
Split	81,5 Kg	0
POLCON	0,125-0,25 Lt	0,125-0,25
water	25 ltr	25 ltr

Tabel 4.5. Rise of concrete parameters after using Polcon

Sifat Mekanis	Kuat Tarik, MPa	Modulus Elastisitas, GPa	Kuat Tekan, MPa		Kuat Lekat Geser,KPa	Serapan Air, %	Ketahanan Thd Asam Klorida
			7 hari	28 hari			
Sebelum Pakai POLCON	2,5	24,5	163,2	251,1	875	5,5	1x
Setelah Pakai POLCON	5,6	14.0	268,6	413,0	≥4.550	...	4x

Table 4.6. Composition of tailings mortar to find out effect of Polcon.

PT Masushita Builders, 2013 has produced special admixture for tailings concrete. The suggested composition is tabulated in Table 4.4. Rise of concrete parameters after using Polcon according to PT Masushita Builders can raise the performance of concrete. See Table 4.5. Based on that table, this study use 2.5 cc for all of mixtures. That volume is 0.50% of the cement and 1% of the water. The samples are named TP-25, TP-50, TP-75 and TP-100. Composition of mixtures are shown in Table 4.6. The result of testing are shown in Table 4.7 and Figure 4.6. Additional of Polcon increase compressive strength of mortar TP-25 and TP-50 as many as 2% and 21%. In mortar with substitution of tailings more than 50%, the effect are not significant.

Tailing (%)	Name of Sample	Cement (gram)	Water (gram)	Silica sand (gram)	Tailing (gram)	Polcon (cc)
0	Acuan	500	242	1375.0	0.0	0
25	TP-25	500	242	1031.3	343.8	2.5
50	TP-50			687.5	687.5	2.5
75	TP-75			343.8	1031.3	2.5
100	TP-100			0.0	1375.0	2.5

Table 4.7. Effect of Polcon to mortar tailings compressive strength

Tailing (%)	Nama sampel	Umur (hari)		
		3	7	28
		Tegangan		
		(MPa)	(MPa)	(MPa)
0	Acuan	19.0	21.9	30.0
25	TP-25	22.9	27.3	33.5
50	TP-50	14.9	15.1	20.1
75	TP-75	13.0	14.7	17.9
100	TP-100	5.2	9.2	11.0

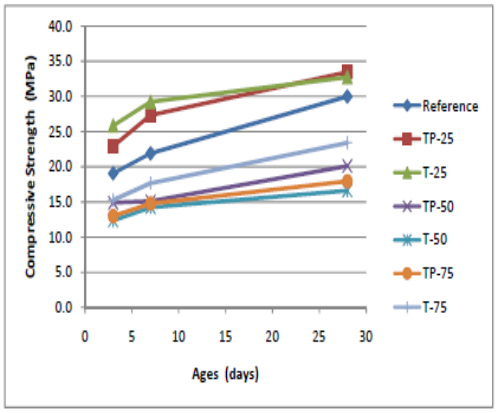

Figure 4.6 Effect of Polcon to mortar tailings compressive strength

c. Effect of sand to tailings mortar compressive strength.

Two testings above used silica sand as find aggregate. In the field producing of shotcrete can not use silica sand. To adjust with the trial in the field, a set of testing using sand from Kota Agung are used for find aggregate. The mixtures still use Polcon as admixture. Mortar composition and test results of 3 days, 7 days and 28 days can be seen in Table 4.8 and Table 4.9.Figure 4.7 shows that compressive strength of tailing mortar using Kota Agung sand (TPS) and tailing mortar using silica sand (TP) at 28 days. From that figure can be concluded that effect of sand is not significant.

Table 4.8. Composition of tailing mortar to find out effect of sand.

Tailing (%)	Name of Sample	Cement (gram)	Water (gram)	Kota Agung sand (gram)	Tailing (gram)	Polcon (cc)
0	Acuan	500	242	1375.0	0.0	0
25	TPS-25	500	242	1031.3	343.8	2.5
50	TPS-50			687.5	687.5	2.5
75	TPS-75			343.8	1031.3	2.5
100	TPS-100			0.0	1375.0	2.5

Table 4.9. Effect of sand to mortar tailing compressive strength

Tailing (%)	Name of sample	Ages (days)		
		3	7	28
		Stress		
		(MPa)	(MPa)	(MPa)
0	Reference	19.0	21.9	30.0
25	TPS-25	14.7	21.0	24.1
50	TPS-50	14.4	20.5	24.4
75	TPS-75	11.5	15	18.2
100	TPS-100	6.6	10.9	12.7

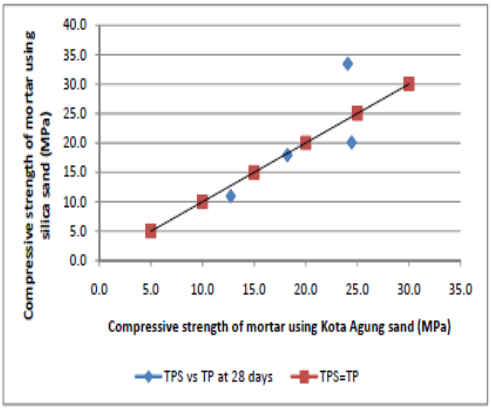

Figure 4.7 Mortar tailing compressive strength using Kota Agung sand versus using silica sand.

