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COMPRESSIVE STRENGTH ANALYSIS OF MORTAR MADE FROM VOLCANIC SAND IN NAGARI AIA ANGEK BASED ON MAGNETIC MINERAL CONTENT

Syahputri Sumanti[1], Hamdi Rifai[*1], Akmam[1], Harman Amir[1], Syafriani[1], Ratna Wulan[1]

[1] *Department of Physics, Universitas Negeri Padang, Jl. Prof. Dr. Hamka Air Tawar Padang 25131, Indonesia*
Corresponding author. Email: rifai.hamdi@fmipa.unp.ac.id

ABSTRACT

Compressive strength testing is carried out on mortar made from a mixture of sand, cement and water. Mortar is one of the construction materials in building structures that has the main function as a material for construction parts. The compressive strength test is useful for measuring and knowing the strength of objects against compressive forces. The method used in this research is rock magnetism to determine the abundance of magnetic minerals and compressive strength testing to determine the relationship of compressive strength results to the magnetic minera content of Nagari Aia Angek volcanic sand. Volcanic sand is measured using a Bartington Susceptibility Meter Type MS2B with 3 forms of mineral separation treatment, namely Magnetic Mineral Reduction (PMM) with a value of χ_{lf} 505,99 x10 m^{-83} /kg, χ_{fd} (%) 2.72%, Additional Magnetic Minerals (TMM) with a value of χ_{lf} 1026.72 x10 m^{-83} /kg, χ_{fd} (%) 2.14%, and No Treatment (TP) with a value of χ_{lf} 853.98 x10 m^{-83} /kg, χ_{lf} (%) 2.16. The results of testing the compressive strength of mortar using Compression Testing Mechine on 3 volcanic sand treatments were obtained (PMM) with a value of 169.14 kg/cm^2, (TMM) with a value of 147.11 kg/cm^2, and (TP) with a value of 141.81 kg/cm^2. The magnetic properties of volcanic sand samples are antiferrimagnetic and have superparamagnetic mixed grains and coarse grains. There is a relationship between the compressive strength value of mortar and the concentration of magnetic minerals, the higher the compressive strength value, the higher the χ_{fd} (%) value obtained.

Keywords : Mortar compressive strength, magnetic minerals, magnetic susceptibility, volcanic sand, rock magnetism method.

I. INTRODUCTION

The compressive strength test is useful for measuring and knowing the strength of objects against compressive forces. This compressive strength test is carried out on mortar made from a mixture of sand, cement and water. Mortar is one of the construction materials in building structures that has the main function as a material for construction parts [1]. The quality of mortar is determined by its constituent materials, because the use of constituent materials in accordance with specifications will produce good mortar. One of the constituent materials is sand [2].

