ISSN (Print) : 2337-9030 ISSN (Online) : 2685-2608
PILLAR OF PHYSICS
JURNAL BERKALA ILMIAH FISIKA
Vol. 17 (1), 2024, page. 39-46
DOI : 10.24036/15247171074

EFFECT OF MAGNETIC MINERAL CONTENT IN KAMUMUAN RIVER SAND ON MORTAR COMPRESSIVE STRENGTH

Fajar Fikri Amirullah[1], Hamdi[1*], Letmi Dwiridal[1], Harman Amir[1], Syafriani[1], Ratnawulan[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

Mortar is a binder or adhesive with a standard viscosity of ingredients (water, cement, and sand). Mortar made has strength, mortar strength is measured using Cement Compression testing machine. Sand in mortar making contains magnetic minerals such as magnetite (Fe3O4) or $Fe_2^{+3}Fe^{+2}O_4^{-2}$, hematite mineral (α-Fe2O3) which will be measured for magnetic susceptibility value using Bartington Magnetic Susceptibility Meter Sensor Type B (MS2B). To determine the concentration of magnetic minerals and their relationship with mortar compressive strength, the rock magnetism method was used. Measurement of sand samples of Kamumuan River, Sungai Limau District using Bartington Magnetic Susceptibility Meter Sensor Type B (MS2B) by categorizing sand into 3 treatment, namely Addition of magnetic minerals (PTM) with χ_{LF} value 3863.3 x $10^{-8}m^3$/kg and χ_{FD} (%) 0.72, reduction of magnetic minerals (PKM) with χ_{LF} value 1920 x $10^{-8}m^3$/kg and χ_{FD} (%) 0.79, normal magnetic minerals (PM) with χ_{LF} value 2334.7 x $10^{-8}m^3$/kg and χ_{FD} (%) 0.62. The sample has a grain type that is almost no superparamagnetic grain and has antiferromagnetic properties. Samples grouped by treatment were made into mortar and tested using a cement compression testing machine with the results of mortar compressive strength, namely ATM of 49.4 Kg/cm², AKM of 46.6 Kg/cm², and AM 52.3 Kg/cm². Based on the analysis conducted, the magnetic minerals contained in the sand affect the results of the compressive strength of the mortar, the higher the susceptibility value in the sand, the stronger the compressive strength of the mortar.

Keywords : Compressive Strength of The Mortar, Magnetic Minerals, Magnetic Susceptibilit, Rock Magnetism Method, River Sand,

I. INTRODUCTION

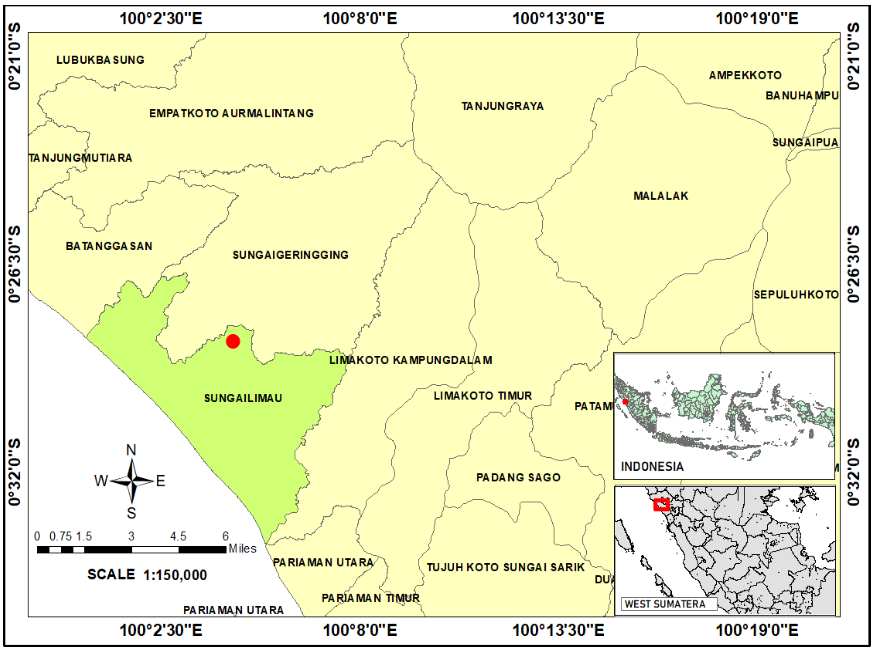
Mortar is a mixture of water, cement and sand that is used as an adhesive in structural parts of constructions. Mortar has the strength to withstand the compressive force exerted on construction parts [1]. There are properties of mortar properties such as adhering well, drying quickly and hardening, one of the materials for making mortar is sand [2]. River sand comes from eroded mountains that flow along the river [3] which has a sand grain size between 0.063 mm to 5mm [4].

