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Analysis of chemical-mineralogical content of brick waste as a pozzolan substitute material in blended cement

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Analysis of chemical-mineralogical content of brick waste as a pozzolan substitute material in blended cement

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Abstract. Bricks are building materials that contain compounds that can increase the compressive strength of a building. This research utilized waste bricks as a substitute for pozzolan for cement manufacture. Testing of waste bricks using the reactivity index test method, characterization with XRD and XRF. Cement powder was tested chemically, and determined the value of its compressive strength on the mortar test object. The results of the characterization of XRF instruments are SiO_2, Al_2O_3, Fe_2O_3 with minor compounds including CaO, ZnO, TiO_2, K_2O, P_2O_5, CuO, V_2O_5, Cr_2O_3, MnO, SrO, Eu_2O_3, and Re_2O_7. Meanwhile, BaO is owned only by the first and third bricks, while PbO is owned by the first. The number of SiO_2, Al_2O_3, and Fe_2O_3 compounds has met the quality requirements as pozzolanic materials (>70%), namely 84.20% of the first sample, 83.70% of the second sample, and 84.30% of the third sample. The reactivity index test also met the target (>75%), namely 75.60% of the first sample, 75.00% of the second sample, and 77.90% of the third sample. The higher the content and the reactiveness of an oxide compound in the waste bricks are directly proportional to the quality of the cement

Keywords: Brick Waste, Pozzolan, reactivity index, compressive strength

1. Introduction

Increasing technological developments and advances in the industrial sector can optimize production with better quality, relatively low production costs, and minimize the impact of waste on the surrounding environment. One industry that has an impact on the environment is the brick-making industry. The adverse effects arise from red brick waste from burning and broken bricks or roof tiles damaged during construction. Reusing ceramic waste as a substitute for cement pozzolan can reduce environmental pollution because it can reduce the consumption of natural resources and CO_2 emissions associated with Portland cement production while increasing the value of waste materials with a long biodegradation period [1].

Good clay bricks mostly come from sand (silica) and clay (alumina), which will then be mixed in a specific ratio so that when given a little water, they become plastic and go through a firing process. The ingredients for making these bricks come from 50-60% clay, sand around 35-50% sand, and water as needed. The chemical composition of bricks consists of 54-61% silica oxide (SiO_2) and 22-32% alumina oxide (Al_2O_3) [2]. Pozzolan material is an additional material in cement. Pozzolan is a material that contains silica and alumina compounds, which, when finely shaped by adding water, can become a solid material. High silica compound content can form strong bonds to provide high strength [3, 4].

The potential for using brick waste as a substitute for pozzolan in Portland cement mortar has been widely studied. Lin et al. [5] explained that the contents of SiO_2, Al_2O_3, and Fe_2O_3 in brick waste were respectively 63.21, 16.41 and 6.05% which could increase the compressive strength value of cement with 10% pozzolan substitution in concrete from 71.20 MPa to 75.10 MPa at 28 days. Nalobile et al. [6] explained that the replacement of pozzolan using brick waste in cement mortar with SiO_2, Al_2O_3, and Fe_2O_3 contents, respectively 64; 84; 21.54; and 7.87% produces compressive strength values of 6 MPa at seven days and 8 MPa at 28 days.

Reactivity index testing was carried out to determine whether brick waste could be used as a substitute for pozzolan. The characterization using an X-ray diffraction (XRD) instrument and analysis of the chemical compound content in various brick wastes using an X-ray fluorescence (XRF) instrument. Making and testing the compressive strength of mortar test specimens, compressive strength tests are carried out according to the length of time they remain. The optimum compressive strength results will be tested using XRD to determine the reactions that occur in the cement. Based on previous considerations, research was carried out on the effect of the chemical-mineralogical content of brick waste as a substitute material for pozzolan on the compressive strength of blended cement. Brick waste comes from 3 different sub-districts in Banyuwangi district, East Java (Blimbingsari, Kabat, and Banyuwangi).