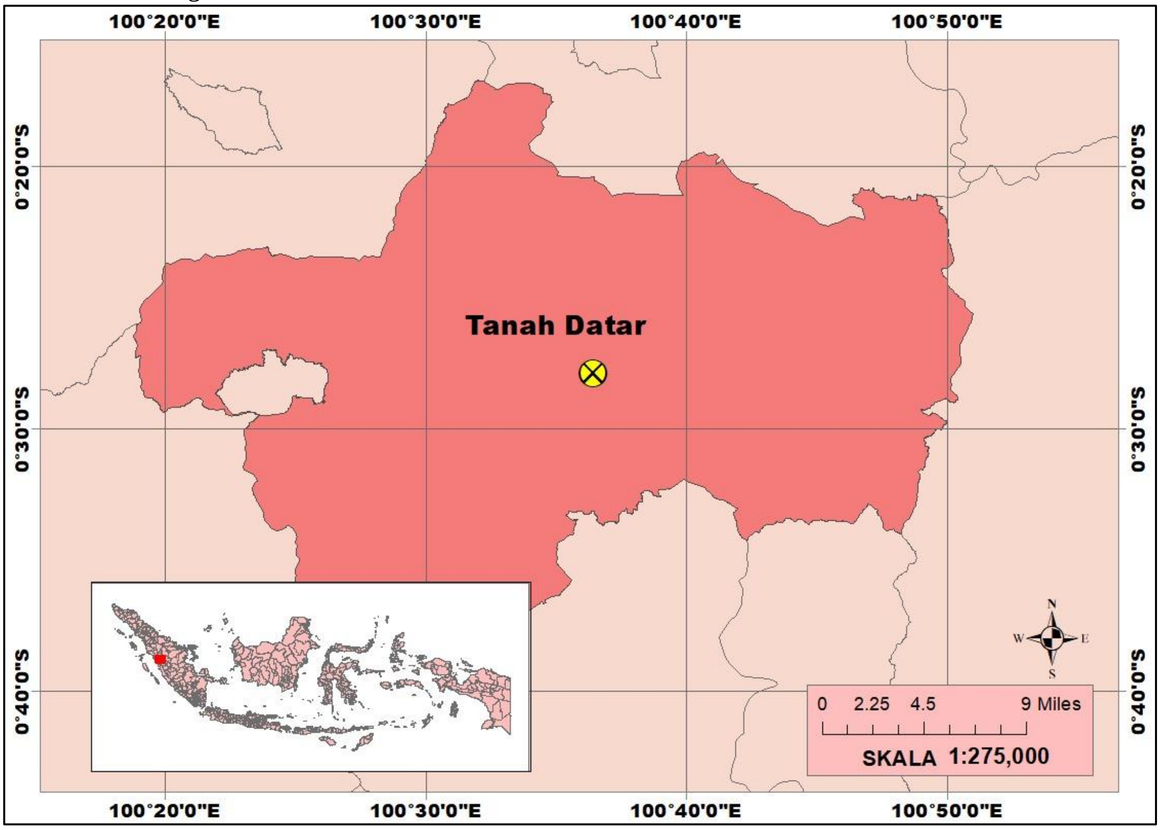
Sand can be found in various places such as in rivers, on beaches and in mountains. River sand is sand originating from mountains that are eroded and carried by river flow. Beach sand is found on the coast due to supply from rivers [3]. Meanwhile, sand in the mountains called volcanic ash is a volcanic rock mineral with a size as large as sand and gravel with a diameter of approximately 2 mm which is the result of volcanic eruptions [4]. Sand is a mineral deposit having a grain size of 0.074 to 0.075 mm, with a fine size of 3 to 5 mm and a coarse size <1 mm [5]. Nagari Aia Angek is one of the villages in X Koto District with most of the area at the foot of Mount Merapi or in the highlands. In this area, people generally get sand as building material taken from lowland rivers such as in one of the sand mining sites in Padang Pariaman Regency. Meanwhile, Nagari Aia Angek has volcanic sand that is no less good than river sand which can also be used as a building material.

Iron sand is one of the natural resources found in Nagari Aia Angek. By processing iron sand, it can be increased several times and used to replace imported products so as to increase the competitiveness of the national industry [6]. This iron sand can be used as a mixture for making cement [7], can be used in making dry ink [8], and can be used as a mixture in making concrete [9]. The use of iron sand can increase compressive strength because mechanically the gradation of iron sand is able to fill the pores between normal sand grains thereby increasing the density of concrete [10], but in reality Nagari Aia Angek does not use volcanic sand for mixing building materials. Magnetite (Fe_3O_4), hematite (α-Fe_2O_3) and maghemite (γ-Fe_2O_3) are magnetic minerals contained in iron sand [11].

Magnetic minerals are minerals that have high magnetic properties, which have 3 properties, namely: diamagnetic, paramagnetic, and ferromagnetic [12]. One method used in determining the abundance of magnetic minerals in iron sand is the Rock Magnetic Method. This method has relatively easy measurements, relatively high accuracy in measurements, affordable, and fast in getting results. Based on the description above, it is necessary to study the comparison of magnetic minerals in volcanic sand so that an analysis can be made of the compressive strength of mortar made from volcanic sand in Nagari Aia Angek based on magnetic mineral content. From the data of the magnetic susceptibility measurement results, the magnetic mineral content can be known after that the strength of mortar from volcanic sand material in Nagari Aia Angek can be known by comparing sand whose magnetic minerals are varied.

