The effect of ferromanganese slag and basalt concentration on the composite mortar products

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Abstract. This research was conducted to study the effect of the concentration of ferromanganese slag and basalt as an additive material for the cement to produce the mortar composite. The mesh size of slag and basalt powder were varied from 325 to 400. Meanwhile, the PCC cement weights were varied from 10 to 40 % of the weight. The physical-chemical analysis shown that the slag and basalt have quality as a cement or pozzolan additive based on ASTM C618. The important content in the slag is 25.889 % of SiO₂, 16.938 % of Al₂O₃, and 25.420 % of Fe₂O₃. Meanwhile in the basalt containing SiO₂ of 48.463 %, Al₂O₃ of 20.143 %, and Fe₂O₃ of 11.510 %. Based on the physical test of cement on compressive strength that has been carried out for 325 mesh and 400 mesh samples, the results show that the compressive strength with the addition of slag and basalt powder has a higher value of compressive strength compared to normal mortar. The highest value of compressive strength was for 325 mesh at a concentration of 10 % at 45.2 Mpa and 400 mesh for the concentration of 10 % at 1.74 MPa. Whereas for standard mortar the compressive strength is 0.848 MPa. The results of XRF characterization can be determined by the presence of SiO₂, Al₂O₃, Fe₂O₃, and CaO oxides.

Keywords: Mortar, slag, basalt, cement.

1. Introduction

Cement is a compound or hydraulic binding agent consisting of compounds C-S-H (calcium silicate hydrate) which when reacting with water will be able to bind other solid materials to form a unity that is compact, solid, and hard [1]. The raw materials used in the manufacture of cement consist of the main ingredients, corrective materials and additives [2]. One of the products in its manufacture uses cement material is Mortar.

According to Maryoto [3], mortar is a mixture consisting of cement, fine aggregates, and water, both hardened and not hardened in the form of cubes of a certain size and certain age. The mortar was made using a strong and high-temperature resistant material such as slag and basalt.

Slag is an industrial waste of metal smelting process [4]. Steel slag waste, included in the category of hazardous and toxic materials (B3). In 2010 slag production in Indonesia was only around 800 thousand tons per year. Every ton of steel production will produce 20 percent of slag waste. PT Krakatau Steel in Cilegon, Banten is one of the steel-producing companies in Indonesia that produces at least 150 tons of slag every day. To omit pollution, the steel association asked the government to
utilize steel waste (slag waste). Based on research conducted by Putra et al. [5] that slag can be used as the main constituent aggregate because it has a compressive strength greater than conventional high-quality concrete.

In addition to slag, basalt is also a material that can be used in strong materials and is resistant to high temperatures. Basalt is the igneous rock which performs well in terms of strength, temperature range, and durability. Basalt contains SiO$_2$ and Al$_2$O$_3$ as the main oxides around 40-50% and 10-20%, each of which consists of SiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$, CaO, MgO and other oxides such as K$_2$O and TiO$_2$. Based on data from the Geological Resource Centre - the Geological Agency of the Ministry of Energy and Mineral Resources in 2014, Indonesia has basalt non-metallic mineral resources around 6,282,661,980 tons. Meanwhile, the Mining and Energy Office of Lampung Province reported that scattered basalt rock reserves amounted to 318,480,000 tons [6]. Basalt powder can be used as a cement additive material measured by natural pozzolan related specifications based on ASTM C618 requirements on chemical components and physical properties [7]. Important requirements are closely related to pozzolanic activity, namely the number of components of SiO$_2$ + Al$_2$O$_3$ + Fe$_2$O$_3$ at least 70%, the level of fineness held up on sieve no.325 (45μm) (wet-sieved on 45μm sieve) maximum 34% and pozzolanic activity index at least 75%. In this study, the manganese slag and basalt scoria powder with XRF testing and XRD characterization. While the PCC cement mortar sample which size of 5×5×5 (cm$^3$) was tested for compressive strength, porosity and absorption, fuel shrinkage, and specific gravity which tested at a 14-day test age.

