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Potential of Gypsum Waste as a Substitution and Filler Material in Concrete Manufacturing

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A B S T R A C T

Gypsum is a dental and construction material that used only at certain times. Gypsum waste can be mixed with food waste so that it endangers the environment. The gypsum waste needs to be separated and recycled. This study examines the potential use of gypsum waste as substitute and filler material in concrete manufacture, including: gypsum characteristic based on XRF, concrete maximum load, concrete compressive strength, concrete water absorption and heavy metal concentration analysis. Gypsum compositions used is 0%, 10%, 20%, 30%, 40% and 50%. The gypsum characterization results showed that there was 98.92% oxide, gypsum was included in type III gypsum, heavy metals such as: Fe = 10 ppm and Al = 16500 ppm, metallic elements such as: Si = 1950 ppm, Ca = 182900 ppm, Mg = 4560 ppm, K = 2200 ppm, and non-metallic elements namely: P = 580 ppm. The content of heavy metals in gypsum is very dangerous for living creatures because the concentration is above the established quality standards. The highest and lowest of maximum load and concrete compressive strength in the gypsum use as substitute and filler material are produced at the addition of 50% and 10% gypsum, respectively. The gypsum addition as substitute or filler material reduces the concrete water percentage. The heavy metals concentrations resulting from the 28-day-old concrete immersion were: Fe = <0.084 ppm and Al = <0.156 ppm.

INTRODUCTION

Gypsum is a natural mineral in the form of a white solid obtained from mining. This mineral contains calcium sulfate dihydrate ($CaSO_4.2H_2O$) which will be converted into calcium sulfate hemihydrate if the calcination process occurs [1]. Gypsum is widely used as a material in dentistry. These products have been used to diagnose, plan, treat and manufacture indirect restorations for many years.

Gypsum can be used at certain times and after that it must be thrown away. Furthermore, gypsum waste disposed of in landfills can be mixed with food waste. This results in the process of breaking down gypsum by bacteria in food waste, thereby releasing hydrogen sulfate gas. This event is very dangerous for land, water, forests, and aquatic biota. To maintain safety, discarded gypsum waste must be separated and recycled [2]. In the construction sector, gypsum is also used as a building material which functions as a substitute material and filler in making concrete. So, gypsum is also known as a material for interior decoration and artistic creation of buildings [1]. This material can also be used as a mixture of Portland cement [3].

Based on the results of research conducted by Hasmudi (2017), it was found that normal concrete has a compressive strength of 36.00 MPa. Meanwhile, concrete with 14%, 17% and 20% gypsum waste additives each obtained a compressive strength of 39.33 MPa: 41.67 MPa and 43.33 MPa. Looking at the research results, it can be concluded that the use of gypsum waste additives greatly influences the compressive strength of concrete. Concrete with variations in gypsum waste additives of 14%, 17% and 20% increased the compressive strength of normal concrete. Thus, the addition of gypsum powder waste can increase the compressive strength value of concrete [4].

Based on the description above, the author is interested in researching the potential of gypsum waste as a substitute material and filler in making concrete. The aim of this research is to examine the potential for using gypsum waste as a substitute material and filler in making concrete. The research results obtained can later be used as a solution to the problem of handling gypsum waste so that it does not pollute the environment and as a recommendation for concrete making materials for construction experts so that it is useful in developing construction technology in the future [5].

METHODS

Materials and Equipment

The materials used in this research were Portland cement type I, fine aggregate (sand), coarse aggregate (gravel), gypsum waste obtained from a dentist's practice in Padangsidimpuan, North Sumatra and water. The equipment used in this research is a set of ASTM sieves, analytical scales, oven, molen machine, square mold measuring 15 cm x 30 cm, Compression Strength Machine, water reservoir, a set of Atomic Absorption Spectroscopy (AAS) tools, X-Ray Flourescence (XRF) Thermo ARL 9900 and other tools.