II. METHOD

Sampling was carried out in Nagari Aia Angek, X Koto District, Tanah Datar Regency. The sampling location is shown in Figure 1.



Basemap: Ina-Geoportal **Fig. 1.** Sampling Location

Based on Figure 1, it can be seen that the samples were taken from the Nagari Aia Angek location with volcanic sand samples at the coordinates S00.24232º E100.24744º. Volcanic sand sample preparation was carried out by pulverizing it until it was inserted into a cylindrical holder with a size of 10 ml (15 volcanic sand sample holders). After that, the separation of magnetic minerals in sand was carried out with 3 forms, namely the addition of magnetic minerals, the reduction of magnetic minerals, and without treatment. Each consists of 3 holders. Cement as a supporting material for making mortar was also put into the holder with 15 sample holders. Samples with the form of 3 treatments were made each mortar mixture (volcanic sand, cement, water), from the mixture was put into the holder (3 holders per treatment). All samples with a total of 48 holders were weighed by mass using an *Ohauss Balance* and magnetic susceptibility measurements were taken using a *Bartington Magnetic Susceptibility Meter Type B* (MS2B) at the Geophysics Laboratory, Department of Physics FMIPA

UNP. For volcanic samples that have been made into mortar (sand, cement, water) with a size of 5x5x5 cm were tested using the *Compression Testing Mechine* UPTD LBK (Regional Technical Implementation Unit of Construction Labor) of the Public Works and Spatial Planning Office of West Sumatra Province.

Measurements for frequency-dependent magnetic susceptibility using the low frequency equation (0.46 kHz) obtained the value of *low field susceptibility* (χ_{lf}) and high frequency (4.6 kHz) obtained the value of *high field susceptibility* (χ_{hf}) [13]. *The* magnetic properties of the sample can be determined through the results of the magnetic susceptibility value of the sample that has been measured [14].

$$\chi_{FD}\% = \frac{\chi lf - \chi hf}{\chi lf} \times 100\%$$

Where, χFD% indicates the presence or absence of superparamagnetic grains in the sample. Where, χlf is the mass unity susceptibility at low field and χhf is the high field mass unity susceptibility [14]. The results of the magnetic susceptibility measurements were analyzed. From the magnetic susceptibility value of the sample that has been measured, the magnetic properties of the sample are determined [15].

The compressive strength of mortar is the maximum force per unit area acting on a mortar specimen. Testing the compressive strength of mortar is carried out based on SNI 03-6825-2002, 2002 [16]. The test specimen is placed on the pressing machine then the test specimen is pressed until the test specimen breaks. At the time of rupture, the maximum compressive force acting was recorded.

The formula used in the calculation of the compressive strength of mortar using the formula [2] :

$$\boldsymbol{\rho = \frac{F}{A}} \quad (1)$$

Where ρ is the compressive strength of mortar against compressive force with units of kg/cm^2, F is the maximum compressive force applied by the machine with units (Newton) unit A which is the cross-sectional area of the test specimen with units (cm^2)[16].

The effect of the magnetic susceptibility value on the compressive strength value of the sample can be seen through the following linear equation [17]:

$$\boldsymbol{y = ax + b} \quad (2)$$

Where, y is the independent variable, x is the dependent variable, a is the gradient / coefficient of the variable x, where if the value of a is positive (+) then the value of the element against χlf has a directly proportional relationship, the more percent of the element, the higher the value of χlf, and if the value of a is minus (-) then the value of the element against χlf has an inversely proportional relationship. b is a constant, R2 is the confidence / determination level, r is the correlation coefficient. A good linearization curve has a determination value of R2 > 0.9 (close to 1)[17].

III. RESULTS AND DISCUSSION

The magnetic susceptibility value of volcanic sand from Nagari Aia Angek which is still pure or can be called unprocessed can be seen in Table 1.

