EFFECT OF SILICA FUME AND FLY ASH MATERIAL TO THE RECYCLED CONCRETE MORTAR STRENGTH: EXPERIMENTAL STUDY

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ABSTRACT

Concrete Mortar is a mixture of cement, sand, and water that usually used for a brick wall, wall plaster, lean concrete, concrete decking, paving block and others, because the concrete mortar has a low strength, that is 2 to 20 MPa. The high-cost component in the concrete mortar is cement, which is 20 – 30 percent of the sand content, so the price of the mortar can high. In the other case, the sand has taken from the river or hill-sand that can devastate the environment, so the research has only focus on the two components. There can be change or reduce to other material that aims to anticipate of two problems above. The cement can be reduced than be substituted by silica fume or fly ash that lower price with cement and the sand can be replaced by a recycled concrete mortar that similar characteristic with sand, so the price can be lower. The percentage of silica fume and fly ash in the experimental study are 0 – 20% from the cement content and the recycled concrete mortar is 100 % replaced the sand in the mortar. Base on the experimental study, the silica fume, and fly ash can increase the strength of the concrete mortar. The strength of recycled concrete mortar can be compared with sand concrete mortar. The percentage of the silica fume concrete in recycled concrete mortar is 10% and fly ash is 15% in order the same to the sand concrete mortar strength.

***Keyword**: silica fume, fly ash, concrete mortar, recycled concrete mortar, strength*

ABSTRAK

Mortar beton merupakan campuran semen, pasir, dan air yang sering digunakan untuk dinding bata, dinding plester, lantai kerja, beton ganjal, paving block dan lain-lain, hal ini dikarena mortar memiliki kekuatan yang rendah, yaitu 2 hingga 20 MPa. Semen merupakan komponen yang mahal dan prosentasenya adalah 20 - 30 persen daripada kandungan pasir, sehingga mortar masih cukup mahal. Dalam kasus lain, pasir yang digunakan diambil dari sungai atau pasir bukit yang dapat merusak lingkungan, sehingga penelitian hanya difokuskan pada kedua komponen. Kedua komponen tersebut adalah komponen yang dapat diganti atau dikurangi dengan tujuan untuk mengatasi kedua masalah tersebut di atas. Semen dapat direduksi dengan silika fume atau abu terbang yang harganya lebih murah daripada semen, dan pasir dapat diganti dengan mortar beton daur ulang yang memiliki karakteristik serupa dengan pasir, sehingga harga mortal menjadi turun. Persentase silica fume dan abu terbang dalam penelitian eksperimental ini adalah 0 - 20% dari kandungan semen dan kandungan mortar beton daur ulang adalah 100% menggantikan pasir dalam mortar. Berdasarkan studi eksperimental, silica fume dan abu terbang dapat meningkatkan kekuatan mortar beton. Dengan demikian, kekuatan mortar beton daur ulang dapat menyamai mortar beton yang dibuat dari pasir. Persentase beton silika fume dalam mortar beton daur ulang adalah 10% dan abu terbang adalah 15% agar kekuata antara mortar dengan pasir dan mortar daur ulang mempunyai yang sama.

Kata kunci *:* Slica fume, abu terbang, Beton Mortar, mortar daur ulang, kekuatan.

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INTRODUCTION

Concrete is a mixture of crushed stone, sand, cement, and water, but the concrete mortar is a mixture without crushed stone, which is only cement, sand, and water. Concrete is generally used for structural components, whereas concrete mortars are only used in non-structural components. Structural components are the main components in a building that support the structure of the building (such as foundations, columns, beams, and slabs), while non-structural components are only a complement to structural components and accessories (such as brick walls, plaster walls, work floors, wedge concrete, paving blocks and etc). Concrete has a compressive strength above 17 MPa (SNI 2847:2013 [25]), and concrete mortar only has strength of between 2 and 20 MPa (SNI 03-6882-2002 [23] or ASTM C270 [6]). Base on the strength capacity of concrete mortar that can be divided into four types, there are: Type O is 2.4 MPa, N is 5.2 MPa, S is 12.5 MPa, and M is 17.5 MPa (SNI 03-6882-2002 [23] or ASTM C270 [6]).