Research Variations

This research was conducted with fixed variables and independent variables so that the dependent variable will be obtained. These variables will be described as follows:

a. Fixed variables, consisting of:
i. Test object size: 15 cm x 30 cm [6]
ii. Mix Design: IS-10262-2009 [7]

b. Independent variables, consisting of:
i. Gypsum mixture composition as a substitute and filler material: 0%, 10%, 20%, 30%, 40% and 50% of the cement requirements used.
ii. Soaking time: 7, 14 and 28 days.
iii. The composition of the use of gypsum waste as a substitute material is presented in Table 1 below:

Table 1. Composition of Gypsum as a Substitute Material [5]

Gypsum Variation (%)	Composition of Ingredients (kg)			
	Gypsum	Cement	Sand	Gravel
0	0	0.83		
10	0.083	0.747		
20	0.249	0.581		
30	0.415	0.415	1.67	2.5
40	0.581	0.166		
50	0.747	0.083		

The use of gypsum waste as a substitute for cement is carried out by reducing the use of cement and adding gypsum waste in the specified amount. This means that the more gypsum waste composition that is added, the less cement composition required.
iv. The composition of gypsum waste used as filler is presented in Table 2 below:

Table 2. Composition of Gypsum as a Filler Material [5]

Gypsum Variation (%)	Compositions of Ingredients (kg)			
	Gypsum	Cement	Sand	Gravel
0	0			
10	0.083			
20	0.249			
30	0.415	0.83	1.67	2.5
40	0.581			
50	0.747			

The use of gypsum waste as a filler is carried out by adding gypsum waste in the specified amount without reducing the required cement composition. This means that the addition of gypsum waste to concrete does not affect the required cement composition.

c. The dependent variable in this research is the compressive strength of the concrete produced after adding gypsum waste as a substitute and filler material.

Research procedure

1. Gypsum characterization analysis using the X-Ray Flourescence (XRF) Thermo ARL 9900 method

Gypsum characterization analysis was carried out with the aim of knowing the elemental content contained in gypsum and its percentage. Gypsum characterization analysis using the XRF method is carried out through the following stages:
a. 5 grams sample of gypsum waste was put into a bottle and weighed.

b. Binder/Carboxy Methyl Cellulose as much as 5 grams was added to the gypsum waste sample.
c. The mixture was put into a Herzog ball mill for 40 seconds.
d. The grinding results are poured into an aluminum tray and the grinder is cleaned with a brush.
e. The crushed sample was inserted into a stainless-steel ring and pressed with a pressure of 120 kN for 40 seconds.
f. The stainless-steel ring was taken, and the sample was inserted into a Thermo ARL 9900 machine [8].

2. Making concrete

The manufacture of test objects is carried out based on SNI 2493: 2011. The process of making test objects is carried out through the following stages:
a. Gypsum solid waste that has been analyzed is prepared and dried.
b. The gypsum waste is mixed with cement, sand, gravel and water until smooth according to the composition in Table 1 and Table 2.
c. Once flat, the mixture is compacted using a milling machine.
d. Then the resulting mixture is put into the mold.
e. The printed concrete is then dried for 24 hours in an open room.
f. Next, the concrete is soaked for 28 days [6].

3. Maximum load and compressive strength testing

Concrete compressive strength testing was carried out at the age of 28 days, where the test specimens were removed from the soaking tub the day before. Concrete compressive strength testing is carried out through the following stages:
a. The compressive strength of the test specimens that are ready is determined using a press machine whose pressing speed has been set.
b. The pressing speed from the application of the material until the test object is destroyed is set at no less than 1 minute and no more than 2 minutes.
c. The compressive strength of the test specimen is calculated by dividing the maximum load when the specimen is crushed by the gross compressive area and is expressed in kg/mm^2. So it is formulated:

$$f'c = P/A \tag{1}$$

Information:
$f'c$ = concrete compressive strength (kg/mm^2)
P = maximum load (kg)
A = area of compression area (mm^2)
d. The experiment was repeated for each test object [9].