Table 1. Magnetic Susceptibility Value of Volcanic Sand Nagari Aia Angek

Number	Sample Name	Magnetic Susceptibility Value ($10^{-8}m^3/kg$)				χ_{FD} (%)	χFDn (%)
		Low Field (χ_{lf})	(χlfn)	High Field (χ_{hf})	(χhfn)		
1	NAA-AA-1	1469,5	0,99	1435,5	0,99	2,31	0,76
2	NAA-AA-2	1485,1	1,00	1450,7	1,00	2,32	0,76
3	NAA-AA-3	1193,2	0,80	1164,2	0,80	2,43	0,80
4	NAA-AA-4	1326,5	0,89	1295,4	0,89	2,34	0,77
5	NAA-AA-5	1339,7	0,90	1313,4	0,91	1,96	0,64
6	NAA-AA-6	1373,9	0,93	1338,6	0,92	2,57	0,84
7	NAA-AA-7	1419,4	0,96	1388,3	0,96	2,19	0,72
8	NAA-AA-8	1379,1	0,93	1349,5	0,93	2,15	0,70

Number	Sample Name	Magnetic Susceptibility Value ($10^{-8}m^3/kg$)				χ_{FD} (%)	χFDn (%)
		Low Field (χ_{lf})	(χlfn)	High Field (χ_{hf})	(χhfn)		
9	NAA-AA-9	1386,7	0,93	1355,9	0,93	2,22	0,73
10	NAA-AA-10	1343,3	0,90	1312,9	0,91	2,26	0,74
11	NAA-AA-11	1401,2	0,94	1358,4	0,94	3,05	1,00
12	NAA-AA-12	1316,2	0,89	1283,5	0,88	2,48	0,81
13	NAA-AA-13	1322,6	0,89	1289,3	0,89	2,52	0,83
14	NAA-AA-14	1292,2	0,87	1264,1	0,87	2,17	0,71
15	NAA-AA-15	1335,6	0,90	1308,9	0,90	2	0,66
	χmin	1193,2	0,80	1164,2	0,80	1,96	0,64
	χmax	1485,1	1	1450,7	1	3,05	1
	χAverage	1358,95	0,92	1327,24	0,91	2,33	0,76
	Standarddeviation	71,8	0,0	70,09	0,05	0,27	0,09

In Table 1, the volcanic sand NAA-AA sample that has the largest χ_{lf} value is found in sample NAA-AA-2 with a value of ($1485.1 \times 10^{-8}m^3/kg$) and a value that has been normalized χ_{lfn} with a value of 1. The sample that has the smallest χ_{lf} is found in sample NAA-AA-3 with a value of ($1193.2 \times 10^{-8}m^3/kg$) and a value that has been normalized χ_{hfn} with a value of 0.8. The average χ_{lf} value is ($1358.95\times10^{-8}m^3/kg$) and the normalized average χ_{lfn} with a value of 0.92. The standard deviation of χ_{lf} is 71.8 and the normalized χ_{lfn} has a standard deviation of 0.

Volcanic sand NAA-AA samples that have the largest χ_{FD} (%) value are found in sample NAA-AA-11 with a value of 3.05 (%) and a value that has been normalized χ_{FDn} with a value of 0.64. The sample that has the smallest χ_{FD} (%) is the NAA-AA-5 sample with a value of 1.96 (%) and a value that has been normalized χ_{FDn} with a value of 0.64. The average χ_{FD} (%) value is 2.33 (%) and the average of the normalized χ_{FDn} with a value of 0.76. The standard deviation of χ_{FD} (%) is 0.27 and the normalized χ_{FD} has a standard deviation of 0.09.

The magnetic susceptibility value of volcanic sand samples that have been separated by magnetic minerals is 3 samples with a total of 9 holders, each of which is measured three times so that the average value is obtained as in Table 2.