In the concrete and concrete mortar, the high price of components is cement, which is 20 – 30 percent of the sand content, so the price of the mortar can be high. In the other case, the sand has taken from the river or hill-sand that can devastate the environment. Base on those problems, the research was only focus to concrete mortar and concern to the cement components that aims to get an optimal research result and limit variable, where the two-components of concrete mortar can be change or reduce to other material. The cement can be reduced than be substituted by silica fume or fly ash that lower price with cement and the sand can be replaced by a recycled concrete mortar that similar characteristic with sand [1] & [7]. So this research is needed to examine the substitute materials of cement and sand to get cheaper the price and still have quality.

Fly ash is a waste material from burning pulverized coal in electric power generating plants and recycled concrete mortar has been taken from building demolish that has been crushed into fine aggregates and has characteristic similarly with sand [7-13].

In several experimental studies that have been done several years ago of the additional silica fume and fly ash in the concrete and recycled concrete aggregates can increase the strength of the concrete [7-19] and how about concrete mortar? So, this research concern to the concrete mortar in especially in the recycle concrete mortar, because the research about recycled concrete mortar did not much be done and especially for additional silica fume and fly ash in the recycled concrete mortar did not much be done.

Base on the result of an experimental study by Antoni [1], and other researchers [8-20] about silica fume and fly ash content in the sand concrete mortar can increase the compressive strength especially at an early age after. The research of Budiman [7], Ginting [10], Kesegić [13], Khalaf [14] have research for recycled concrete mortars and the result of the researches was decreasing strength when comprised of sand concrete mortar. Referring to the above researches, this research carries out the silica fume and fly ash material which is blended in the recycled concrete mortar to know the strength it. What about did the use of silica fume and fly ash in the recycled concrete mortar? Is it increases likes sand concrete mortar when using silica fume and fly ash?

EXPERIMENTAL PROGRAM

A. Concrete Mortar Base Material Test

The experimental program of recycled concrete mortar has been started from taking cement, silica fume, fly ash, sand, water, and collecting a building demolish material, and then it is crushed by manual to get a fine aggregate.

Cement and silica fume have been taken from building material store near Wiralodra University - Indramayu. Fly ash is taken from PLTU Sumur Adem, Sukra, Indramayu - West Java. Sand is taken from Tomo, Sumedang - West Java.

Base on the laboratory test [2-6] & [21-24] of fly ash physical traits are:

a) Color is whitish gray;
b) Density is 2.15 g/cm^3;
c) Fine grain is 80% passing sieve no. 200.

Silica fume physical traits are:

a) Color is grayish;
b) Specific gravity is 0.65 g/cm^3;
c) Fine grain is more than 90% passing sieve no. 200.

The fine aggregate that is taken from building demolish is called recycled fine aggregate (RFA). The characteristic of it shall be similar to sand, such as gradation (grain level arrangement), water content, specific gravity, and water absorption, so they are would be tested as SNI [22] or ASTM C-136-06 [3].
Base on the result testing of fine aggregate characteristics, the sand and recycled fine aggregate can be seen in the following figure and table.

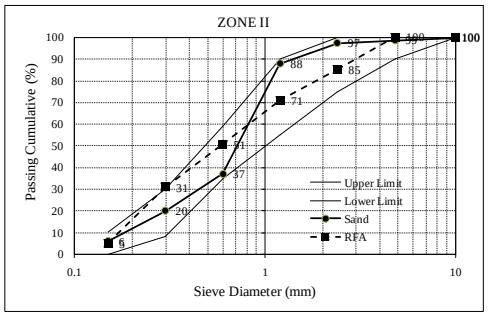

Figure 1. Sieve analysis of fine aggregate

Figure 1 indicates that all fine aggregate (sand and recycled fine aggregate or RFA) are in the limit range of the Zone II SNI [24] or ASTM standard [5], so those fine aggregate can use to make concrete mortar. The water content of sand is 11.71% and recycled fine aggregate is 19.71%. The water absorption of RFA is larger than sand. The specific gravity of sand is 2.53, and recycled aggregate is 1.88. The specific gravity of RFA is smaller than sand.

B. Preparation of Specimens

The type specimen is a cube in which the dimension is 5 cm for all sides. This dimension bases on SNI [23] or ASTM [6].

a) Form work b) Pouring c) curing

Figure 2. Pouring and curing specimen

All of the specimens have made in various that based on silica fume and fly ash content (there are 0%, 5%, 10%, 15%, and 20%), and the water-cement ratio (w/c) (there are: 0.5 and 0.6).
A material proportion of mortar that makes the specimen can be seen in Table 1.