2. Materials and Methods

2.1. Materials

The materials needed include brick waste, clinker, gypsum, distilled water (H_2O), kerosene, concentrated hydrochloric acid (HCl), nitric acid (HNO_3), sulfuric acid (H_2SO_4), 50% phosphoric acid (H_3PO_4), ammonium nitrate (NH_4NO_3), ammonium hydroxide (NH_4OH), diammonium hydrogen phosphate solution [$(NH_4)_2HPO_3$], standard solution of potassium dichromate ($K_2Cr_2O_7$), tin (II) chloride solution ($SnCl_2$), ammonium chloride (NH_4Cl), ammonium acetate (CH_3COONH_4), ammonium oxalate ($(NH_4)_2C_2O_4.H_2O$), barium chloride ($BaCl_2$), methyl red indicator ($C_{15}H_{15}N_3O_2$), bariumdiphenylamine sulfonate indicator ($C_{24}H_{20}BaN_2O_6S_2$), standard solution of potassium permanganate ($KMNO_4$), saturated solution of mercury(II) chloride ($HgCl_2$), solvent (glycerol: ethanol = 1: 3), calcium carbonate ($CaCO_3$), strontium dinitrate $Sr(NO_3)_2$, cement, silica sand, water, filter paper No. 41 and No. 42.

2.2. Sample Preparation

Samples of brick waste that are still wet are first dried in an oven and then crushed using a grinding tool. The brick powder is then sieved with a 170-mesh sieve. The brick powder was tested physically through reactivity index, XRD, and XRF analysis. Storage of mortar samples is only carried out on one day of testing, namely at 28 days, using a compressive strength machine [7]. The compressive strength value obtained from the tool is kN, so the kN value is converted into units in Kg/cm^2. The brick reactivity index is calculated using Equation 1.

$$\text{Brick Reactivity Index } = \frac{compressive\ strength\ mix}{compressive\ strength\ control\ mix} \times 100\%$$

2.3. Making and Characterization of Cement

Before making cement, a material sampling process is first carried out in the form of gypsum, brick waste, and clinker. Then, reduce the size and clinker in the jaw crusher tool. The three materials that makeup cement are then weighed according to predetermined proportions, namely 75% clinker, 4% gypsum, and 21% brick. Next, the material is milled into a mini ball mill until it becomes cement within a specific time, and its fineness is tested using a Blaine apparatus.

2.3.1 Analysis SO_3. One gram of brick cement was weighed and dissolved in 25 mL of distilled water and 5 mL of concentrated HCl solution. The sample mixture was stirred, 25 mL of distilled water was added and heated on a hotplate. After that, the sample was filtered, 100 mL of hot NaOH solution was added, and the mixture was heated. A few drops of methyl red indicator and concentrated HCl were added to the cement mixture sample until the colour changed to pink. The mixture was then filtered and washed using hot NH_4NO_3. The filtrate obtained is then diluted to 250 mL and boiled. After that, 10 mL of $BaCl_2$ was added to the filtrate and boiled until a precipitate formed. The solution is digested at almost boiling temperature for 12-24 hours, filtered, and washed using hot distilled water. The filter paper and precipitate were calcined at ±900ºC for 30 minutes. The residue combustion results are then weighed, and the yield is calculated.

2.3.2 Analysis SiO_2. 0.50 grams of brick waste and 0.50 grams of NH_4Cl were added to a 100 mL beaker. The beaker is covered with a watch glass. 5 mL of HCl solution is poured slowly into the rim of the beaker. The watch glass is removed, and 1-2 drops of HNO_3 solution are added. Then, the mixture is stirred and heated for 30 minutes. The solution was then filtered and rinsed with a hot 16% HCl. Then, the residue was washed with hot water 10-12 times. Filter paper and precipitate were calcined at ±1000ºC for 30 minutes. The residue combustion results are then weighed, and the yield is calculated.