Table 2. Magnetic Susceptibility Value of Volcanic Sand After Magnetic Mineral Separation

Number	Sample Name	Magnetic Susceptibility Value ($10^{-8}m^3/kg$)		χ_{fd} (%)
		Low Field (χ_{lf})	High Field (χ_{hf})	
1	AA-TP-1	1329,8	1307,8	1,65
2	AA-TP-2	1370,5	1344,2	1,92
3	AA-TP-3	1231,5	1208	1,9
	χAverage	1310,6	1286,7	1,8
4	AA-TMM-1	1597,9	1568,5	1,84
5	AA-TMM-2	1593	1565,7	1,71
6	AA-TMM-3	1617	1583,4	2,08
	χAverage	1602,6	1572,5	1,9
7	AA-PMM-1	690,4	672,1	2,65
8	AA-PMM-2	667,7	650,3	2,61
9	AA-PMM-3	688,8	671,6	2,5
	χAverage	682,3	664,7	2,6

In Table 2, it can be seen that the volcanic sand sample that has the largest magnetic susceptibility value is in the sample with the addition of AA-TMM magnetic minerals and the sample that has the smallest magnetic susceptibility value is in the AA-PMM magnetic mineral reduction sample. In the sample without treatment, the magnetic susceptibility value is between the addition and reduction values found in the sample without AA-TP treatment.

The value of *frequency dependent magnetic susceptibility* χ_{fd} *(%)* is the smallest in sample AA-TP, which is an additional magnetic mineral and the *frequency dependent magnetic susceptibility value is the largest in* *sample AA-PMM, which is a magnetic mineral reduction sample.* χ_{fd} *(%) is* greatest in sample AA-PMM which is a magnetic mineral reduction sample. While the value of *frequency dependent magnetic susceptibility* χ_{fd} *(%) of the* AA-TMM untreated sample is between the value of no treatment and magnetic mineral reduction with a value of 1.9%.

For volcanic (gray) sand samples that are already in a mixture of cement, sand and water or mortar dough, the magnetic susceptibility values can be seen in Table 3.

Table 3. Magnetic Susceptibility Value of Volcanic Sand After Making Mortar Dough

Number	Sample Name	Magnetic Susceptibility Value ($10^{-8}m^3/kg$)		χFDn (%)
		Low Field (χ_{lf})	High Field (χ_{hf})	
1	AA-TP-M-1	872,03	853,3	2,14
2	AA-TP-M-2	857,53	839,83	2,06
3	AA-TP-M-3	832,37	813,4	2,28
	χAverage	853,98	835,51	2,16
4	AA-TMM-M-1	1007,7	985,8	2,17
5	AA-TMM-M-2	1034,73	1012,46	2,15
6	AA-TMM-M-3	1037,73	1015,76	2,11
	χAverage	1026,72	1004,67	2,14
7	AA-PMM-M-1	501,1	488,43	2,53
8	AA-PMM-M-2	518,76	504,66	2,72
9	AA-PMM-M-3	498,13	483,6	2,91
	χAverage	505,99	492,23	2,72

In Table 3, it can be seen that the volcanic (gray) sand sample that has been made into mortar dough has the greatest magnetic susceptibility value found in the AA-TMM-M magnetic mineral addition sample with an average of 1026.72 x $10^{-8}m^3/kg$ and the sample that has the smallest magnetic susceptibility value found in the AA-PMM-M magnetic mineral reduction sample with an average of 505.99 x $10^{-8}m^3/kg$. In the sample without treatment, the magnetic susceptibility value is between the addition and reduction values found in the AA-TP-M sample with an average of 853.98 x $10^{-8}m^3/kg$.

The frequency dependent magnetic susceptibility value χ_{fd} *(%)* is the smallest in the AA-TMM-M sample. The *frequency dependent magnetic susceptibility* value χ_{fd} *(%) is* greatest in sample AA-PMM-M which is a magnetic mineral reduction sample. While the value of *frequency dependent magnetic susceptibility* χ_{fd} *(%) of the* additional magnetic mineral sample AA-TP-M is between the value of additional magnetic minerals and magnetic mineral reduction with a value of 2.16%. There is a variation in the magnetic susceptibility value of the volcanic sand sample due to the withdrawal of volcanic sand samples and each sample has a variety of magnetic minerals [18].