Table 1. Material proportion of mortar

Material	Type N-w/c 0.5 (gr)	Type S-w/c 0.5 (gr)	Type M-w/c 0.5 (gr)	Type N-w/c 0.6 (gr)	Type S-w/c 0.6 (gr)	Type M-w/c 0.6 (gr)
Cement	309	323	337	309	313	329
Water	155	162	169	186	188	196
Concrete Mortar						
Sand	1886	1857	1828	1886	1799	1769
Recycled Concrete Mortar						
RFA	1402	1380	1359	1.402	1337	1314

Furthermore, all material proportions in Table 1 make several variations for silica fume and fly ash content there are a percentage of silica fume and fly ash are 0%, 5%, 10%, 15%, and 20% by weight of cement. It aims to know the optimum percentage content of silica fume and fly ash in the mortar.

C. Crushing Test

The next step of the experimental study is a crushing test for all of the specimens that the crushing machine uses Universal Testing Machine (UTM). The UTM can be seen in Figure 3. The crushing test aims to get a compressive strength of the mortar that is an indicator of the type of concrete mortar as an above explanation.
The specimen set in the UTM (see Figure 4.a) and the loading rate is 2 kg/cm^2/second [4] until crushed (see Figure 4.b). The maximum load shall be recorded.

Figure 3. Universal Testing Machine (UTM)

a) Setting up specimen b) Post testing

Figure 4. Testing specimen

TEST RESULT AND DISCUSSION

The concrete specimen has been measured density. The result of the measuring can be seen in Table 2.

Table 2. Average weigh/volume of concrete mortal

Concrete mortar	Type N-w/c 0.5 (kg/m^3)	Type S-w/c 0.5 (kg/m^3)	Type M-w/c 0.5 (kg/m^3)	Type N-w/c 0.6 (kg/m^3)	Type S-w/c 0.6 (kg/m^3)	Type M-w/c 0.6 (kg/m^3)
Sand concrete mortar	2225	2258	2268	2221	2234	2233
Recycled concrete mortar	2218	2222	2228	2154	2156	2166

Base on the density measurement, the recycled concrete mortar has lower than sand concrete mortar. The RFA specific gravity of RFA is smaller than sand, so the density and water absorption are larger than sand. Those results can cause to the density. The absorption values of the materials can the porosity of the concrete mortar, so the density value of recycled concrete mortar smaller than sand concrete mortar.

The next step of the analysis is a crushing test. The concrete mortar specimen has been tested by crushing test to obtain the strength of concrete mortar. The concrete mortar strength result can be seen in Table 3 and 4.

Table 3. Crushing test of silica fume content in concrete mortar at 28 days age

Concrete mortar	Type N-w/c 0.5 (kg/m^3)	Type S-w/c 0.5 (kg/m^2)	Type M-w/c 0.5 (kg/m^2)	Type N-w/c 0.6 (kg/m^2)	Type S-w/c 0.6 (kg/m^2)	Type M-w/c 0.6 (kg/m^2)
0%						
Sand concrete mortar	6.02	12.84	18.50	5.96	12.40	18.22
Recycled concrete mortar	5.76	11.54	18.12	5.52	11.26	17.07
5%						
Sand concrete mortar	6.51	13.00	18.70	6.10	12.80	18.34
Recycled concrete mortar	5.84	12.20	18.32	5.78	11.64	17.14
10%						
Sand concrete mortar	6.62	13.24	18.84	6.23	13.20	18.54
Recycled concrete mortar	5.98	12.54	18.70	5.96	12.28	17.26
15% SF						
Sand concrete mortar	6.56	13.12	18.73	6.15	12.90	18.41
Recycled concrete mortar	5.28	12.28	18.38	5.90	12.12	16.90
20% SF						
Sand concrete mortar	6.10	12.90	18.55	6.00	12.50	18.20
Recycled concrete mortar	5.24	12.14	18.24	5.22	11.76	16.72