2.3.3 Analysis CaO. 200 mL of SiO_2 filtrate is acidified with 10-15 mL of HCl, added two drops of methyl indicator, and heated until boiling. The 50% NH_4OH solution was then poured until the solution was yellow and a precipitate formed. The sample is then digested for 10 minutes, and the formed precipitate is filtered and washed with hot ammonium nitrate solution (max. four times). The filtrate was acidified with 5 mL HCl and evaporated to 200 mL. The sample was then added with methyl red indicator, 30 mL of hot ammonium oxalate, and heated at 70-80ºC. Then 50% NH_4OH was added to the mixture, and the white precipitate formed was washed using hot distilled water until it was free of chloride. Then, the residue will be titrated with potassium permanganate K_2MnO_4 solution, and the volume will be recorded.

2.3.4 Analysis Fe_2O_3. Total of 1 gram of cement powder plus 40 mL of distilled water and 10 mL of HCl. The solution is then heated and crushed with a glass stir bar until all the cement is broken down. Then, the solution was boiled, and the $SnCl_2$ solution was added gradually until the solution was colourless. The inside part containing the remaining solution is rinsed using distilled water. The inner walls of the glass were rinsed with distilled water. After that, 10 mL of mercuric chloride ($HgCl_2$) solution was added. Then, the solution was stirred quickly for 1 minute. A solution of 10 mL of 50% phosphoric acid (H_3PO_4) and two drops of barium diphenylamine sulfonate indicator were added simultaneously. The compound used to standardize the solution in this titration is potassium dichromate. Then, the $K_2Cr_2O_7$ solution was titrated until the sample colour became violet-red.

2.4. Making and Testing Mortar Test Objects. Making mortar test objects is carried out to determine the compressive strength of the mortar. This test was carried out at 1, 3, 7, and 28 days of age. The stage for making mortar is adding 740 grams of cement to a mixing bowl filled with water. Run the cement mixer at low speed for 30 seconds. Then, 2035 grams of sand was added slowly within 30 seconds. Next, the stirrer was run at high speed for 30 seconds. After the cement is mixed, the mixer is stopped for 90 seconds; at an interval of 15 seconds, the mortar on the bowl wall is collected, and the mixer is rerun at high speed for 60 seconds.

The mortar is then put into the mould until it is half filled, pounded 20 times, continued serving until it is complete, levelled, and pounded again 20 times. The mortar surface is levelled, and the flow table is run to a height of 12.70 mm for 25 taps in 15 seconds. The cement mortar is put in a wet box for 20-24 hours. Then, it opened and soaked in a soaking bath (curring) until the test age. It is testing the compressive strength of mortar using a compressive strength tool.

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3. Results and Discussion

3.1. Analysis of the Chemical Content of Bricks

The samples used were brick waste from three different areas. Brick waste is dried using an oven and crushed in a grinding machine. Brick powder was analyzed using XRF to determine the suitability of the chemical content as a substitute for pozzolan in cement. The compound content of brick waste is presented in Table 1.

The results of XRF analysis on three brick samples produced different percentages. SiO_2, Al_2O_3, and Fe_2O_3 compounds were detected as significant compounds because they made high percentage levels. The content of minor compounds in the three samples has slight differences. Minor compounds detected in the bricks included CaO, ZnO, TiO_2, K_2O, P_2O_5, CuO, V_2O_5, Cr_2O_3, MnO, SrO, Eu_2O_3, and Re_2O_7. The BaO compound is only present in the first and third bricks, while PbO is only in the first brick sample.

The research results show that the total SAF oxide content (SiO_2+Al_2O_3+Fe_2O_3) of the first brick, second brick, and third brick, respectively, is 84.20, 83.70, and 84.30%. This research meets the requirements for pozzolan according to the theory of the Kenya Bureau of Standards (KEBS). Pozzolan has a quality standard with a minimum amount of aluminium, silicon, and iron oxides of 70% [8]. ASTM American Society for Testing and Materials C-618 [9] states that the sum of SiO_2, Al_2O_3, and Fe_2O_3 compounds in pozzolan should not be less than 70%. The research results of Cheng et al. [10] from stable expansive soil containing lime and natural pozzolan showed that the oxide contents of SiO_2, Al_2O_3, and Fe_2O_3 were respectively 43.56, 13.85, and 12.63% so that the amount of SAF obtained was 70.04%.