2. Methodology
Preparation of slag and basalt powder is done by destroying chunks of basalt using a jaw crusher and grinding in the ball mill for ± 5 hours. Slag and basalt powder then sifted using mesh sieve no. 325 and no. 400. Characterization of basalt powder using XRF (Epsilon 3XLE Top Bench) to determine the content of oxide, meanwhile XRD (PANalytical X’Pert$^3$ Powder) to find out the phase formed and wet sieve method for smoothness. The raw materials of the mortar used are Semen Batu Raja brand portland cement (PCC), beach sand from Maringgai Lampung Timur, water, and slag and basalt powder.

Checking cement and water materials is only by visual observation. While the examination of sand material includes testing of moisture content, gradation, specific gravity, sludge content, and absorption. The raw material composition of mortar is the ratio of cement: sand of 1:5, cement water factor of 0.6, and variations in the concentration of weight of slag and basalt from cement weight of 10, 20, 30, and 40%.

Making mortar test materials begins by mixing all the ingredients in each mixture composition into a mixer container. The mixture is then given water and stirred until it is homogeneous. After that, the dough is put into a 5×5×5 (cm$^3$) cube mold. The specimen is flattened, coded and silenced for 24 hours and removed from the mold. The treatment of mortar (curing) is done by immersing the test object into a bucket that has been filled with water until the age of 14 days. After the age of 14 days, the mortar specimens were tested for compressive strength and physical properties.

3. Results and Discussions
3.1. Preliminary testing
Preliminary testing is an activity that must be done before testing the mechanical properties of mortar. The following are preliminary tests that have been carried out including XRF testing, characterization using XRD, and testing of aggregate properties consisting of tests (sludge content, water content, gradation, specific gravity, and absorption). The results of the XRF testing of slag and basalt samples are presented in Table 1.
Table 1. XRF slag and basalt test results

| Oxide Compound | Slag   | Basalt  |
|----------------|--------|---------|
| SiO2           | 25.898 | 48.463  |
| Al2O3          | 16.938 | 20.143  |
| Fe2O3          | 25.420 | 11.510  |
| CaO            | 23.243 | 9.605   |
| MgO            | 2.131  | 4.269   |
| TiO2           | 0.680  | 1.226   |
| K2O            | 0.292  | 0.605   |
| MnO            | 1.613  | 0.195   |
| SiO2 + Al2O3 + Fe2O3 | 68.256 | 80.116 |

Table 1 shows that the basalt sample has the major oxide content are 48.463 % of SiO2 of followed by 20.143 % of Al2O3, 11.510 % of Fe2O3 of CaO of 9.605 % and MgO of 4.269 %. While the slag sample has the major oxide content is 25.889 % of SiO2 followed by 25.420 % of Fe2O3, 23.293 % of CaO, 16.938 % of Al2O3 and 2.131 % of MgO. According to [8] in his research, the content of pozzolan with a total percentage of SiO2, Al2O3, and Fe2O3 more than 50 % generally produced good pozzolanic material and high pozzolanic activity so that it could be used as cement substitution material. The result of the XRD analysis of the basalt sample diffractogram pattern before calcination is shown in Figure 1. Meanwhile, the results of the analysis of the basalt sample diffractogram pattern before calcination are shown in Figure 2.

Figure 1. XRD diffractogram pattern basalt sample(symbol: ♦ =Anorthite, ■ = Forsterite, □ = Augite, ● = Cristobalite Low).
Figure 2. XRD diffractogram pattern of a slag sample (symbol: ♦=Magnetite, □= Hedenbergite, △= Gehlenite, □= Calcite, ●= Quartz Low).