4.2.2. Results of shotcrete trial in the field.

One of the reason of this study is in the mining industry, there are a lot of shotcrete work. Shotcrete is needed for protecting slope and tunnel wall and tunnel roof from slope failure and collapse.
In this study, the shotcrete testing work is conducted in Way Linggo mining. The location of taking the tailing can be seen in Figure 4.8 (a) (b). Samples was made in the mold wood. The width and length of mold are 50 cm as many as 3 unit. Making shotcrete samples intended to apply the composition of the mixture of mortar tailings in the laboratory.
There are two kinds of shotcrete mixture composition those are: See Table 4.10.

a. First is composed of materials commonly used by PT Natarang Mining in the manufacture of shotcrete, ie cement, sand, water, and materials admixture (Sika grouting). The name of sample L-1.
b. Second is composed of material in this study those are cement, sand, tailing, water, and materials admixture (Polcon and Viscocrete).The name of sample L-2.

Table 4.10 Composition of tailings shotcrete in the field trial.

	Shotcrete without Tailings (L-1)	Shotcrete with Tailings (L-2)
Cement (kg)	50	50
Water (kg)	30	22
Sand (kg)	109	51
Admixture (mL)	270 (Sika Grouting)	100 (Polcon), 85 (Viscocrete)
Tailings (kg)	-	111 (wet)

At the time of the spraying process the L-1, there was the presence of falling concrete, this is due to adhesion only from cement, sand and water, so that the necessary concrete mix are pretty much the in order to achieve the desired sample thickness. Materials admixture (Sika grout) used to increase workability, moisture tolerant, solvent-free, and suitable for epoxy grouting sytem. At the time of one day old concrete, concrete surface begins to harden and crack does not occur. This is caused by the addition of admixture can prevent shrinkage forces (shrinkage, micro cracks, macro crack)

At the time of the spraying process the L-2, there was not much falling concrete, it caused the grain of tailings can fill the pores of the concrete mixture (cement, sand and water). At the time of the tailings shotcrete samples one day-old, the surface of the concrete begins to harden. but cracks occurred. These cracks are due at the time of hardened, concrete shrinks and the presence of internal stress cause the crack.

Compressive strength testing is done by using a hammer test equipment. Crushing compressive strength of sample L-1 and L-2 respectively are 17.5 MPa and 20.3 MPa. While the characteristic compressive strength of sample L-1 and L-2 respectively are 14.7 MPa and 9.2 MPa. Deviation standard of sample L-1 and L-2 respectively are 1.6 MPa and 6.8 MPa. It means that lack of uniformity of L-2 is much larger than L-1. This results in the characteristic compressive strength of L-2 is smaller than L-1.

Figure 4.9 shows the magnitude of the crushing compressive strength at 28 days of field samples and laboratory samples. It turns out that crushing compressive strength L-1 equivalent to TP-75 and crushing compressive strength of L-2 is equivalent to the TP-50. Tailings samples were used on the L-2 was 111 kg, and 51 kg of sand. Percentage of tailings on the total weight of fine aggregate = 111 / (111 + 51) x 100% = 68%. Water was 22 kg and cement was 50 kg, so that the ratio of Water / Cement (w/c) is 22/50 = 0,44. This figure is smaller than w/c mortar. Although tailings content is bigger, but the ratio w/c is smaller. Thus, the results of the L-2 is approximately equal to the laboratory results.The weakness of the L-2 is less homogeneous sample, so resulting large standard deviation.

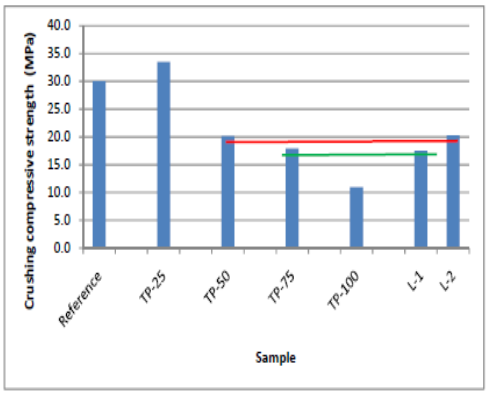

Figure 4.9 Laboratory and field crushing compressive strength. Laboratory sample: Reference, TP-25, TP-50, TP-75, TP-100 and field sample :L-1, L-2.

Conclusion

1. Mortar compressive strength according Indonesian standard (using silica sand) is 30 MPa
2. Compressive strength of mortar achieve optimum when the substitution of tailings by 25%. The compressive strength achieved in this experiment was 32.7 MPa when not using Polcon as added material. When using Polcon, the compressive strength reached 33.5 MPa. Dose Polcon is 0,50% of the cement and 1% of the water.
3. Effect of sand is not clear. Replacement of silica sand with sand of Kota Agung may increase or decrease the compressive strength of mortar.
4. Crushing compressive strength of sample L-1 and L-2 respectively are 17.5 MPa and 20.3 MPa. While the characteristic compressive strength of sample L-1 and L-2 respectively are 14.7 MPa and 9.2 MPa.
5. Crushing compressive strength of L-1 equivalent to TP-75 and crushing compressive strength of L-2 is equivalent to TP-50. Persentase of tailings of L-2 on the total aggregate was 68%.

Suggestion

1. It should be performed experiments using Polcon or other added admixture with higher doses. This is because higher admixture can increase the compressive strength of mortar.
2. Re-trial should be done in order to crack that occurs in shotcrete sought to be eliminated
3. The experiment should be carried out in the field again with the composition of the tailings 25% of the total weight of aggregate.
4. Care should be taken so that samples made in the field can be more homogeneous.

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