Table 4. Crushing test of fly ash content in concrete mortar at 28 days age

Concrete mortar	Type N-w/c 0.5 (kg/m^2)	Type S-w/c 0.5 (kg/m^2)	Type M-w/c 0.5 (kg/m^2)	Type N-w/c 0.6 (kg/m^2)	Type S-w/c 0.6 (kg/m^2)	Type M-w/c 0.6 (kg/m^3)
0%						
Sand concrete mortar	6.02	12.84	18.50	5.96	12.40	18.22
Recycled concrete mortar	5.76	11.54	18.12	5.52	11.26	17.07
5%						
Sand concrete mortar	6.10	12.91	18.62	6.02	12.52	18.24
Recycled concrete mortar	5.86	11.90	18.52	5.61	11.46	17.13
Concrete mortar	Type N-w/c 0.5 (kg/m^2)	Type S-w/c 0.5 (kg/m^2)	Type M-w/c 0.5 (kg/m^2)	Type N-w/c 0.6 (kg/m^2)	Type S-w/c 0.6 (kg/m^2)	Type M-w/c 0.6 (kg/m^3)
10%						
Sand concrete mortar	6.53	13.04	18.73	6.17	12.97	18.42
Recycled concrete mortar	5.93	12.13	18.70	5.77	12.02	17.22
15% SF						
Sand concrete mortar	6.56	13.18	18.82	6.19	12.96	18.41
Recycled concrete mortar	5.88	12.53	18.63	5.83	12.30	17.23
20% SF						
Sand concrete mortar	6.11	12.92	18.64	6.06	12.53	18.33
Recycled concrete mortar	5.13	11.75	17.88	4.42	11.21	16.87

All values of the crushing or compressive test in Tables 3 and 4 can be made a curve to see ascending or descending strength value of concrete mortar and accession strength value to standard value that has been write on the above chapter as ASTM [6] & SNI [21]. The curve of concrete mortar strength versus the percentage of silica fume and fly ash content in the concrete mortar can be seen in Figure 5 to 8. All of the curves illustrate for each strength value of concrete mortar and those curves also can signify the peak strength for each specimen that

different percentages of silica fume and fly ash content. The peak value indicates the optimum value of silica fume and fly ash content in the mortar.

The names of several specimens as shown in the curves are:

- SCM-N-w/c 0.5: SCM is Sand Concrete Mortar; N is type of mortar that is type N; w/c 0.5 is a water-cement ratio. The type of line is a straight line with a square mark.
- SCM-S-w/c 0.5: SCM is Sand Concrete Mortar; S is a type of mortar that is type S; w/c 0.5 is a water-cement ratio. The type of line is a straight line with a triangle mark.
- SCM-M-w/c 0.5: SCM is Sand Concrete Mortar; S is a type of mortar that is type M; w/c 0.5 is a water-cement ratio. The type of line is a straight line with a round mark.
- RCM-N-w/c 0.5: RCM is Recycled Concrete Mortar; N is a type of mortar that is type N; w/c 0.5 is a water-cement ratio. The type of line is a dash-dot line with a cross mark.
- RCM-S-w/c 0.5: RCM is Recycled Concrete Mortar; S is a type of mortar that is type S; w/c 0.5 is a water-cement ratio. The type of line is a dash-dot line with a star mark.
- RCM-M-w/c 0.5: RCM is Recycled Concrete Mortar; S is a type of mortar that is type M; w/c 0.5 is a water-cement ratio. The type of line is a dash-dot line with a plus mark.

Those names are also similar for w/c 0.6.

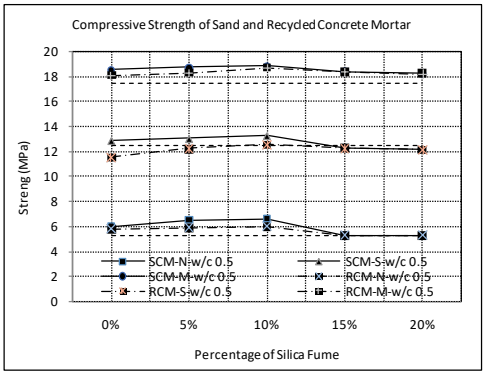

Figure 5. Compressive strength curve of silica fume content in the w/c 0.5.