Table 2. Results of sand testing analysis

| No | Testing       | Percentage | Standard          |
|----|---------------|------------|-------------------|
| 1  | Sand Gradation| 2.33 mm    | 2.2 – 3.2         |
| 2  | Density       | 2.53 g/cm³ | -                 |
| 3  | Mud Content   | 3.69%      | ≤ 5%              |
| 4  | Water Content | 3.52%      | -                 |
| 5  | Sand Absorption| 10.26%    | 13.27%            |

The results of several studies also showed that slag and basalt were very potential as pozzolanic material similar to artificial pozzolan, namely class F fly ash with high pozzolanic reactivity and mineral admixture which could improve the workability of the mixture. The results of the sand test analysis used are presented in Table 2. The results of the sand analysis showed that overall, the sand material in this study met the standard as fine aggregate for mortar mixture.

3.2. Evaluation of the mortar from slag and basalt

The physical tests carried out on samples of mortar specimens included compressive strength, absorption, porosity, density (density), fuel shrinkage and XRF testing and characterization using XRD.

3.2.1. The effect of slag and basalt concentration towards the compressive strength of mortar

The testing of compressive strength carried out to determine the optimum levels of slag powder and basalt against cement. The specimens were made 12 samples on using 325 and 400 mesh for 14 days of immersion time. These specimens were used different compositions of slag and basalt powder with
a value of 10%, 20%, 30%, and 40% with each sample 3 specimens. The process of testing specimens (in the form of cubes with a size of 5×5×5 (cm³) is installed on a compressive strength machine centrally.

Based on the table above, the mortar compressive strength of cement-based binder mixture on slag and basalt powder has a higher compressive strength than normal compressive strength (0 %wt), but the compressive strength of mortar decreases with the increasing content of slag powder and basalt. The highest compressive strength occurs in the addition of 10% slag and basalt, then the compressive strength will decrease further until the addition of 40% slag and basalt powder. The highest value of mesh 325 mortar compressive strength was found in the addition of slag powder and 10% basalt at 4.52 MPa and the lowest compressive strength was at 40% addition with a value of 3.15 MPa. Whereas the mortar compressive strength for the highest 400 value mesh is found in the addition of 10% with a value of 1.74 Mpa and the lowest compressive strength is in the addition of 40% of 0.872 Mpa. Mortar without the addition of slag powder and basalt has a compressive strength of 0.848 MPa.

| Table 3. Results of mortar compressive strength |
|-----------------------------------------------|
| No | Percentage of slag dan basalt substitution (%) | Compressive strength (MPa) |
|    |                                              | Mesh 325 | Mesh 400 |
| 1  | 10                                           | 4.52     | 1.74     |
| 2  | 20                                           | 3.72     | 1.51     |
| 3  | 30                                           | 3.22     | 1.19     |
| 4  | 40                                           | 3.15     | 0.872    |
| 5  | Standard                                     | 0.848    |          |

Mortar compressive strength with the addition of slag powder and basalt which has a higher compressive strength value is due to a good pozzolanic reaction. When the silica-containing pozzolan material was added during the hydration of portland cement, then is reacted with calcium hydroxide Ca(OH)₂ to provide an additional amount of calcium silicate hydrate (C-S-H) which is the main component in cement hydration. Gradually, the additional calcium silicate hydrate that is formed is binding and fills the space to provide impermeability, durability, and strength will increase [9]. The pozzolanic reaction that occurs during hydration is:

\[
\text{Ca(OH)}_2 + \text{SiO}_2 \rightarrow \text{C-S-H} \tag{1}
\]

3.2.2. The effect of slag and basalt concentration towards the porosity of mortar

Porosity testing was carried out on specimens with 14 days of immersion. The porosity test results of mortar specimens are shown in Table 4.