Table 1. Results of XRF analysis of compound content in brick waste samples

Oxide compound content	Sample weight (%)		
	Brick 1	Brick 2	Brick 3
SiO_2	49.10	49.80	48.80
Al_2O_3	14.00	13.00	14.00
Fe_2O_3	21.10	20.90	21.50
CaO	9.00	9.10	8.40
ZnO	0.03	0.058	0.03
TiO_2	1.77	1.77	1.54
K_2O	2.51	2.63	2.52
P_2O_5	0.96	1.10	1.10
CuO	0.084	0.087	0.092
V_2O_5	0.05	0.05	0.05
Cr_2O_3	0.047	0.087	0.049
MnO	0.44	0.45	0.46
SrO	0.34	0.34	0.29
Eu_2O_3	0.26	0.32	0.35
Re_2O_7	0.10	0.10	0.10
BaO	0.10	-	0.10
PbO	0.13	-	-
SiO_2 + Al_2O_3 + Fe_2O_3	84.20	83.70	84.30

Next, XRD analysis was performed on the three samples (Figure 1). The diffractograms of the three brick samples show that the peaks and crystal intensities detected in the three samples have almost the same peaks. The highest power detected was the quartz phase SiO_2 compound, followed by cristobalite and tridymite (SiO_2 phases). Apart from SiO_2, metal oxide impurities are found in the three brick samples, including metals Cr, P, Fe, Pb, Ca, and Mn, common metals in soil. The high or low intensity indicates that the crystalline level of the compound is increasing. The first and second bricks have quartz, tridymite, and cristobalite phases, while the third has quartz, cristobalite, and coesite phases. The differences in compound phases are influenced by differences in temperature during firing and the type of clay used when making bricks. Quartz is a silica phase with a high crystalline level and orderly arrangement.

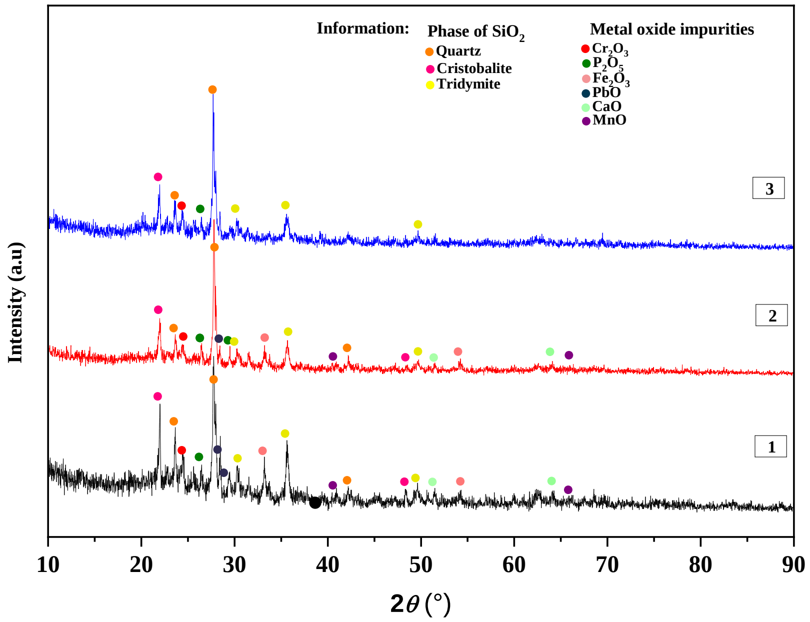

Figure 1. Results of XRD analysis of variations in brick waste samples

The phase difference of the silica compound in the third brick sample explains that it has the highest reactivity compared to the first and second bricks. The difference in sample contribution to cement quality between the first and second samples is based on the minor compounds detected. Both examples have twelve minor oxide compounds (CaO, ZnO, TiO_2, K_2O, P_2O_5, CuO, V_2O_5, Cr_2O_3, MnO, SrO, Eu_2O_3, and Re_2O_7) with almost the same levels. The advantage of the first sample is that it has two types of compounds not found in the second sample, namely PbO and BaO compounds, so the presence of these two types of compounds can affect the quality of the cement.