4. Water absorption testing

Water absorption testing is carried out by soaking concrete samples for 24 hours at an age of more than 28 days. Water absorption testing is carried out through the following stages:
a. The test object is completely soaked in water for up to 24 hours, then its weight is weighed while wet.
b. Then the test object is dried in an oven for ± 24 hours at a temperature of 105°C until the difference between the first and second weighings is no more than 0.2%.
c. The amount of water absorption is calculated using the equation:

$$\text{Water absorption} = \frac{(B - B_0)}{B_0} \text{ x } 100\% \tag{2}$$

Information:
B_0 = dry weight of the test object (kg)
B = weight of the test object after immersion (kg) [10]

5. Metal concentration analysis test

The metal concentration analysis test was carried out using Atomic Absorption Spectroscopy (AAS). The stages of the metal concentration analysis test are as follows:
a. A sample of 50 mL of the solution was taken and put into a beaker glass.
b. Then ± 30 mL of concentrated HCl and 10 mL of concentrated HNO_3 were added to the sample and covered with a watch glass.
c. Next, the sample was heated over a water bath until it boiled for ± 30 minutes.
d. Then the watch glass cover is opened and the solution is evaporated in a water bath until dry and a little HCl is added until the solution is dry and cold.
e. The solution is added with ± 25 mL of HCl and heated until everything is dissolved then cooled.

f. Next, the solution was transferred into a 100 mL volumetric flask and diluted with distilled water to the mark.
g. Then the solution was measured with AAS [11].

RESULT AND DISCUSSION

Gypsum Characterization Analysis Using Thermo Arl 9900 X-Ray Flourescence (XRF) Method

XRF analysis is used to determine the element content in gypsum and its percentage. The results of the gypsum characterization analysis that have been carried out are presented in Table 3 below.

Table 3. Content of Chemical Ingredients in Gypsum

Oxide	Amount (%)	Element	Amount (%)	Amount (ppm)	Quality Standards (ppm)
SiO_2	0.55	Si	0.195	1950	30
Fe_2O_3	0.017	Fe	0.001	10	55000
CaO	28.85	Ca	18.29	182900	500
P_2O_5	0.2	P	0.058	580	0.2
SO_3	68.145	S	27.35	273500	-
TiO_2	0.28	Ti	0.168	1680	-
K_2O	0.087	K	0.22	2200	10
SrO	0.104	Sr	0.0088	88	-
Lu_2O_3	0.002	Lu	2.34	23400	-
V_2O_5	0.001	V	0.0006	6	-
ZrO_2	0.001	Zr	0.0007	7	-
MgO	0.228	Mg	0.456	4560	500
Al_2O_3	1.145	Al	1.65	16500	16554.30

From Table 3 above, it can be seen that the largest oxide content in the gypsum used is SO_3 (68.145%), CaO (28.85%), Al_2O_3 (1.145%), SiO_2 (0.55%) and MgO (0.228%) . So the largest total oxide content in the gypsum is 98.92%. Based on the total oxide content obtained, it shows that the gypsum used in this research is type III gypsum. For more details, the comparison between types I, II, III, IV and V gypsum can be seen in Table 4.

Type III gypsum is a type of gypsum that has a SO_3 content of 66.995%-69.294%, CaO of 28.113%-29.586%, Al_2O_3 of 1.018%-1.272%, SiO_2 of 0.435%-0.655% and MgO of 0.149%-0.307%. Apart from that, the total oxide content in this type of gypsum is 96.868%-100% [13]. The high calcium content in type III gypsum means this material can improve the properties of concrete.

Calcium is one of the constituent elements of Portland cement so it can be used as a partial replacement for cement to increase and improve the mechanical and physical properties of concrete so that it is better than concrete without additives [14]. Gypsum does not have the binding ability like cement, but the silica oxide (SiO_2) in it can react with calcium hydroxide, ($Ca(OH)_2$), the result of the cement hydration process to produce a compound that is capable of binding. The reactions that occur in this process are [15]:

$$3Ca(OH)_2 + 2SiO_2 + H_2O \rightarrow 3CaO.2SiO_2.3H_2O$$

$$3Ca(OH)_2 + 2\,Al_2O_3 + H_2O \rightarrow 3CaO + 2\,Al_2O_3 + 3H_2O \quad (3)$$

From Table 3 above it can also be seen that the gypsum used contains heavy metals but does not exceed the specified quality standards, such as: iron (Fe) = 10 ppm with a quality standard value of 55,000 ppm [16] and aluminum (Al) = 16,500 ppm with a standard value. quality 16554.30 ppm [17]. So, these two heavy metals are not dangerous for living creatures and the environment because their concentrations are below the threshold.