| Table 4. Porosity test results |
|--------------------------------|
| No | Percentage of slag and basalt (%) | Porosity (%) |
|    |                                  | Mesh 325 | Mesh 400 |
| 1  | 10                                | 6.13     | 2.93     |
| 2  | 20                                | 6.66     | 3.46     |
| 3  | 30                                | 6.93     | 4.8      |
| 4  | 40                                | 7.2      | 5.33     |
| 5  | Standard                          | 1.6      |          |
Based on the table above, it can be seen that the percentage of each different composition has a large influence on the axle value of the mortar, which the porosity of the mortar will increase with increasing slag and basalt content in the mixture. The manufacture of mortar in a good mix of mineral percentages, namely (0-15 % partial replacement for Portland cement) where the results can improve the nature of the porosity of a mixture. The higher the compressive strength and the lower the porosity, the porosity describes the value of the concrete strength that supports a construction. The denser the concrete, the higher the density, the greater the compressive strength or the quality of the concrete and its strength in supporting heavier construction.

3.2.3. The effect of slag and basalt concentration towards the absorption of mortar
Absorption testing was carried out on specimens with 14 days of immersion age. The results of the absorption tests for mortar specimens are presented in Table 5. The results of absorption or water absorption are increased due to the factor of the pore sample grain from the composition of the material itself. Aggregate items can be less powerful because two things are composed of weak material or consisting of particles that are strong but not good in binding [6]. Another factor that affects the absorption value is due to the presence of large enough grains such as slag powder and basalt which are less able to enter into the holes between the grains. So that the addition of slag and basalt powder will affect water absorption in this sample. Increasing the value of absorption in mortar is caused by the addition of slag and basalt powder that exceeds the optimum limit. The more slag powder and basalt gave to a mixture, the greater the absorption value produced. By binding to the absorption value of the mortar, the compressive strength and density will decrease with increasing value of absorption in a mortar mixture [10].

| No | Percentage of slag and basalt (%) | Absorption (%) |
|----|----------------------------------|---------------|
|    |                                  | Mesh 325      | Mesh 400      |
| 1  | 10                               | 43.38         | 25.55         |
| 2  | 20                               | 44.65         | 29.48         |
| 3  | 30                               | 46.76         | 37.43         |
| 4  | 40                               | 47.71         | 40.17         |
| 5  | Standard                         | 16.36         |               |

3.2.4. The effect of slag and basalt concentration towards the specific gravity of mortar
The results of testing the density of the mortar mixed with the addition of the percentage of slag powder and basalt (wt %) to the weight of cement at the age of 14 days are presented in Table 6. The density or density results decrease due to the presence of sample grain factors, pores and the composition of the material itself. Slag and basalt powder grains can be less strong because of two things that consist of weak material or consist of particles that are strong but not good in binding [6].

The mortar pores are caused by the presence of large enough grains such as slag powder and basalt which are less able to enter into the spacing holes between the grains so that the addition of slag and basalt powder will affect the addition of pores in this sample. While the composition also affects the density because if you use a composition that has a high level of hardness and has a size that can enter the pore gap it will increase the value of density. But if a material which has a low hardness level and has a very large grain size such as slag powder and basalt in making mortar, it will increase the amount of mortar density itself.
Table 6. Density test results

| No | Percentage of slag and basalt (%) | Density (g/cm³) | Mesh 325 | Mesh 400 |
|----|----------------------------------|----------------|----------|----------|
| 1  | 10                               | 2.36           | 2.02     |
| 2  | 20                               | 2.35           | 1.94     |
| 3  | 30                               | 2.13           | 1.86     |
| 4  | 40                               | 1.79           | 1.83     |
| 5  | Standard                         | 1.888          |          |

3.2.5. The effect of slag and basalt concentration towards the fuel shrinkage of mortar

The purpose of the fuel shrinkage test was to see the effect of adding slag and basalt powder to changes in mass and dimensions of the mortar. The results of fuel shrinkage testing of mortar specimens are presented in Table 7.

The difference between standard mortar and mortar with the addition of slag and basalt powder is seen in the decrease in mass shrinkage in which the mortar sample with additives (slag and basalt) undergoes better densification due to the composition of silica in the mortar body. The decrease in fuel shrinkage in standard mortar samples against mortar samples with the addition of slag and basalt powder has indicated that increased silica content can reduce fuel shrinkage in mortar.