3.2 Brick Reactivity Index

Testing the content of chemical compounds in bricks in SiO_2, Al_2O_3, and Fe_2O_3 (SAF) cannot yet determine whether brick material can be used as a substitute for pozzolan. Further testing of pozzolan material is a reactivity index that functions to determine the reactivity of a material. This stage is the same as making a test object as a cement mortar cube through mixing, moulding, curing, and breaking the sample. Turanli et al. [11] reported the reactivity index results for brick waste for 28 days of 78%. The ASTM C 618 (1993) standard for the reactivity index has an average calculated value of 75% [9].

The reactivity index test is based on the percentage of the results of dividing the natural compressive strength value as a blank with the compressive strength of bricks for the three samples of 75.60, 75.00, and 77.90%. The first sample has a higher reactivity index value than the second sample. There may be minor compounds that the second sample does not have that help contribute to the cement hydration process. Based on the high percentage of compounds, the large number of minor compounds detected, and the high reactivity index of the three brick waste samples, it can be stated that the third brick waste sample has the best quality, followed by the first sample and the second sample. This statement supports the XRD characterization results that the third brick sample used as a substitute for pozzolan had a more reactive phase.

Table 2. Reactivity index test results for brick waste samples

Materials	Compressive strength (kN)	Compressive strength (Kg/cm^2)	Average compressive strength (Kg/cm^2)	Brick reactivity index
Control mix (blanko)	81.03	331	340	-
	85.32	348		
	90.00	367		
Brick 1	60.16	246	257	75.60%
	65.89	268		
	63.29	258		
Brick 2	62.43	255	255	75.00%
	61.92	253		
	63.01	257		
Brick 3	64.92	265	265	77.90%
	65.18	262		
	65.91	269		

3.3 Cement Quality Analysis

Cement that has gone through the grinding process using a mini ball mill machine is tested for fineness based on the Blaine apparatus test. The standard set based on the fineness test on blended cement is a minimum of 2800 cm^2/g. The value range of 5000 cm^2/g was chosen to maximize the quality of cement that was successfully made using substitute pozzolan for brick waste. Data from the cement fineness test results can be presented in Table 3. The fineness test of 3 cement samples showed 5008-5052 cm^2/g values.

Table 3. Data on cement fineness test results

Test results	Blended Cement		
Sample name	Brick 1	Brick 2	Brick 3
Subtlety (cm^2/g)	5008	5033	5052

The cement powder was then analyzed qualitatively for the content of the chemical compounds SO_3 (Sulfur trioxide), SiO_2 (Silicon dioxide), Al_2O_3 (Aluminum oxide), CaO (Calcium oxide), and Fe_2O_3 (Iron oxide) as parameters to determine the quality of the cement. The sulfur trioxide compound in cement comes from gypsum material, which is rich in sulfate compounds. The sulfate compound will dissolve in hydrochloric acid (HCl) solvent and can be precipitated by reacting the sulfate with $BaCl_2$ [12,13]. The resulting residue is ignited so that it is weighed as barium sulfate. The cement sediment remaining on the filter paper was filtered so that the levels of SO_3 compounds in the three cement samples with brick pozzolan were 2.00, 2.10, and 2.10%. The research results have met the standards set for pozzolan-type Portland cement; the maximum limit for SO_3 content in cement is 4% [14].