West Sumatra has many rivers that flow into the sea, where river sand is used by the community as a building material [5]. The aggregate used for making mortar is fine aggregate or sand, because mortar is made from sand that contains magnetic minerals such as magnetite (Fe_3O_4) or $Fe_2^{+3}Fe^{+2}O_4^{-2}$, hematite (α-Fe_2O_3) and maghemite (γ-Fe_2O_3) minerals [6]. To determine the concentration of magnetic minerals, the Rock Magnetism Method is used. The magnetism method is one of the geophysical methods that investigates the magnetic properties of a material. The magnetic parameter used in this Rock Magnetism Method is magnetic susceptibility which is used to determine the value of magnetic minerals in a material [7].

Rock magnetism method has been widely used in assessing susceptibility values to characterize the magnetic properties and mineral content of iron sand in Batang Kuranji, Padang, West Sumatra[8]; irregular magnetic susceptibility pattern of iron sand from Pasia Jambak Beach, Pasia Nan Tigo, Padang, Indonesia [9]. Analysis of the effect of magnetic minerals on mortar compressive strength requires the Rock Magnetism Method assisted by Mortar Compressive Strength. Mortar compressive strength is the maximum force per unit area acting on a cube-shaped mortar of a certain size and a certain age [10]. The strength of mortar is very influential to determine the quality of the material by conducting a compressive strength test. The compressive strength test is useful for measuring and knowing the strength of mortar against compressive forces so that the quality of the mortar can be known. Factors that affect the compressive strength of mortar such as cement water, amount of cement, age of mortar and aggregate properties [11]. The Kamumuan River is one of the main sand producers in Padang Pariaman which is used by the surrounding community for construction, but there has been no research that discusses how the quality of mortar is produced from Kamumuan River sand by varying the content of magnetic minerals contained in Kamumuan River sand without adding other materials which aims to use the right mortar in construction parts in the community around the Kamumuan River. This is different from other compressive strength studies that utilize the addition of main ingredients other than water, cement, and sand such as coal ash containing silica to produce higher strength [12] where the coal has been little produced. Therefore, it is necessary to analyze to determine the susceptibility value of Kamumuan river sand which affects the compressive strength of mortar in mortar produced from Kamumuan river sand, so that the quality of the mortar is known using the rock magnetism method.

II. METHOD

Sampling was conducted in Kamumuan River, Sungai Limau District, Padang Pariaman Regency. The sampling location is shown in Figure 1.



Basemap : Ina-Geospasial

Fig 1. Sampling Locations Kamumuan River, Sungai Limau District

Based on Figure 1, it can be seen that the position of Kamumuan river sand sampling was carried out in Sungai Limau District with coordinates S 00°24.236' to E 100°24.760'. Preparation of Kamumuan river sand samples was carried out at the Geophysics Laboratory, Department of Physics, Faculty of Matematics and Natural Science, Universitas Negeri Padang by drying at room temperature for 3 - 4 days. Then the river sand was put into a tube-shaped holder with a size of 10 ml as many as 15 holders for pure samples. After that, grouping was carried out based on the treatment of the sample, the first treatment was the withdrawal of magnetic minerals in sample 1, the second treatment was the addition of magnetic minerals withdrawn in sample 1 to sample 2, and the third treatment was no treatment in sample 3. Then each treatment is inserted into the holder as many as 3 holders. PCC cement as a supporting material for making mortar was also inserted into 15 holders. Samples that have been grouped based on the treatment will be made mortar (a mixture of sand, cement and water).