The following plot of the relationship between χ_{lf} value and χ_{fd} value (%) in pure volcanic sand samples of magnetic mineral separation and mortar dough is shown in Figure 2.

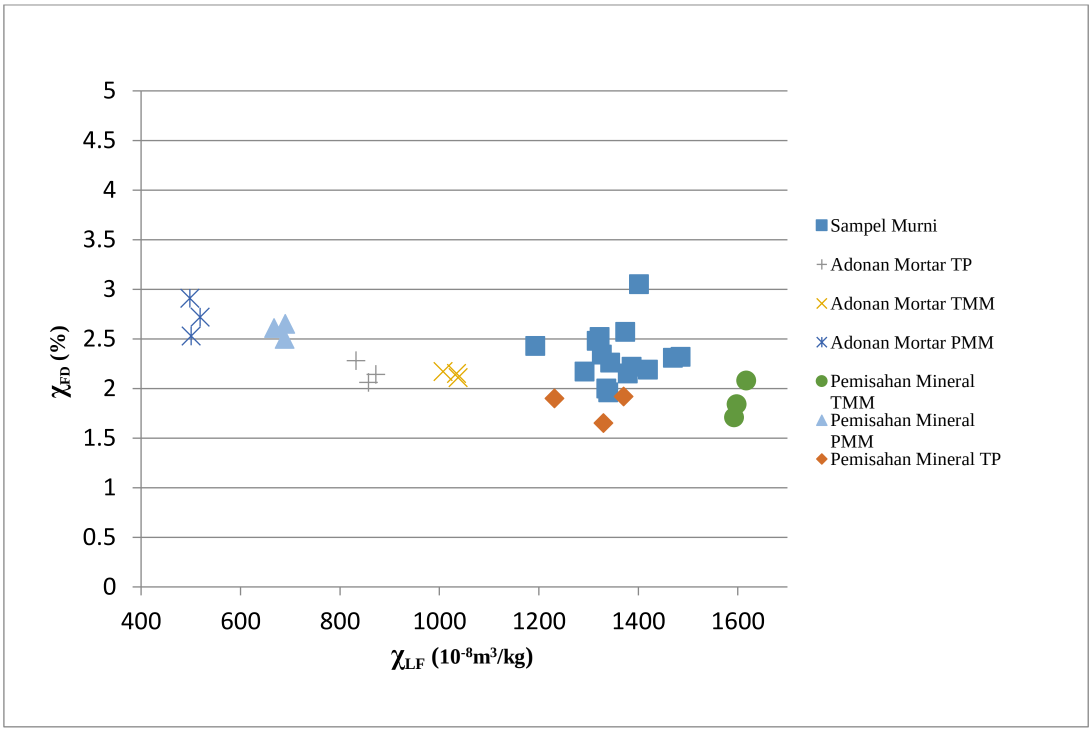


Fig. 2. Plot of Relationship between χ_{lf} Value and χ_{fd} Value (%) of Pure Volcanic Sand Sample, Separation of Magnetic Minerals and Mortar Mixes.

From the plot of the relationship between the χ_{lf} value and the χ_{fd} value (%) in (Figure 2), it can be seen the difference in the magnetic susceptibility value of each sample. The type of grain and magnetic properties in each sample can be grouped so that the characteristics of magnetic minerals in the sample can be seen in Table 4.

Table 4. Magnetic Mineral Characteristics of Volcanic Sand from Nagari Aia Angek

No	Sample Name	Magnetic Susceptibility		Magnetik properties	Grain type
		χ_{lf} (x10^{-8}m^3/kg)	χ_{fd} (%)		
1	NAA-AA	1193,2 – 1485,1	1,96-3,05	Antiferromagnetic	Has almost no SP grains, SP mixture and coarse grains
2	AA-TP	1231,5 – 1370,5	1,65-1,92	Antiferromagnetic	Has almost no SP grains
3	AA-TMM	1593,0 – 1617,0	1,71-2,08	Antiferromagnetic	Has almost no SP grains, SP mixture and coarse grains
4	AA-PMM	667,7 – 690,4	2,50-2,65	Antiferromagnetic	Has almost no SP grains, SP mixture and coarse grains
5	AA-TP-M	832,37 – 872,03	2,06-2,28	Antiferromagnetic	A mixture of SP and coarse grains
6	AA-TMM-M	1007,7 – 1037,73	2,11-2,17	Antiferromagnetic	A mixture of SP and coarse grains
7	AA-PMM-M	498,13 – 518,76	2,53-2,91	Antiferromagnetic	A mixture of SP and coarse grains