The silicon dioxide compound in cement comes from brick and clinker materials. SiO_2 is determined by adding NH_4Cl to separate Si from Al. This process produces crystalline silica precipitates and a yellowish solution containing insoluble residues [12,13]. The filtrate obtained from determining the SiO_2 compound was used to determine $Al(OH)_2$ and $Fe(OH)_3$. The SiO_2 levels in the three cement samples were 17.94, 18.21, and 17.74%. Alumina content is not determined based on qualitative tests of compounds in cement with specific reagents but are calculated based on differences in yield. Ammonium hydroxide precipitates in cement are assumed to consist of Al_2O_3, Fe_2O_3, TiO_2, P_2O_5, and SiO_2 residues. Al_2O_3 calculations are carried out by subtracting the percentages of $Al(OH)_2$ and $Fe(OH)_3$) from Fe_2O_3. The Al_2O_3 content results in the three cement samples were 3.59, 3.43, and 3.51%.

The filtrate from the qualitative analysis of the SiO_2 compound was alkalized with NH_4OH to precipitate Mg^{2+} ions as hydroxide. Then, Ca^{2+} is added with ammonium oxalate to form a white precipitate [13]. After a precipitate is formed, H_2SO_4 is added, which will later dissolve to form oxalic acid, a reducing agent whose amount is equivalent to Ca^{2+} [12]. Then, the oxalic acid formed is titrated with $KMnO_4$ until a pink solution is developed by adding H. The volume resulting from the titration is recorded and used to determine the CaO content in the cement. The CaO levels in the three cement samples were 56.50, 56.03, and 56.91%.

The principle of analyzing the Fe_2O_3 compound in cement is to reduce iron(III) to iron(II) with tin(II) chloride ($SnCl_2$). Reduction of iron(III) to iron(II) using the solvent $SnCl_2$ [15], adding $HgCl_2$ because $K_2Cr_2O_7$ will oxide Sn^{2+} means the Sn^{2+} ion must be converted into Sn^{4+} ion. $HgCl_2$ is a potent oxidizing agent, forming a white residue. Calculating Fe_2O_3 content in cement is assisted by $K_2Cr_2O_7$ titration to produce a violet-red solution. Fe_2O_3 levels in 3 cement samples were 4.49, 4.34, and 4.58%. If dividing $\%Al_2O_3$ by $\%Fe_2O_3$ exceeds 0.64, then the C_3S, C_2S, C_3A, and C_4AF values are determined by calculating chemical oxide compounds selected by Bogue's equations [16].

The compound that contributes to the quality of cement setting time is the compound tricalcium aluminate (C_3A) [17, 18]. The calculations based on Bogue's equations showed that the C_3A content in the three types of cement was 1.92, 1.55, and 1.75%. Lower C_3A content can increase sulfate resistance. So, the cement with more optimum sulfate resistance is the second cement with a value of 1.55%. However, all cement in this study was within the minimum threshold of cement quality standards.

The tetracalcium aluminoferrite (C_4AF) compound is related to the colour of the cement produced. The calculations showed that the C_4AF content in cement was 13.66, 13.94, and 13.20%. A higher amount of ferrite causes the cement colour to become darker [19]. So, in this study, the one with a deeper colour was the third cement with a ferrite content of 13.20%. The initial stage of the ferrite phase reacts with gypsum and Ca(OH) to produce needle-like crystals from a solid solution consisting of sulfoaluminate and sulfoferrite [20, 21].

C_3S is the most important phase in cement for strength development during the first phase, while C_2S reacts much more slowly and contributes to the long-term strength of the cement. Based on the C_3S calculation results, the compound content in cement was 57.43, 58.05, and 57.16%. Meanwhile, the C_2S calculation results in cement are 8.10, 8.42, and 7.74%. The reaction of the compounds $3CaO.SiO_2$ (C_3S) and $2CaO.SiO_2$ (C_2S) with water in the hydration process produces calcium silica hydrate (CSH). CSH is a chemical compound that determines the compressive strength value of mortar. CSH will fill the gap cavity, producing stiffness. This increase in strength is due to the formation of calcium silica hydrate (CSH) due to the reaction between tricalcium silica hydrate (C_3S) in water to produce that in cement [22].