Table 4. Characteristics of Gypsum Types I, II, III, IV and V [12]

Specification	Type I	Type II	Type III	Type IV	Type V
Characteristic	Stiff material	High compression, large expansion settings	Medium compression and expansion settings	The smallest compression and expansion settings	High compression, large expansion settings
Utility	Scoring the edentulous area	-Filling cuvettes in making dentures - Model study and model embedding in the articulator	Create a working model of a denture	- Create a night pattern from a restoration - As a tool for inlays, crowns and bridges	As a tool to compensate for the shrinkage of metal casting when cooling after heating to high temperatures
Total Oxide	78.1%-79.65%	89.7%	96.868%-100%	98.646%	99.6%
Main Ingredient	Calcined calcium sulfate hemihydrate	Calcined calcium sulfate/β-hemihydrate	Hydrocal/α-hemihydrate	Cuboidal and salt particles	Cuboidal particles and a small amount of salt

Apart from that, there are several metals that have concentrations above the threshold value, such as: silicon (Si) = 1950 ppm with a quality standard value of 30 ppm [18], calcium (Ca) = 182900 ppm with a quality standard value of 200 ppm [19], magnesium (Mg) = 4560 ppm with a quality standard value of 150 ppm [19], potassium (K) = 2200 ppm with a quality standard value of 10 ppm [19]. Heavy metals that have concentrations above this quality standard are very dangerous for the health of living creatures because they are toxic in the body. Apart from that, there are also non-metallic elements contained in gypsum and their concentrations exceed the threshold, namely: phosphorus (P) = 580 ppm with a quality standard value of 1 ppm [20]. Metal and non-metal elements that have concentrations above quality standards will be dangerous for living things and the environment, causing gypsum waste to become B_3 waste.

One of the methods used to process B_3 waste is the stabilization/solidification (S/S) method. This method is widely used to process inorganic substances in B_3 waste using cement as a binding material. The working principle is to mix gypsum with cement, fine aggregate (sand), coarse aggregate (gravel) and water. So gypsum functions as a substitute material and filler in making concrete [5].

Concrete Maximum Load Test

1. The effect of the percentage of gypsum as a substitute material on the maximum load of concrete

The maximum load test results for concrete with gypsum waste as a substitute material can be seen in Figure 1 below.

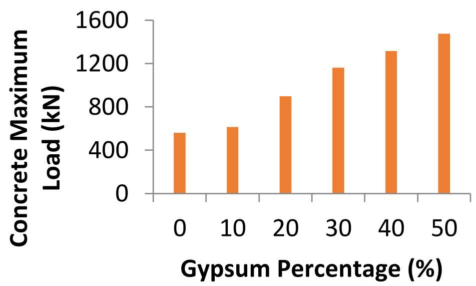

Figure 1. Graph of the Effect of the Percentage of Gypsum as a Substitute Material on the Maximum Load of Concrete

Based on Figure 1 above, the maximum load on concrete produced from a mixture composition using 0% gypsum (without gypsum substitution) is 562.19 kN. The highest maximum concrete load produced was obtained when using gypsum as a 50% substitution material, namely 1476.31 kN. Meanwhile, the lowest maximum concrete load produced was obtained when using 10% gypsum as a substitute material, namely 613.40 kN. The use of gypsum as a substitute material results in the maximum load of concrete continuing to increase.