Table 4 shows the characteristics of the magnetic minerals of each sample. The magnetic properties of volcanic samples on the NAA-AA sample are antiferromagnetic, with its χ_{lf} value from the range of 1193.2 $10^{-8}m^3/kg$ - 1485.1 x $10^{-8}m^3/kg$. In volcanic sand samples, the magnetic mineral separation is sample AA-TP (No Treatment) with its χ_{lf} value from the range of 1231.2 x $10^{-8}m^3/kg$ - 1370.1 $10^{-8}m^3/kg$, sample AA-TMM (Additional Magnetic Minerals) with its χ_{lf} value from the range of 1593 x $10^{-8}m^3/kg$ - 1617.1 x $10^{-8}m^3/kg$, sample AA-PMM (Magnetic Mineral Reduction) with its χ_{lf} value from the range of 667.7 x $10^{-8}m^3/kg$ - 690.4 x $10^{-8}m^3/kg$. In volcanic sand samples after separation of magnetic minerals that have been made into mortar mix, namely sample AA-TP-M (No Treatment) with its χ_{lf} value from the range of 832.37 x $10^{-8}m^3/kg$ - 872.03 x $10^{-8}m^3/kg$, sample AA-TMM-M (Additional Magnetic Minerals) with its χ_{lf} value from the range of 1007 x $10^{-8}m^3/kg$ - 1037.73 x $10^{-8}m^3/kg$, sample AA-PMM-M (Reduction of Magnetic Minerals) with its χ_{lf} value from the range of 498.13 x $10^{-8}m^3/kg$ - 518.76 x $10^{-8}m^3/kg$. In the magnetic mineral separation sample and mortar dough, the magnetic properties are antiferromagnetic.

In the pure volcanic sand without treatment (AA-TP) has a grain type of almost no superparamagnetic grains with a range of 1.65 (%) - 1.92 (%), volcanic sand added magnetic minerals (AA-TMM) has a grain type of almost no superparamagnetic grains, superparamagnetic mixture and coarse grains with a range of 1.71 (%) - 2.08 (%). The magnetic mineral reduction volcanic sand (AA-PMM) has a grain type of almost no superparamagnetic grains, superparamagnetic mixture and coarse grains with a range of 2.50 (%) - 2.65 (%). Volcanic sand that has become a mortar mix without treatment (AA-TP) has a grain type of superparamagnetic mixture and coarse grains with a range of 2.06 (%) - 2.28 (%), volcanic sand added with magnetic minerals (AA-TMM) has a grain type of superparamagnetic mixture and coarse grains with a range of 2.11 (%) - 2.17 (%), and volcanic sand reduced magnetic minerals (AA-PMM) has a grain type having superparamagnetic mixed grains and coarse grains with a range of 2.53 (%) - 2.91 (%) [19]. Magnetic minerals are strongly influenced by magnetic grain size, this is due to the same magnetic susceptibility value in high and low frequency measurements [19].

Volcanic sand samples from Nagari Aia Angek that have been divided into magnetic minerals are tested for compressive strength by making mortar according to SNI and ASTM standards. The mortar was tested after 7 days of manufacture with a *Compression Testing Machine. The* results of the mortar compressive strength test can be seen in Table 5.