Table 7. Fuel shrinkage test results

| No | Percentage of slag and basalt (%) | Mass shrinkage (%) | Mesh 325 | Mesh 400 |
|----|----------------------------------|--------------------|----------|----------|
| 1  | 10                               | 10.566             | 6.26     |
| 2  | 20                               | 9.655              | 4.32     |
| 3  | 30                               | 7.262              | 4.13     |
| 4  | 40                               | 5.95               | 3.79     |
| 5  | Standard                         | 5.58               |          |

3.3. XRF and XRD testing mortar testing

The compressive strength values of each PCC cement mortar test showed that the substitution of slag powder and basalt dominantly had higher compressive strength than slag and basalt powder without any addition. Therefore, XRF mortar samples were tested at various concentrations of heavy slag and basalt. The results of the XRF testing of PCC cement mortar with the concentration of slag and basalt powder weight are shown in Table 8.

The test results showed that the PCC mortar sample which contained the highest CaO compound was located at the addition of 10 % slag and basalt which was equal to 75.279 %. CaO content decreased with increasing concentration of basalt powder. While the content of SiO₂, Al₂O₃ and Fe₂O₃ increases with the addition of heavy concentrations of slag and basalt powder. Standard PCC cement mortar and with a heavy concentration of slag powder and 40 % basalt have a fairly large decreasing value, while for other substitution concentrations always increase. These results indicate that the PCC cement mortar content was dominated by CaO, SiO₂, Al₂O₃, and Fe₂O₃.

XRD characterization is carried out to determine the phase formed in the tested sample. The characterization results obtained data in the form of diffraction distribution of intensity to 2 thetas, the peak results obtained can determine crystalline properties, and where sharp peaks with high intensity
are crystalline phases and widening peaks are amorphous phases. Tests were carried out on five mortar product samples calcined at 900 °C. XRD results for mortar products using 325 mesh with variations in slag powder and 10 % basalt can be seen in Figure 3.

Table 8. Results of XRF testing of PCC cement mortar variations in a weight concentration of slag and basalt powder

| No | Oxide    | Percentage (%) |
|----|----------|----------------|
|    |          | Standard | BS Mesh 325 10 | BS Mesh 325 20 | BS Mesh 400 30 | BS Mesh 400 40 |
| 1  | CaO      | 65.252  | 75.279         | 68.959         | 61.970         | 69.965         |
| 2  | SiO₂     | 26.374  | 13.489         | 18.410         | 17.737         | 15.301         |
| 3  | Al₂O₃    | 3.686   | 5.067          | 5.637          | 9.471          | 6.302          |
| 4  | Fe₂O₃    | 1.741   | 3.345          | 3.874          | 5.695          | 5.086          |
| 5  | TiO₂     | 1.006   | 0.804          | 0.761          | 0.910          | 0.851          |
| 6  | MgO      | 0.459   | 0.686          | 0.769          | 1.188          | 0.913          |
| 7  | SO₃      | 1.126   | 0.445          | 0.606          | 0.506          | 0.495          |
| 8  | K₂O      | 0.455   | 0.445          | 0.460          | 1.392          | 0.401          |