An increase in the maximum load of concrete shows that the quality of concrete as a construction material is getting better. The maximum concrete load is directly proportional to the compressive strength of the concrete. So, an increase in the maximum load of concrete also shows an increase in the compressive strength of the concrete. The compressive strength of concrete also increases with the more gypsum added to normal concrete, indicating that the quality of the concrete is getting better. Thus, the increase in maximum load resulting from the addition of gypsum as a substitute material also shows better concrete quality.

2. The effect of the percentage of gypsum as a filler on the maximum load of concrete

The maximum load test results for concrete with gypsum waste as filler material can be seen in Figure 2 below.

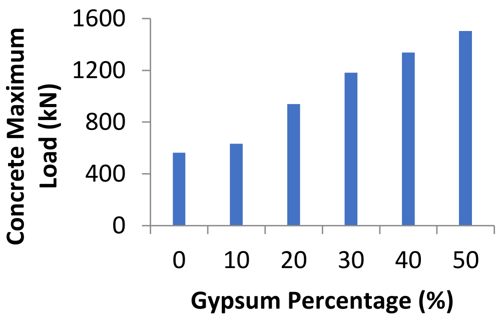

Figure 2. Graph of the Effect of the Percentage of Gypsum as a Filler Material on the Maximum Load of Concrete

Based on Figure 2 above, it can be seen that the maximum load on concrete produced from a mixture composition using 0% gypsum (without gypsum substitution) is 562.19 kN. The highest maximum concrete load produced was obtained when using 50% gypsum as a filler material, namely 1502.12 kN. Meanwhile, the lowest maximum concrete load produced was obtained when using 10% gypsum as a filler material, namely 633.58 kN. The use of gypsum as a filler material results in the maximum load of concrete continuing to increase. Thus, the use of gypsum as a filler material in making concrete can also increase the maximum load of concrete [5].

The maximum load resulting from adding gypsum as a filler material is higher than the maximum load resulting from adding gypsum as a substitute material. This is because the addition of gypsum to cement as a filler does not reduce the percentage of cement so that the binder element in cement (SiO_2) will increase so that the maximum load of the resulting concrete also increases [21].

Previous research shows that gypsum's function as a filler can increase internal cohesion and reduce porosity as a transition area (smallest area) in concrete. This makes the concrete stronger. Apart from that, gypsum also plays an important role in changing the strength of concrete aged 7 days to 28 days. This increase in concrete strength is due to a combination of cement hydration and pozzolan reaction [22].

Concrete Compressive Strength Test

1. The effect of the percentage of gypsum as a substitute material on the compressive strength of concrete

Concrete compressive strength tests are carried out to determine the strength of concrete according to the needs of the planned building structure [5]. The results of testing the compressive strength of concrete with gypsum waste as a substitute material which was carried out after 28 days can be seen in Figure 3 below.

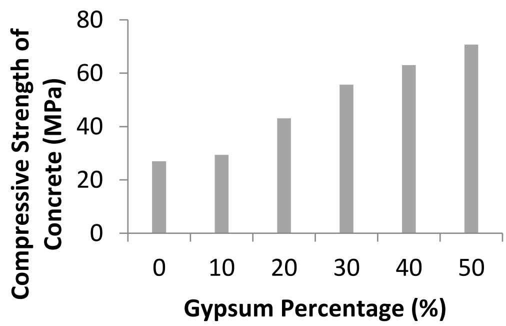

Figure 3. Graph of the Effect of the Percentage of Gypsum as a Substitute Material on the Compressive Strength of Concrete

Based on Figure 3 above, it can be seen that the compressive strength of concrete produced from a mixture composition using 0% gypsum (without gypsum substitution) is 26.93 MPa. The highest value of concrete compressive strength produced was obtained when using gypsum as a 50% substitute material, namely 70.73 MPa. Meanwhile, the lowest concrete compressive strength value produced was obtained when using 10% gypsum as a substitute material, namely 29.39 MPa. The use of gypsum as a substitute material above 10% results in continuously increasing concrete compressive strength values. Thus, the use of gypsum as a substitute material in making concrete can increase the compressive strength value of concrete [4].