All samples amounted to 48 holders which were measured by mass with an Ohauss balance and magnetic mineral measurements using the Bartington Magnetic Susceptibility Meter Sensor Type B (MS2B) at the Physics Laboratory, Physics Department FMIPA Padang State University. Samples that have been in the form of mortar with a size of 5 cm x 5 cm x 5cm are measured for compressive strength using the cement compression testing machine at the UPTD LBK (Regional Technical Implementation Unit for Construction Material Labor) of the Public Works and Spatial Planning Office of West Sumatra Province. Measurement of the magnetic susceptibility value of magnetic susceptibility at two different frequencies, this is due to the nature of SP grains that are sensitive to changes in frequency. The difference in magnetic susceptibility in frequency differences is known as the frequency-dependent susceptibility (χ_{FD}) parameter. (χ_{FD}) can be presented as magnetic susceptibility per unit mass (χ_{FD}). Where the low field magnetic susceptibility (χ_{LF}) at 0.46 kHz and the high field magnetic susceptibility (χ_{HF}) at 4.6 kHz are the susceptibility per unit mass at low frequency and high frequency, respectively."[13][14]

$$\chi_{FD}\% = \frac{\chi lf - \chi hf}{\chi lf} \times 100 \quad (1)$$

The compressive strength of mortar is the maximum force per unit area acting on a mortar specimen. The mortar compressive strength test was conducted based on SNI 03-6825-2002 [15]. 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 [1]

$$\rho = \frac{F}{A} \quad (2)$$

Where ρ is the compressive strength of the mortar in kg/cm^2. F is the total maximum load applied to the sample with units of newtons. A is the surface area of the test load with units of cm^2 [2]. To determine the relationship between χ_{LF} and compressive strength in beach sand samples, a linear equation can be used. [16]:

$$y = ax + b \quad (3)$$

Where y = independent variable, x = dependent variable, a = gradient / coefficient of variable x, where if the value of a is positive (+) then the value of compressive strength to χ_{LF} is influenced, the more percent of compressive strength the higher the value of χ_{LF}, and if the value of a is minus (-) then the value of compressive strength to χ_{LF} has no effect. b = constant, R^2= confidence level / determination, r = correlation coefficient. A good linearization curve has a determination value of R^2 > 0.9 [16].

III. RESULTS AND DISCUSSION

The magnetic susceptibility value of pure river sand sample SK-01-230330 is inserted into 15 holders which can be seen in Table 1.

Table 1. Magnetic Susceptibility Value of Pure Kamumuan River Sand

No.	Sample Name	Magnetic Susceptibility		χ_{FD} (%)	Magnetic Susceptibility Normalization		χ_{FDN} (%)
		Low Field (χ_{LF})	*High Field (χ_{HF})*		*Low Field (χ_{LFN})*	*High Field (χ_{HFN})*	
1	SK-01-230330-01	2730	2704.8	0.92	0.96	0.96	0.77
2	SK-01-230330-02	2527.1	2503	0.95	0.89	0.89	0.80
3	SK-01-230330-03	2175.4	2156.8	0.86	0.77	0.77	0.72
4	SK-01-230330-04	2341.6	2324.8	0.72	0.82	0.83	0.61
5	SK-01-230330-05	2619.5	2596.7	0.87	0.92	0.92	0.73
6	SK-01-230330-06	2786	2752.8	1.19	0.98	0.98	1.00
7	SK-01-230330-07	2381.4	2368.4	0.55	0.84	0.84	0.46
8	SK-01-230330-08	2839.6	2811.6	1	1.00	1.00	0.84
9	SK-01-230330-09	2463.3	2436.5	1.09	0.87	0.87	0.92
10	SK-01-230330-10	2454.8	2428.5	1.07	0.86	0.86	0.90
11	SK-01-230330-11	2240.7	2223	0.79	0.79	0.79	0.66
12	SK-01-230330-12	2708.4	2680.3	1.04	0.95	0.95	0.87

No.	Sample Name	Magnetic Susceptibility		χ_{FD} (%)	Magnetic Susceptibility Normalization		χ_{FDN} (%)
		Low Field (χ_{LF})	*High Field (χ_{HF})*		*Low Field (χ_{LFN})*	*High Field (χ_{HFN})*	
13	SK-01-230330-13	2382.1	2361.5	0.86	0.84	0.84	0.72
14	SK-01-230330-14	2682	2659.3	0.83	0.94	0.95	0.70
15	SK-01-230330-15	2221	2202.9	0.81	0.78	0.78	0.68
	χ_{MAX}	2839.6	2811.6	1.19	1	1	1
	χ_{MIN}	2175.4	2156.8	0.55	0.77	0.77	0.46
	$\chi_{AVERAGE}$	2503.5	2480.7	0.903333	0.9	0.9	0.76
	Standard deviation	215.2	211.1	0.162	0.1	0.1	0.136