Table 5. Results of Mortar Compressive Strength Testing (Volcanic Sand, Water, Cement)

Sample Name	Sand (gram)	Cement (gram)	Water (ml)	Age (days)	Average Compressive Strength (Kg/cm^2)	χ_{fd} (%)
AA-TP	618,75	206,25	120	7	141,81	2,16
AA-TMM	618,75	206,25	120	7	147,11	2,14
AA-PMM	618,75	206,25	120	7	169,14	2,72

Based on Table 5, it can be seen the results of compressive strength testing of mortar, in mortar with sample AA-TP (Untreated) has a compressive strength of 141.81 kg/cm^2 , mortar sample AA-TMM (Additional Magnetic Mineral) has a compressive strength of 147.11 kg/cm^2 , and mortar sample AA-PMM (Reduction of Magnetic Mineral) has a compressive strength of 169.14 kg/cm^2 . Each sample used 618.75 g of sand, 206.25 g of cement, and 120 ml of water. The mortar was aged for 7 days before strength testing using a *Compression Testing Machine* [16].

To see the effect of the magnetic mineral content of the sample on the compressive strength in Figure 3

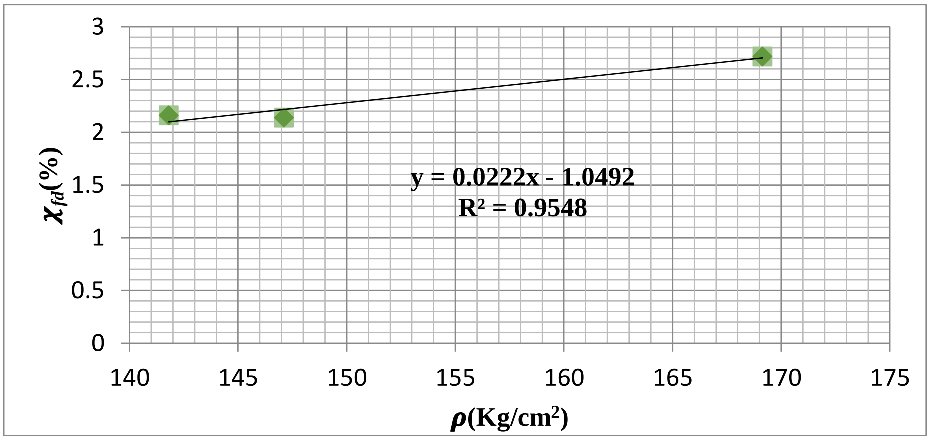


Fig. 3. Plot of Relationship between Compressive Strength *(ρ)* and χ_{fd} *(%)*

Based on Figure 3, there is a relationship between compressive strength and χ_{fd}, it can be seen that the relationship between compressive strength and frequency-dependent susceptibility (χ_{fd} (%)) is directly proportional, the higher the susceptibility value of frequency-dependent susceptibility (χ_{fd} (%)), the higher the compressive strength value of mortar and the lower the susceptibility value of frequency-dependent susceptibility (χ_{fd} (%)) with the highest compressive strength value in the magnetic mineral reduction sample (AA-PMM), for χfd value is rated highest. The medium compressive strength value is in the magnetic mineral addition sample (AA-TMM), for the χ_{fd} value is at the lowest value. The lowest compressive strength value is found in the sample without treatment (AA-TP), for its χfd value is at the middle value. It can be seen from the positive gradient value with a value of (0.0222) and a confidence level of (0.9548).

IV. CONCLUSION

Based on the results of the separation of magnetic minerals in volcanic sand Nagari Aia Angek, the highest susceptibility value is obtained in the sample of additional magnetic minerals and the lowest is in the sample of magnetic mineral reduction. Each sample has magnetic properties, namely antiferromagnetic and has a mixture of superparamagnetic and coarse grains. In the results of compressive strength testing on mortar, the highest compressive strength value is found in the volcanic sand mortar sample minus the magnetic minerals, the intermediate value is found in the volcanic sand mortar sample plus magnetic minerals and the lowest value is found in the volcanic sand mortar sample without treatment. Based on the analysis that has been done, it is found that there is an influence of the susceptibility value or concentration of magnetic minerals on the compressive strength value of mortar, namely the higher the magnetic susceptibility value of sand, the higher the compressive strength value of the mortar obtained.

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