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# Mortar Based on Compressive Strength and Chemical Elements

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***Abstract***— *Mortar is a mixture of binder material (portland cement/portland pozzolan cement/fly ash), fine aggregate and water in which the material must meet standard requirements. Mortar is generally used as a binder (species) and cover (plastering) of red brick in wall work. In a test (press test) to determine the quality (quality) of the mortar that has been installed on the wall work, it will be difficult to carry out because it has dimensions of less than 5 x 5 x 5 cm which is the minimum sample size requirement for the compressive test. It is necessary to carry out a test that has a close correlation (relationship) with the compressive strength test and the chemical element forming the mortar so that when the mortar is installed in the building element, the inspection only needs to take a sample and see the chemical constituents. From the research results obtained mortar-forming elements include: $Al_2O_3$ - $SiO_2$ - CaO - $Fe_2O_3$ which have different percentages based on the compressive strength of the mortar.*

***Keywords***— *Mortar, compressive strength, chemical elements*

## I. Introduction

Infrastructure development facilities are currently increasingly advanced, it can be seen from the construction of high-rise buildings, housing and other housing. The increasing development of development makes all parties create something new that can be used in the manufacture of building materials [1]. Therefore, it is necessary to create a construction engineering that is simple or more complex by utilizing currently existing materials and resources[2]. Like Indonesia, which is a developing country with abundant natural potential for building materials as construction materials.

Sand is a non-renewable natural resource, in very large quantities. One way to overcome it is to use the sand, one of which is volcanic sand. This volcanic sand can be used as a mixture because it contains silica (SiO) and has a relatively high content of iron (FeO).

Mortar is a versatile material that is widely used as a masonry job with a variety of different requirements. The main purpose of mortar in pairs is to bind the masonry units into a single unit in order to work as an integral element that has the desired functional performance characteristics[3]. The compressive strength of mortar is influenced by several factors, including cement content, type of cement, water-cement ratio, aggregate properties, age of mortar and content of chemical compounds. it is necessary to do a test that has a close correlation (relationship) with the compressive strength test and the chemical elements forming the mortar so that when the mortar is installed in the building element, the inspection only needs to take a sample and see the chemical constituents of it[2]. From the research results obtained mortar-forming elements, among others: $Al_2O_3$ - $SiO_2$ - CaO - $Fe_2O_3$ which has a different percentage based on the compressive strength of the mortar.

Lilies [4] has investigated the Effect of Chemical Properties on Mortar Performance. This study aims to determine the magnitude of the increase in the compressive strength of mortar due to C3S and C2S compounds formed from the reaction between CaO, SiO2, Al2O3 and Fe2O3 compounds with H2O (water) that occurs in mortar, based on the results of research and discussion it is known that the hydration reaction between these compounds with water affects the performance of mortar that is binding, hardening and speed, heat of hydration, compressive strength and resistance to sulfate. C3S hardens in a few hours and affects the strength of the concrete at early age, especially in the first 14 days. While the formation of the C2S compound took place slowly with a slow heat release, this compound had an effect on the process of increasing the strength that occurred from 14 days to 28 days[5].

Faizal Rizki [6] has also conducted research on the Study of Compressive Strength of Normal Concrete with Mount Kelud Ash as an Addictive Substitute for Cement. This study aims to determine the effect of the use of Kelud mountain ash as a cement substitute on the compressive strength of normal concrete. MPa and with a mixture of Mount Kelud ash with a proportion of 10%, 15% and 20% of the cement weight, the compressive strength of concrete at the age of 28 days experienced a decreasing trend of 4.87%, 6.33%, and 26.63% of the strength compress the concrete with a mixture of 0% Mount Kelud ash. However, for the design quality f'c = 18.7 MPa, the addition of Mount Kelud ash 10%, 15% and 20% can increase the quality of concrete up to 43.80%, 41.82%.

Mortar is a mixture with a certain composition between binder and fine aggregate (sand) that has hardened with water as the solvent. The binding materials used are clay, lime and portland cement. If lime is used as a binding material, it is called lime mortar, and if cement is used as a binding material, it is called cement mortar [4]

Cement mortar is usually used for plastering walls, masonry species, river stone masonry species, floor plastering, lightweight bricks, and so on. In the building materials industry, cement mortar is usually used as a material for making bricks, tiles, "rooster", "paving", concrete buis and so on[7].