In table 1, it can be seen that the river sand sample which has the largest magnetic susceptibility value is in sample SK-01-230330-06 with a value of 2786 x $10^{-8}m^3/kg$ and has normalized χ_{LFN} which is worth 1. the river sand sample which has the smallest magnetic susceptibility value is in sample SK-01-230330-03 with a value of 2175.4 x $10^{-8}m^3/kg$ and has normalized χ_{LFN} which is worth 0.77. The average susceptibility value of Kamumuan river sand is 2503.5 x $10^{-8}m^3/kg$ and the normalized average χ_{LFN} is 0.9. The standard deviation is 215.2 and the normalized standard deviation of χ_{LFN} is 0.1. Kamumuan river sand has the largest χ_{FD} (%) value in sample SK-01-230330-06 with a value of 1.19 (%) and has normalized χ_{FDN} which is 1. The smallest χ_{FD} (%) value is in sample SK-01-230330-07 0.55 (%) and has normalized χ_{FDN} which is 0.46. The average value of χ_{FD} (%) is 0.93 (%) and the normalized average χ_{FDN} is 0.76. The standard deviation is 0.16 and the normalized standard deviation of χ_{FDN} is 0.16.

The susceptibility value of river sand that has been grouped into 3 treatments, namely the addition of magnetic minerals (PTM), reduction of magnetic minerals (PKM), and without treatment (PM) that have been measured can be seen in Table 2.

Table 2. Susceptibility value of river sand that has been categorized into 3 treatment PTM, PKM, and PM

No	Sample Name	Magnetic Susceptibility (10^{-8} m^3/kg)		χ_{FD} (%)
		Low Field (χ_{LF})	*High Field (χ_{HF})*	
1	SK-01-PTM-230517-01	3958.5	3929.3	0.74
2	SK-01-PTM-230517-02	3503.1	3476.6	0.75
3	SK-01-PTM-230517-03	4128.3	4101.2	0.66
	$\chi_{AVERAGE}$	3863.3	3835.7	0.72
4	SK-01-PKM-230517-01	1957.1	1940.8	0.83
5	SK-01-PKM-230517-02	1991.5	1975.7	0.79
6	SK-01-PKM-230517-03	1813.2	1799.4	0.76
	$\chi_{AVERAGE}$	1920.6	1905.3	0.79
7	SK-01-PM-230517-01	2382.1	2370.6	0.65
8	SK-01-PM-230517-02	2381.7	2371.4	0.78
9	SK-01-PM-230517-03	2240.4	2221.1	0.63
	$\chi_{AVERAGE}$	2334.7	2321	0.62

In table 2. it can be seen the susceptibility value that has been grouped based on treatment, the highest susceptibility value in the PTM sample with an average value of 3863.3 x $10^{-8}m^3/kg$. The lowest susceptibility value is in the PKM sample with an average value of 1920.6 x $10^{-8}m^3/kg$. The normal susceptibility value in the PM sample with an average value of 2334.7 x $10^{-8}m^3/kg$. The largest χ_{FD} (%) value is in the magnetic mineral reduction sample (PKM) with a value of 0.79 (%). The smallest χ_{FD} (%) value in the normal magnetic mineral (PM) sample with a value of 0.62 (%). The medium χ_{FD} (%) value in the magnetic mineral addition (PTM) sample with a value of 0.79 (%).

Susceptibility value of kamumuan river sand, the mortar mixture (mixture of sand, cement and water) that has been made can be seen in Table 3.