The gypsum contained in the cement mixture is able to increase the strength of concrete because the reactive SiO_2 in the gypsum reacts with residual lime which is liberated in the reaction of the cement compound and water to form $CaO.SiO_2$ or calcium silica hydrate (C-S-H) which is hard and has low solubility. The use of gypsum as a substitute material was able to increase the compressive strength of concrete when compared to without the addition of gypsum. However, excessive use of gypsum can reduce the strength of the concrete itself. Because the greater the amount of gypsum added, the smaller the amount of cement. This causes the tricalcium silicate (C_3S) and dicalcium silicate (C_2S) compounds which are responsible for the strength of concrete to reduce the bonding capacity between aggregate/sand to become imperfect [22].

From the test results, there was an increase in the compressive strength of concrete for the use of gypsum as a substitute material of more than 10%. When viewed from the quality aspect, the compressive strength of concrete with 10% gypsum addition is below 40 MPa. So the concrete produced with the addition of 10% gypsum is of medium quality. Meanwhile, the compressive strength of concrete produced with additions above 10% is above 40 MPa. In other words, the concrete produced is of high quality and requires special handling. This concrete is suitable for use in high-rise building structures, bridge structures or other high-quality concrete buildings that require large concrete compressive strength to carry the structural load received [23].

2. The effect of the percentage of gypsum as a filler on the compressive strength of concrete

The results of testing the compressive strength of concrete using gypsum waste as a filler material which was carried out after 28 days can be seen in Figure 4 below.

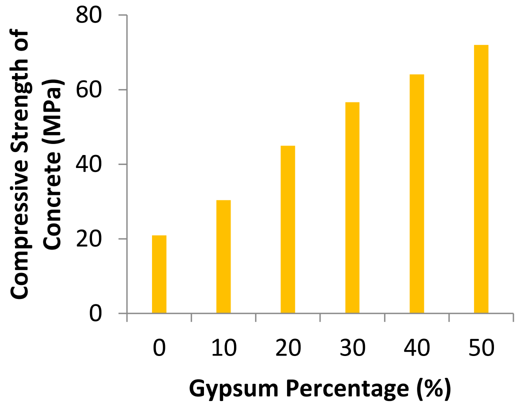

Figure 4. Graph of the Effect of the Percentage of Gypsum as a Filler Material on the Compressive Strength of Concrete

Based on Figure 4 above, it can be seen that the compressive strength of concrete produced from a mixture composition using 0% gypsum (without gypsum substitution) is 26.93 MPa. The highest value of concrete compressive strength produced was obtained when using 50% gypsum as a filler material, namely 71.96 MPa. Meanwhile, the lowest concrete compressive strength value produced was obtained when using 10% gypsum as a filler material, namely 30.35 MPa. The use of gypsum as a filler above 10% results in continuously increasing concrete compressive strength values. Thus, the use of gypsum as a filler material in making concrete can increase the compressive strength value of concrete [5]. The results of this research are supported by previous studies which show that the more gypsum used as a filler material, the higher the compressive strength of the concrete produced [21] [8] [24].

The use of gypsum as a filler material causes a free lime binding reaction resulting from the cement hydration process by the silica in the gypsum. In addition, the much smaller gypsum grains make the concrete denser due to the gypsum filling the voids between the aggregate grains, thus reducing the pores and taking advantage of the pozzolanic properties of gypsum to repair the concrete. Gypsum is an additive that actively reacts with lime or cement. Concrete containing a gypsum mixture has a higher compressive strength compared to normal concrete (without the addition of gypsum). The use of gypsum as a filler material shows two effects in concrete, namely as a fine aggregate and pozzolan [25].

The results of previous research show that the pozzolanic properties of gypsum containing reactive silica can reduce free lime, ($Ca(OH)_2$). This compound is the result of the hydration of tricalcium silicate (C_3S) and dicalcium silicate (C_2S) which produces adhesive by-products. The adhesive formed will fill the large capillary cavities in the hydrated Portland cement, resulting in reduced porosity of the hydrated cement paste and the transition area between the hydrated cement paste and the aggregate. Thus, the quality of concrete will increase [26].