Figure 3. The diffractogram of the XRD analysis of sample slag powder and 325 10% basalt mesh. Symbol: ☐ = Portlandite, ☑ = Calcium Silicide Hydride, ■ = Calcite, ● = Anorthite, ● = Quartz Low.
The phases formed before calcination include Portland (\(\text{Ca(OH)}_2\)) which corresponds to the ICSD 98-020-2222 file number at the highest peak (001), then the Calcite (\(\text{CaCO}_3\)) phase that matches the ICSD 98 file number -004-0112 at the highest peak at (104) and (113). Then, the other phase formed is the Anorthite \(\text{Ca(AlSi}_3\text{O}_8)\) phase which corresponds to the ICSD number file 98-006-7953 at the highest peak at (224). Furthermore, the other phase is Calcium Silicide Hydride (CSH) which corresponds to the ICSD 98-038-0316 file number at the highest peak at (423) and other peaks at (114) and (116). And the next phase is Quartz Low (\(\text{SiO}_2\)) which corresponds to the file number ICSD 98-008-3849 at the highest peak at (011) and the other peaks are at (010), (011), (020), (112), (203), (104), (302), and (220). Furthermore, the results of the mortar analysis substituted with slag and basalt using 325 mesh with a concentration of 40 % can be seen in Figure 4.

The phases formed before calcination include Quartz Low (\(\text{SiO}_2\)) which corresponds to the file number ICSD 98-003-4636 at the highest peak (011) and the other peaks are at (010), (102), (111), (020), (201), (112), (121), (203), (104), (302), and (220), the Calcite (\(\text{CaCO}_3\)) phase that matches the ICSD file number 98-004-0107 at the highest peak at (104). Then, the other phase formed is the phase of Calcium Silicon Oxide Hydride which is by the file number ICSD 98-015-1962 at the highest peak (016). Furthermore, another phase is Calcium Silicide Hydride (CSH) which is by ICSD 98-038-0316 file number at the highest peak (116). And the next phase is Portlandite (\(\text{Ca(OH)}_2\)) which matches the ICSD file number 98-003-4241 at the highest peak (001). Furthermore, the results of the mortar analysis substituted with slag and basalt using 400 mesh with a concentration of 10 % can be seen in Figure 5.

Figure 4. The diffractogram of XRD analysis of slag powder samples and 325 40 % basalt mesh. Symbol : = Portlandite, = Calcium Silicide Hydride, = Calcite, = CSHH, = Quartz Low.
Figure 5. Diffractogram results of XRD analysis of slag powder samples and 400 10 % basalt mesh. Symbol: ■ = Portlandite, □ = Calcium Silicide Hydride, ▼ = Calcite, □ = Gehlenite, ● = Quartz Low, ● = Anorthite.

The phases formed before calcination include Quartz Low (SiO₂) which corresponds to the file number ICSD 98-004-1412 at the highest peak (011) and other peaks at (010), (020), (201), (113), (104), (302), and (220), then the phase of Calcite (CaCO₃) which corresponds to the file number ICSD 98-007-9674 at the highest peak at (104) and (113). Then, the other phase formed is the Anorthite Ca₂Al₂O₆ phase which corresponds to the ICSD file number 98-006-7953 at the highest peak (202) and (222). Furthermore, another phase is Calcium Silicide Hydride (CSH) which is by the ICSD 98-038-0316 file number at the highest peak (114). Furthermore, another phase is Gehlenite (Ca₂Al₂[Al₂SiO₇]) which corresponds to the ICSD file number 98-002-4588 at the highest peak (001), (251) and (423). And the next phase is Portlandite (Ca(OH)₂) which corresponds to the ICSD file number 98-003-4241 at the highest peak (102). Furthermore, the results of the mortar analysis substituted with slag and basalt using 400 mesh with a concentration of 40% can be seen in Figure 6.

The phases formed before calcination include Quartz Low (SiO₂) which corresponds to the ICSD file number 98-064-7406 at the highest peak (011) and the other peaks are at (010), (012), (111), (020), (202), (121), (104), (032), and (220), then the phase Calcite (CaCO₃) which corresponds to the file number ICSD 98-015-8258 at the highest peak at (104). Then, the other phase formed is the Anorthite Ca₂Al₂O₆ phase which is by ICSD file number 98-006-7953 at the highest peak (231) and (224). Furthermore, another phase is Calcium Silicon Oxide Hydroxide Hydrate which is by ICSD 98-015-1962 file number at the highest peak (003). Furthermore, the other phase is Gehlenite (Ca₂Al₂[Al₂SiO₇]) which corresponds to the file number ICSD 98-002-4588 at the highest peak (251). And the next phase is Portlandite (Ca(OH)₂) which corresponds to the ICSD file number 98-003-4241 at the highest peak (102). Furthermore, the results of the XRD analysis of standard mortar or mortar products without using slag and basalt powder can be seen in Figure 7.
Figure 6. Diffractogram results of XRD analysis of slag powder samples and 400 40% basalt mesh. Symbol: □ = Portlandite, □ = Calcium Silicon Oxide Hydroxide Hydrate, ■ = Calcite, ♦ = Anorthite, ● = Silicon Oxide, □ = Gehlenite.