Table 3. Magnetic susceptibility values of Kamumuan river that has become mortar mix based on treatment

No	Sample Name	Magnetic Susceptibility (10^{-8} m^3/kg)		χFD (%)
		Low Field (χ_{LF})	*High Field (χ_{HF})*	
1	SK-01-ATM-230530-01	2860.5	2856.5	0.84
2	SK-01-ATM-230530-02	2913.5	2889.3	0.83
3	SK-01-ATM-230530-03	2865.7	2841.1	0.86
	$\chi_{AVERAGE}$	2879.9	2862.3	0.84
4	SK-01-AKM-230530-01	1089.8	1081.5	0.76
5	SK-01-AKM-230530-02	1104.3	1096.3	0.73
6	SK-01-AKM-230530-03	1169.5	1160.4	0.78
	$\chi_{AVERAGE}$	1121.2	1112.7	0.76
7	SK-01-AM-230530-01	2300.2	2281	0.83
8	SK-01-AM-230530-02	2234.6	2215.2	0.87
9	SK-01-AM-230530-03	2207.7	2189.5	0.82
	$\chi_{AVERAGE}$	2247.5	2228.6	0.84

In Table 3, it can be seen that the magnetic mineral addition river sand sample has the largest magnetic susceptibility value in sample SK-01-PTM-230517-03 and the magnetic mineral addition sand sample has the smallest magnetic susceptibility value in sample SK-01-PTM-230517-02. The largest χ_{FD} (%) value is found in sample SK-01-PTM-230517-02 and the smallest χ_{FD} (%) value is found in sample SK-PTM-230517-03. Magnetic mineral reduction river sand sample has the largest magnetic susceptibility value in sample SK-01-PKM-230517-02 and the magnetic mineral reduction sand sample has the smallest magnetic susceptibility value in sample SK-01-PKM-230517-03. The largest χ_{FD} (%) value is found in sample SK-01-PKM-230517-03 and the smallest χ_{FD} (%) value is found in sample SK-PKM-230517-03. River sand sample without treatment has the largest magnetic susceptibility value in sample SK-01-PM-230517-01 and the river sand sample without treatment has the smallest magnetic susceptibility value in sample SK-01-PM-230517-03. The largest χ_{FD} (%) value is found in sample SK-01-PM-230517-02 and the smallest χ_{FD} (%) value is found in sample SK-PM-230517-03.

The values of χ_{HF} between χ_{FD} (%) of pure Kamumuan river samples, river sand samples grouped by treatment and sand samples that have become mortar dough will be plotted in the graph in Figure 2.

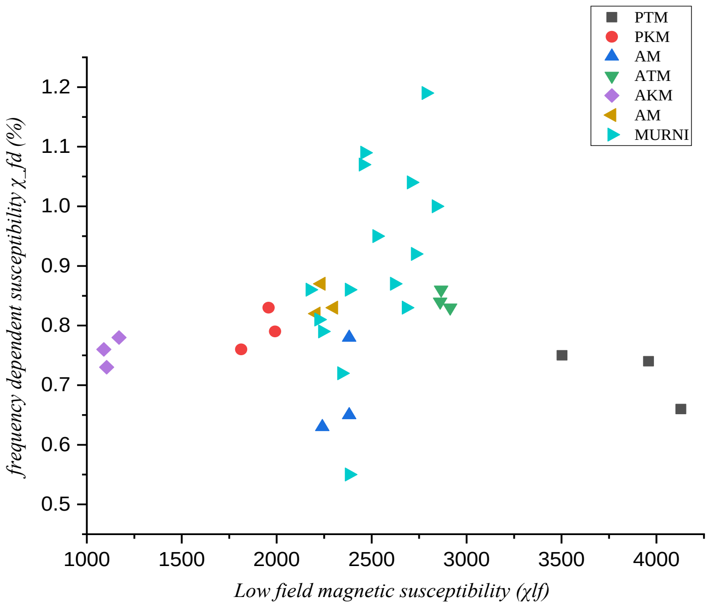


Fig 2. Relationship of χ_{LF} values between χ_{FD} (%) of pure sand, segregated sand and sand mortar samples.

From Figure 2 we can see the relationship between the value of χ_{HF} and χ_{FD} (%) in the form of a plot. It can be seen the difference in susceptibility values between samples. Based on the above results, the shape of the grain and the characteristics of the magnetic minerals from these samples can be seen in Table 4.