From the test results, there was an increase in the compressive strength of concrete when using gypsum as a filler material of more than 10%. When viewed from the quality aspect, the compressive strength of concrete with 10% gypsum addition is below 40 MPa. So, the concrete produced with the addition of 10% gypsum is of medium quality. Meanwhile, the compressive strength of concrete produced with additions above 10% is above 40 MPa. In other words, the concrete produced is of high quality and requires special handling. This concrete is suitable for use in high-rise building structures, bridge structures or other high-quality concrete buildings that require large concrete compressive strength to carry the structural load received [23].

Concrete Water Absorption Test

1. The effect of the percentage of gypsum as a substitute material on concrete water absorption

Concrete water absorption testing is carried out after the concrete is more than 28 days old. The aim is to find out the amount of water that can be absorbed by concrete [5]. In the concrete mixture, water has two functions: 1. to enable chemical reactions that cause binding and hardening to take place; 2. As a lubricant for a mixture of gravel, sand and cement to make printing easier [12]. The results of water absorption testing of concrete with gypsum waste as a substitute material after being aged for more than 28 days can be seen in Figure 5 below.

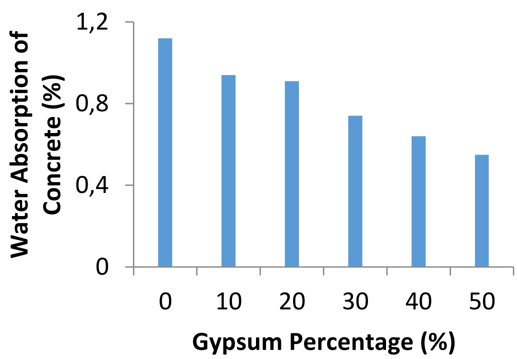

Figure 5. Graph of the Effect of the Percentage of Gypsum as a Substitute Material on Concrete Water Absorption

Based on Figure 5 above, it can be seen that the percentage of concrete water absorption is decreasing due to the addition of gypsum waste as a substitute material. The water absorption value obtained when using gypsum as a substitute material ranges from 0.55%-1.12%. The best water absorption capacity of 0.55% occurs when gypsum is used as a 50% substitute material. The relationship between water absorption and the percentage of gypsum used is inversely proportional. The larger the gypsum used, the smaller the water absorption. This is because gypsum has softer grains than cement so it can fill smaller pores. Thus, the resulting concrete is denser [27]. Previous research shows that the finer shape of gypsum particles provides advantages, namely reducing porosity. In addition, the use of gypsum in lightweight concrete can improve concrete properties such as: concrete compressive strength and water absorption [28].

2. The effect of the percentage of gypsum as a filler on concrete water absorption

The results of the water absorption test for concrete with gypsum waste as filler material after being aged for more than 28 days can be seen in Figure 6 below.

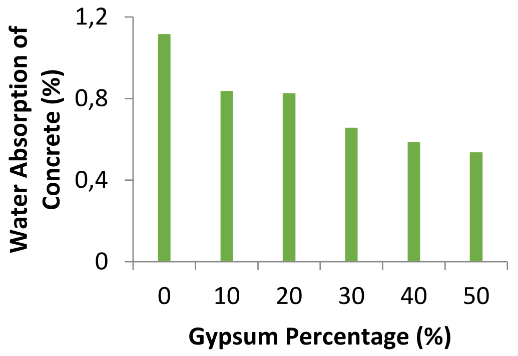

Figure 6. Graph of the Effect of the Percentage of Gypsum as a Filer Material on Concrete Water Absorption

Based on Figure 6 above, it can be seen that the percentage of concrete water absorption is decreasing due to the addition of gypsum waste as a filler material. The water absorption value obtained when using gypsum as a filler material ranges from 0.55% -1.12%. The best water absorption capacity of 0.55% occurs when 50% gypsum is used as a filler material. The relationship between water absorption and the percentage of gypsum used is inversely proportional. The larger the gypsum used, the smaller the water absorption. This is because gypsum has softer grains than cement so it can increase internal cohesion and reduce porosity as a transition area (smallest area) in concrete [22]. Previous research results showed that the absorption and abrasion values decreased with the presence of gypsum [29].