The hydration reaction when cement reacts with water produces a side reaction in the form of the compound $Ca(OH)_2$. If the $Ca(OH)_2$ compound produced is high, it will affect cracking in the cement. This is caused by the nature of $Ca(OH)_2$, which is sensitive to sulfate compounds ($MgSO_4$) from seawater. The $Ca(OH)_2$ compound, which is the result of a side reaction from the hydration process, is an essential compound that is sensitive to sulfate (acid) [23].

One of the materials needed to reduce cracking caused by sulfate compounds is pozzolan material, which goes through a burning process. Clay materials fired at 600 ─ 900 °C in suitable powder form are highly reactive with cement. The reactivity of fired clay bricks is caused by the loss of clay mineral crystallinity, which then changes to meta-stable or amorphous properties [24]. Maximum strength is achieved when the SiO_2 content in the pozzolan is sufficient to change the cement hydration product, namely calcium hydroxide, into calcium silicate and aluminate hydrate, which increases its strength properties [25]. The overall content of chemical compounds in the mixed cement of brick waste as a substitute for pozzolan is shown in Table 4.

Table 4. Test results for the chemical content of cement oxide

Oxide compound content	Sample weight (%)		
	Cement 1	Cement 2	Cement 3
SO_3	2.00	2.10	2.10
SiO_2	17.94	17.74	18.21
Al_2O_3	3.59	3.51	3.43
Fe_2O_3	4.49	4.58	4.34
CaO	56.50	56,03	56,91
C_3S (Alite)	57.43	57.16	59.05
C_2S (Belite)	8.10	7.74	8.42
C_3A (Aluminate)	1.92	1.55	1.75
C_4AF (Ferrite)	13.66	13.94	13.20

Based on the results of the characterization analysis of each peak of the diffractogram in Figure 2, several compounds were detected in the mixed cement of brick waste and an overview of the crystal structure of the cement. Several peak positions in cement that use brick as a substitute for pozzolan experience changes in the structure of the compound. The coesite compound at an angle of 2θ 14.41 does not change brick and cement materials. The Al_2O_3 compound did not experience a compound change but experienced a shift in peak position from 2θ 83.59 in brick to 83.53 in cement. Likewise, the Fe_2O_3 compound only experienced a peak shift from 2θ 33.10 in brick to 33.25 in cement.

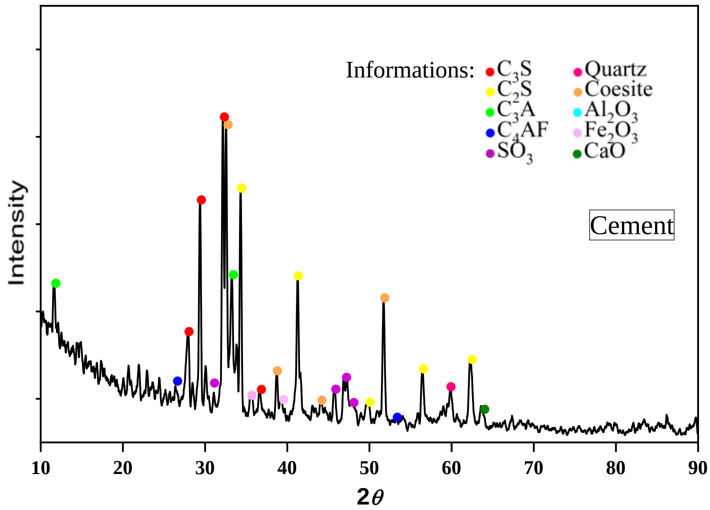

Figure 2. Diffractogram graph on cement

The compound with the highest intensity at 2θ 27.69 was previously detected in brick waste as a SiO_2 compound with a quartz phase changing to a tricalcium silicate (C_3S) compound. Position 2θ 20.49, once seen in brick waste as a SiO_2 compound in the coesite phase, altered to a tricalcium silicate (C_3S) compound. Position 2θ 21.89 of the SiO_2 compound in the cristobalite phase becomes the tricalcium silicate (C_3S) compound at 2θ 21.91. Other compounds such as Fe_2O_3 at position 2θ 54.05 change to C_4AF, the CaO compound at position 2θ 64.35 becomes C_4AF, and CaO at position 2θ 51.53 becomes C_2S, the Al_2O_3 compound at position 2θ 74.63 becomes C_3A at position 2θ 74.65 in cement. Reactions may occur in brick compounds, which contribute to the development of the compressive strength of cement by combining these compounds with compounds from other materials.