Table 4. Magnetic Mineral Characterization of Kamumuan River Sand

Sample Name	Magnetic Susceptibility χ_{LF} (10^{-8} m^3/kg)	χ_{FD} (%)	Magnetic Properties	Grain Type
SK-01-230330	2222 - 2844.1	0.55 - 1.19	Antiferomagnetic	Almost no SP granules
SK-01-PTM-230517	3963.5 - 4124.1	0.66 - 0.75	Antiferomagnetic	Almost no SP granules
SK-01-PKM-230517	1813.5 - 1994.2	0.76 - 0.83	Antiferomagnetic	Almost no SP granules
SK-01-PM-230517	2240.2 - 2381.8	0.63 - 0.78	Antiferomagnetic	Almost no SP granules
SK-01-ATM-230530	2862.8 - 2914.1	0.83 - 0.86	Antiferomagnetic	Almost no SP granules
SK-01-ATM-230530	1090.3 - 1170.5	0.73 - 0.78	Antiferomagnetic	Almost no SP granules
SK-01-AM-230530	2208.9 - 2300.9	0.82 - 0.87	Antiferomagnetic	Almost no SP granules

Based on table 4, it can be seen that the nature of the magnetism of the kamumuan river sand sample is antiferromagnetic which is almost no superparamagnetic grains [14][18]. In sample SK-01-230330 ranging from 2222 - 2844.1 x $10^{-8}m^3$/kg. Furthermore, for the range of susceptibility values obtained from sand samples that have been grouped into 3 treatments, namely the addition of magnetic minerals (PTM), the reduction of magnetic minerals and without treatment (PM). In the sample of magnetic mineral addition SK-01-PTM-230517 ranging from 3963.5 - 4124.1 x $10^{-8}m^3$/kg, the sample of magnetic mineral reduction SK-01- PKM-230517 ranging from 1813.5 - 1994.2 x $10^{-8}m^3$/kg, and the sample without treatment SK-01-PM- 230517 from 2240.2 - 2381.8 x $10^{-8}m^3$/kg. Furthermore, the range of susceptibility values obtained from sand samples that have been made into mortar dough is grouped into 3 treatments, namely magnetic mineral addition dough (ATM), magnetic mineral reduction dough (AKM) and dough without treatment (AM). In the additional magnetic mineral dough SK-01-ATM-230530 ranging from 2862.8 - 2914.1 x $10^{-8}m^3$/kg, magnetic mineral reduction dough ranging from 1090.3 - 1170.5 x $10^{-8}m^3$/kg, and dough without treatment ranging from 2208.9 - 2300.9 x $10^{-8}m^3$/kg.

Mortars made from kamumuan river sand from sample point SK-01 were grouped into 3 treatments of additional mineral dough (ATM), mineral reduction dough (AKM) and Normal magnetic mineral dough (AM). Each sample made 3 mortars so that there were 9 mortar samples measured compressive strength of the sample on June 6, 2023 tested in accordance with SNI using Cement Compression testing machine [18]. The results of mortar compressive strength can be seen in Table 5.

Table 5. Compressive strength results of mortar made from river sand based on 3 treatments of kamumuan river sand

Sample Name	Treatment	Compressive Strength (Kg/cm²)	Magnetic Susceptibility (χlf) $10^{-8}m^3$/kg	χ_{FD} (%)
SK-01-230330	ATM	49.4	2879.9	0.84
	AKM	46.6	1121.2	0.76
	AM	52.3	2247.5	0.84

Based on table 5. It can be seen the results of each sample that has been categorized into 3 categories. mortar making is done by mixing 618.75 grams of sand, 206.25 grams of cement and 120 ml of water. Mortar tested using Cement Compression testing machine aged 7 days [19] For the results of the compressive strength of mortar with the addition of magnetic minerals in sand (ATM) amounted to 49.4 Kg / cm². The compressive strength of mortar with reduced magnetic minerals in sand (AKM) amounted to 46.6 4 Kg/cm². Furthermore, the results of the compressive strength of mortar with no treatment on sand (AM) amounted to 52.3 4 Kg/cm².

To find out the relationship between magnetic minerals and compressive strength can be seen in Figure 3.