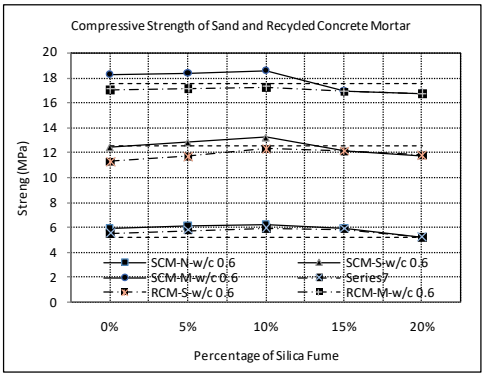

Figure 6. Compressive strength curve of silica fume content in the w/c 0.6.

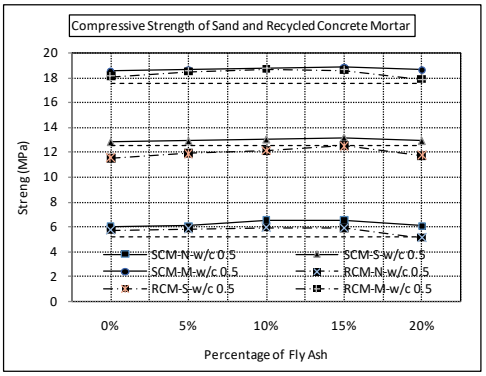

Figure 7. Compressive strength curve of fly ash content in the w/c 0.5

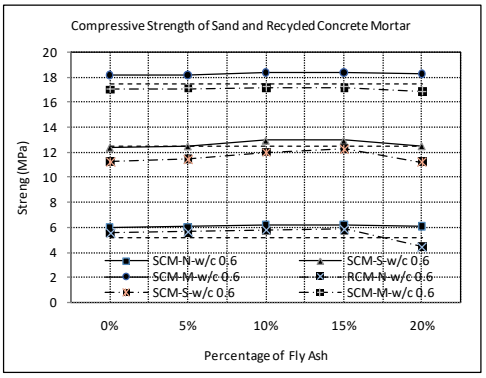

Figure 8. Compressive strength curve of fly ash content in the w/c 0.6

All of the curves indicate which the strength of recycled concrete mortar is lower than the sand concrete mortar. That cause that the recycle fine aggregate water absorption is higher than sand and a specific gravity of recycled fine aggregate is a lower value than sand. Those characteristics may cause more porous in the concrete mortar and those also cause density of recycled concrete mortar lower value than sand concrete mortar.

The w/c 0.5 of sand concrete mortar strength can reach above the target strength standard, but the recycled concrete mortars strength cannot suitable to the target strength standard for all various silica fume and fly ash that an original recycled concrete mortar that is 0% silica fume and fly ash content. So, the original recycled concrete mortar has not recommended, except for the lower strength.

The w/c 0.6 of sand concrete mortar strength can meet above the target strength standard, but all of the recycled concrete mortar strength cannot meet the target strength standard. So the w/c 0.6 of recycled concrete mortar has not been recommended. So, the w/c 0.6 is not recommended for construction material.

Furthermore, those curves can be analyzed to get the optimum value of silica fume and fly ash content in the concrete mortar and strength values target to the standard. Base on the curves, the optimum strength values of concrete mortar are 10% content of silica fume and 15% content of fly ash for sand concrete mortar. The recycled concrete mortar can increase the strength to the standard when it is added by 10% silica fume and 15% fly ash, so the recycled concrete aggregate can be used for non-structural material that it is similarly characteristic with san concrete mortar.

CONCLUSION

Based on the experimental study, conclusions can be taken in the following sentences:

- The water absorption of recycled fine aggregate is higher than sand and the specific gravity is lower than sand. Those can affect the porosity that is indicated with a lower value of density of concrete mortar. The density of recycled concrete is lower than sand concrete mortar.
- Specimens have been made with two several of water-cement ratios (w/c) those are 0.5 and 0.6. Base on the experimental result. The recycled concrete mortar strength with w/c 0.6 did not reach to the strength standard. So, a recycled concrete mortal cannot be used for nonstructural building material, because it cannot reach to strength standard. So, recycled concrete mortar with w/c 0.6 is not recommended.
- The experimental result of silica fume and fly ash optimum content in the concrete mortar are 10% for silica fume and 15% for fly ash. Those percentages obtain peak strength for each variation of a mixture of concrete mortar. So, those percentage can be used for all mixture of sand and recycle concrete mortar.

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