3.4 Analysis of Compressive Strength Results of Mortar Cement

Cement quality is determined by applying cement through a test object in the form of a mortar cube whose compressive strength value is tested. The mortar cube is a test object with 5 x 5 x 5 cm^3 in compressive strength analysis. The cement stirred into a mortar paste is moulded and cured in a soaking bath (curring). Soaking in water will help speed up hydration and increase the pozzolanic reaction in the cement. The value obtained will be converted into units from kN to Kg/cm^2.

Figure 3 shows that the soaking time curve is directly proportional to the compressive strength value of each sample on days 1, 3, 7, and 28. The longer the wet time in curing will help maximize the hydration process and increase the compressive strength value [26]. Analysis of the compressive strength test results of cement mortar (Kg/cm^2) with a soaking time of 1 day on the first, second, and third cement bricks, respectively amounted to 72, 64, and 74. The compressive strength test values of cement mortar (Kg/cm^2) with the 3-day holding time for the first, second, and third brick cement were 162, 151, and 168, respectively. The compressive strength test values of cement mortar (Kg/cm^2) with the 7-day holding time for the first, second, and third brick cement were 218, 206, and 243, respectively. The compressive strength test values for cement mortar (Kg/cm^2) with a holding time of 28 days for the first, second, and third cement bricks were respectively 378, 347, and 410.

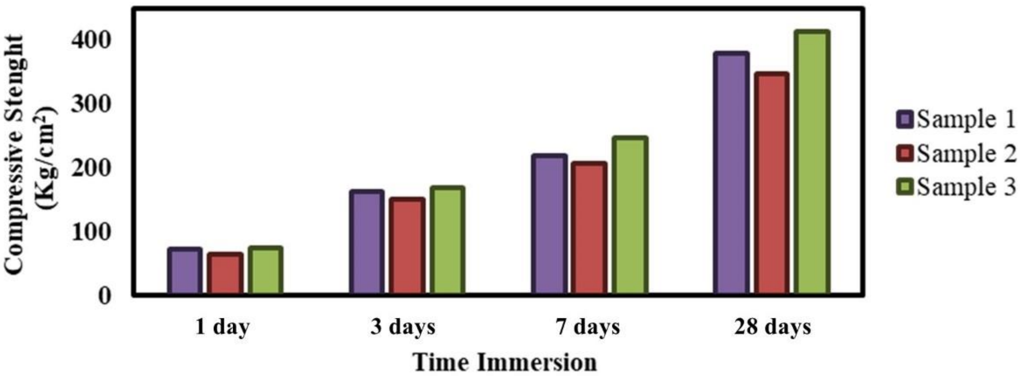

Figure 3. Compressive strength graph based on damping time

Based on the compressive strength values obtained for each soaking time, the third sample had the highest compressive strength value, then the first and second samples. This compressive strength test value results from the quality analysis of the three brick waste. The higher the content of SAF compounds in the brick, the higher the reactivity index of the compounds therein. The hydration reaction is produced based on the reactivity of pozzolan compounds as a determinant of cement quality in the form of cement mortar development.

4. Conclusion

Characterization using XRD result shows that the three bricks produced several compounds, including SiO_2, Al_2O_3, Fe_2O_3, CaO, and several minor compounds. The SAF compound qualifies and the reactivity index test meets the pozzolan quality requirements (>70% and >75%). The results of chemical analysis in cement identified are SO_3, SiO_2, Al_2O_3, CaO and Fe_2O_3. A comparison of the XRD test results of bricks with cement shows a reaction of several brick compounds with other materials to form C_3S, C_2S, C_3A, and C_4AF compounds. Based on the compressive strength values obtained for each soaking time, the third sample had the highest compressive strength value.

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