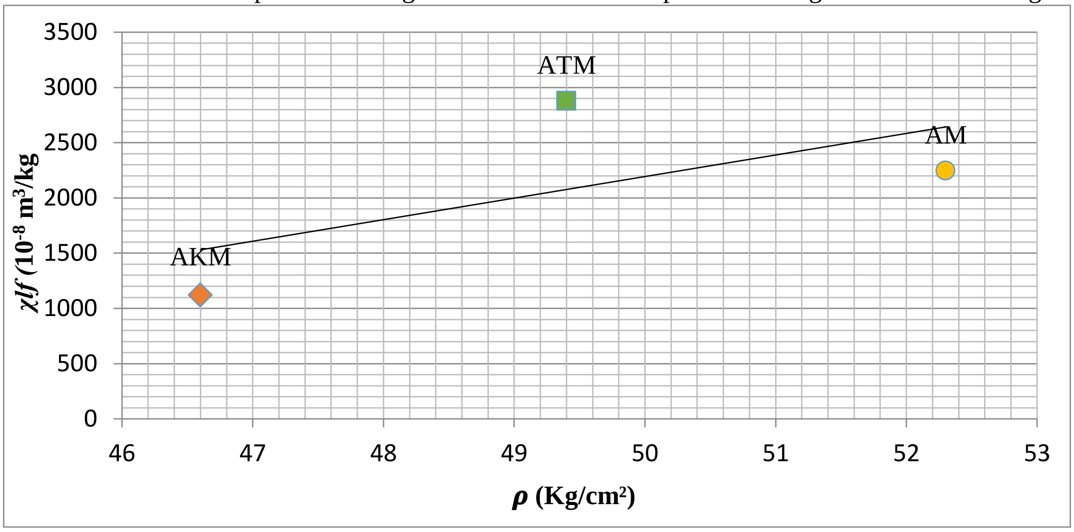


Fig 3. Plot of the relationship between χ_{LF} values and compressive strength values of mortar made from river sand grouped by 3 treatments.

Based on Figure 3 above, there is a relationship between compressive strength and χ_{LF}. Where the highest compressive strength value in the sample without treatment (AM), for the χ_{LF} value is at the result of the medium susceptibility value of the sample. The middle compressive strength value in the magnetic mineral addition sample (ATM), for the χ_{LF} value is at the result of the highest susceptibility value of the sample. The lowest final compressive strength value in the magnetic mineral reduction sample (AKM), for the χ_{LF} value is at the lowest susceptibility value result. It can be seen for a gradient value of 195.12 and an average confidence level of 0.3897. based on the above results, the compressive strength is also influenced by the magnetic mineral factor that is varied in the main material, namely sand. compressive strength is also influenced by external materials other than the main ingredients such as coconut shell charcoal and coal ash[12][17], this shows that the variation or addition of magnetic minerals affects the results of compressive strength in mortar.

IV. CONCLUSION

Based on the results of measurements of Kamumuan river sand samples, Sungai Limau District and carried out 3 treatments, namely the addition of magnetic minerals, reduction of magnetic minerals, and without treatment contained in Kamumuan river sand samples. The highest susceptibility value is in the addition of magnetic minerals and the lowest value is in the reduction of magnetic minerals. Each sample tested has the same grain type, namely the absence of superparamagnetic grains and has antiferromagnetic properties. The results of the mortar compressive strength test showed the highest value in the normal magnetic mineral sample and the lowest value in the magnetic mineral reduction sample. Based on the analysis conducted, the magnetic minerals contained in the sand affect the results of the compressive strength of the mortar, the smaller the susceptibility value in the sand, the smaller the compressive strength of the mortar. The types of mortar produced from Kamumuan River Sand are types S and O, where the use of type S mortar in the layer above the ground and type O mortar in the wall layer to not withstand the load.

ACKNOWLEDGMENT

The author give as much appreciate to UNP Research and Community Service Institute for Indonesia Collaborative Research funding between Universitas Negeri Padang Indonesia and Milan University (Frascesca Forni) Italia through Contract Number 1463/UN35.15/LT/2023.