Analysis of Heavy Metal Concentrations Using Atomic Absorption Spectroscopy (AAS)

In this research, analysis of heavy metal concentrations with AAS focused on Fe and Al metals which have metal levels of 10 ppm and 16,500 ppm respectively based on XRF test results. These two metals do not exceed established quality standards. Fe and Al metal testing was carried out after soaking for 7, 14 and 28 days. This heavy metal analysis aims to determine the heavy metal content that still accumulates in the environment after gypsum is used as a concrete mixture [5]. The results of the analysis of Fe and Al metal concentrations in the concrete mixture can be seen in Table 5 below.

Table 5. Results of Analysis of Fe and Al Metal Concentrations

Meta l	XRF Test Result s (ppm)	Quality Standard s (ppm)	Concentration (ppm)		
			7th day	14th day	28th day
Fe	10	55000	<0.08 4	<0.08 4	<0.08 4
Al	16500	16554.30	<0.15 6	<0.15 6	<0.15 6

Based on Table 5 above, it can be seen that the concentration of released Fe and Al metals does not change with additional days of soaking. Fe and Al metal concentrations were <0.084 ppm and <0.156 ppm respectively for immersion ages of 7, 14 and 28 days. Metal that is confined and trapped in the cement-sand bond in concrete will be difficult to hydrolyze by water. If the compressive strength of the concrete increases due to the addition of waste, the bond between the cement and waste becomes stronger so that the Fe and Al levels are difficult to release. The strength of concrete depends on the strength of the bond between cement-waste and the surface reactive properties of the waste in binding with cement [26].

The maximum levels of Fe and Al from S/S are 10 ppm and 16500 ppm respectively. Meanwhile, the concentration of heavy metals released when the concrete was soaked for up to 28 days was: Fe = <0.084 ppm and Al = <0.156 ppm. Thus, the concentrations of these two heavy metals are still far below their respective quality standards [5]. So these two heavy metals are not dangerous for living creatures and the environment because their concentrations are below the threshold.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the results of the analysis of gypsum characteristics using XRF show that the amount of oxide contained in gypsum is 98.92% and the gypsum used is included in type III gypsum. Type III gypsum contains two heavy metals, namely Fe = 10 ppm and Al = 16500 ppm. Where these two types of metal have concentrations below the quality standards, so they are not dangerous for living things and the environment. However, metal and non-metal elements that have concentrations above the quality standards make gypsum dangerous for living creatures and the environment.

The maximum load and highest compressive strength of concrete when using gypsum as a substitute material were 1476.31 kN and 70.73 MPa respectively, resulting from the addition of 50% gypsum. Meanwhile, the maximum load and lowest concrete compressive strength when using gypsum as a substitute material were 613.40 kN and 29.39 MPa respectively, resulting from the addition of 10% gypsum. Thus, the maximum load and compressive strength of concrete obtained are directly proportional to the addition of gypsum as a substitute material.

The maximum load and highest compressive strength of concrete when using gypsum as a filler material were 1502.12 kN and 71.96 MPa respectively, resulting from the addition of 50% gypsum. Meanwhile, the maximum load and lowest concrete compressive strength when using gypsum as a filler material were 633.58 kN and 30.35 MPa respectively, resulting from the addition of 10% gypsum. Thus, the maximum load and compressive strength of the concrete obtained are also directly proportional to the addition of gypsum as a filler material.

Based on the results of concrete water absorption testing, it was concluded that the addition of gypsum as a substitute or filler material could reduce the percentage of concrete water absorbed. The concentration of heavy metals released from concrete immersion until 28 days is: Fe = <0.084 ppm and Al = <0.156 ppm. Where the concentration of these two metals is still far below the threshold. However, this soaking method is only suitable if the production of building materials is used in small quantities. If the production of building materials is used in large quantities, it is not recommended to use the soaking method because it takes a long time.

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