The phases formed before calcination include Quartz Low (SiO₂) which corresponds to ICSD 00-053-1161 file number at the highest peak (010) and other peaks at (110), (112), (121), (302), and (220), then the phase of Calcite (CaCO₃) which corresponds to the file number ICSD 00-005-0586 at the highest peak at (113) and the other peaks at 2θ (012) and (024). Then, another phase that is formed is phase Hatrurite Ca₃ (SiO₅) which corresponds to the file number ICSD 98-008-1100 at the highest peak (221) and the other peaks are at (113), (203), (510), (330), (530), and (444). Furthermore, the other phase is Calcium Silicide Hydride (CSH) which corresponds to the ICSD 98-038-0316 number file at the highest peak (210) and the other peaks are at (113), (114), (020), (006), (116), and (1004). Next, another phase is Hydrotalcite (Mg₆Al₂CO₃(OH)₁₆) which is by the file number ICSD 98-000-6296 at the highest peak (003). And the next phase is Portlandite (Ca(OH)₂) which matches the ICSD file number 98-003-4241 at the highest peak (001).

Several other studies on the use of basalt or slag powder as cement substitution material on mortar or concrete also showed dominant phases of the Plagioclase Feldspar mineral group with the composition of Anorthite (CaAl₂Si₂O₈), then phase from the Pyroxene mineral group with Augite aluminium composition (Ca (Mg, Fe, Al) (Si, Al)₂O₆) and SiO₂ [10], besides the Olivine mineral group with the composition Forsterite (Mg₂SiO₄) also found in slag and basalt [11]. The results of several of these studies indicate that the slag and basalt are very potential as pozzolanic material similar to artificial pozzolan, namely class F fly ash with high pozzolanic reactivity and mineral admixture which can improve the workability of the mixture.
Overall, the results of XRD on the sample showed the presence of silica phase in the slag and basalt samples with the formation of the Quartz Low phase which had the highest peak, while for expanded slag and basalt the amorphous silica phase was essentially slag and basalt had the highest element, silica.

4. Conclusion
Based on the characterization of the slag samples the highest compound content was found in $\text{SiO}_2$ of 25.889 $\%$, $\text{Al}_2\text{O}_3$ of 16.938 $\%$, and $\text{Fe}_2\text{O}_3$ of 25.420 $\%$ and in basalt samples the highest compound content was found in $\text{SiO}_2$ of 48.463 $\%$, $\text{Al}_2\text{O}_3$ of 20.143 $\%$, and $\text{Fe}_2\text{O}_3$ of 11.510 $\%$. And for the phase structure formed on the highest peak slag is Gehlenite, while for the highest basalt sample is Anorthite. Then the physical test is carried out, where the value of porosity and absorption that is formed on the mortar increases, the lower the value of density, compressive strength, and fuel shrinkage. Whereas the results of XRF characterization can be characterized by the presence of $\text{SiO}_2$, $\text{Al}_2\text{O}_3$, $\text{Fe}_2\text{O}_3$, and $\text{CaO}$ oxides, while the XRD characterization results on mortar products with the addition of slag powder and highest peak basalt are found in the quartz low phase, while for mortar products without the addition of slag powder and The highest basalt peak was found in the Calcium Silicide Hydride phase.

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