REFERENCES

[1] T. Mulyono, "TEKNOLOGI BETON: Dari Teori Ke Praktek," no. March, 2019.
[2] Y. dkk Lado, "Uji Kuat Tekan Beton dan Mortar Menggunakan Pasir Kali Noeleke," *J. Tek. Sipil*, vol. VII, no. 1, pp. 37–44, 2018.
[3] M. Pataras, I. F. Astira, J. Arliansyah, P. Rangkuti, and B. Roynaldo, "Analisis penggunaan pasir pantai,

darat, dan sungai terhadap kinerja laston dan lataston wearing course," *J. Tek. Sipil Unsri*, no. September, pp. 479–487, 2017.
[4] M. Qomaruddin, "Studi Komparasi Karakteristik Pasir Sungai Dikabupaten Jepara," *J. Ilm. Teknosains*, vol. 4, no. 1, pp. 6–10, 2018, doi: 10.26877/jitek.v4i1.2283.
[5] M. Ito, A. H. Daulay, and L. H. Lubis, "Karakterisasi Kandungan Mineral dan Pengaruh Treatment Panas Pasir Besi Hulu Sungai Seruai Kabupaten Deli Serdang," vol. 5, no. 3, pp. 151–160, 2023.
[6] Helmita, H. Rifai, and L. Dwiridal, "Characterization and Identification of Magnetic Mineral Content in Industrial Dry Ink (Toner)," *J. Phys. Conf. Ser.*, vol. 2309, no. 1, 2022, doi: 10.1088/1742-6596/2309/1/012014.
[7] R. N. Fajri, R. Putra, C. B. De Maisonneuve, A. Fauzi, Yohandri, and H. Rifai, "Analysis of magnetic properties rocks and soils around the Danau Diatas, West Sumatra," *J. Phys. Conf. Ser.*, vol. 1185, no. 1, 2019, doi: 10.1088/1742-6596/1185/1/012024.
[8] Afdal and L. Niarti, "KARAKTERISASI SIFAT MAGNET DAN KANDUNGAN MINERAL PASIR BESI SUNGAI BATANG KURANJI PADANG SUMATERA BARAT," vol. 5, no. 1, pp. 24–30, 2013.
[9] R. Rahmayuni, H. Rifai, L. Dwiridal, A. N. Yuwanda, D. A. Visgun, and A. Rahmi, "Eksakta Article Distribution Pattern of Magnetic Susceptibility Value of Iron Sand on the Surface of Pasia Jambak Beach Pasia Nan Tigo Padang," vol. 22, no. 04, pp. 302–310, 2021, [Online]. Available: https://doi.org/10.24036/eksakta/vol22-iss4/274
[10] SNI 03-1974, "Metode Pengujian Kuat Tekan Beton," *Sni 03-1974-1990*, pp. 2–6, 1990.
[11] W. I. Dharmawan, D. Oktarina, and M. Safitri, "Perbandingan Nilai Kuat Tekan Beton Menggunakan Hammer Test dan Compression Testing Machine terhadap Beton Pasca Bakar," *Media Komun. Tek. Sipil*, vol. 22, no. 1, pp. 35–42, 2016, doi: 10.14710/mkts.v22i1.12404.
[12] M. Yunanda, "Perbandingan Kuat Tekan Mortar Dengan Memanfaatkan Coal Ash Waste," *J. Tek. Sipil*, vol. 7, no. 2, pp. 33–40, 2019, doi: 10.36546/tekniksipil.v7i2.241.
[13] J. A. Dearing *et al.*, "Frequency-dependent susceptibility measurements of environmental materials," *Geophys. J. Int.*, vol. 124, no. 1, pp. 228–240, 1996, doi: 10.1111/j.1365-246X.1996.tb06366.x.
[14] H. Rifai, R. Putra, M. R. Fadila, E. Erni, and C. M. Wurster, "Magnetic Susceptibility and Heavy Metals in Guano from South Sulawesi Caves," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 335, no. 1, 2018, doi: 10.1088/1757-899X/335/1/012001.
[15] SNI 03-6825-2002, "Sni 03-6825-2002," *Standar Nas. Indones. Metod. Penguji. kekuatan tekan mortar semen Portl. untuk Pekerj. sipil*, 2002.
[16] S. S. Mukrimaa *et al.*, *Graham Borradaile, 2003 - Statistics of Earth Science Data_ Their Distribution in Time, Space, and Orientation*, vol. 6, no. August. 2016.
[17] A. P. Sihombing, Y. Afrizal, and A. Gunawan, "Pengaruh Penambahan Arang Batok Kelapa Terhadap Kuat Tekan Mortar," *Inersia, J. Tek. Sipil*, vol. 10, no. 1, pp. 31–38, 2018, doi: 10.33369/ijts.10.1.31-38.