The main purpose of mortar in masonry is to bind the masonry units together so that they work as integral elements having the desired functional performance characteristics. Mortar affects the structural properties of the assembly as it increases its resistance to water [1]

The compressive strength of mortar is the mortar's ability to withstand external forces that come in a direction parallel to the

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fibers pressing the mortar. Mortar used for building materials must have strength, especially for masonry walls, brick masonry walls or other wall pairs [8].

Mortar that meets property specifications must consist of a mixture of cement, aggregate, and water, all of which meet the material requirements and property specification requirements [3].

The compressive strength of mortar is calculated by the formula:

$$f'c = P/A$$

Where P is compressive load (KN); and A is the Surface area of the test object ($mm^2$)

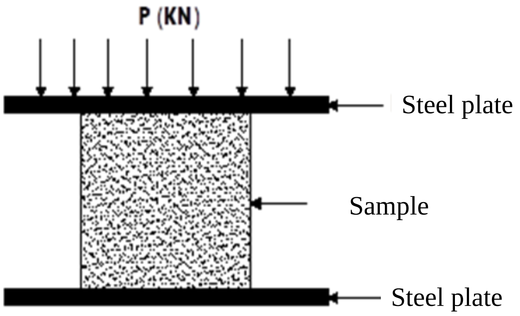


Fig. 1. Mortar Compressive Strength Test Scheme

### A. *Mortar Forming Material*

Fine aggregate (sand) is a fine rock material consisting of grains of 0.14 mm - 5 mm obtained from the results of the integration of natural stone (natural sand) or can also be broken (artificial sand). Fine aggregate is a filler in the form of sand. Good fine aggregate must be free of organic matter, clay, smaller particles, or other materials that can damage the mixture. Size variations in a mixture must have good gradations [9].

The requirements for sand in order to be used as a building material are as follows:

1. The sand must be clean. When tested using a special washing solution, the apparent height of the sand deposit compared to the total height is not less than 70%.
2. The content of the part that passes through a 0.063 mm sieve (mud) is not greater than 5% by weight.
3. The fine modulus of grains lies between 2.2 and 3.2 when tested using a series of sieves with sieves measuring 0.16 mm, 0.315 mm, 0.63 mm, 1.25 mm, 2.5 mm, and 10 mm respectively with the fraction passing through a 0.3 mm sieve of at least 15% by weight.
4. Sand must not contain organic substances that can reduce quality. Therefore, when immersed in a 3% NaOH solution, the liquid above the precipitate should not be darker than the color of the comparison solution. II-9
5. Conservation of $MgSO_4$ solution, the disintegrated fraction is not more than 10% by weight[10].

### B. *Portland Cement*

Hydraulic cement is produced by grinding portland cement mainly consisting of calcium silicate which is ground together with additives in the form of one or more crystalline forms of calcium sulfate compounds and may be added [3].

### C. *Water*

Water is an important basic material but the price is the cheapest. In the manufacture of the test object, water is needed to react with portland cement and become a lubricant between the aggregate grains so that it can be easily worked (stirred, poured and compacted) [8].

Water as a building material should meet the following requirements:

1. The water must be clean.
2. Does not contain mud or suspended matter more than 2 grams/liter.
3. Does not contain salts that damage the mortar (acids and organic substances) more.
4. Does not contain mud, oil and other floating objects that can be seen visually.
5. When compared with the compressive strength of the mortar using distilled water, the decrease in the strength of the mortar using distilled water was not more than 10%.
6. The degree of acidity (pH) is normal ± 7.
7. All water of questionable quality is chemically analyzed and evaluated for quality according to usage.
8. Does not contain sulfate compounds (as $SO_3$) more than 1 gram/liter.
9. Does not contain chloride (Cl) more than 0.5 grams / liter.

## II. Methods

### A. *Speciments*

Making test objects by making samples by printing test objects in the form of cubes, blocks, and number 8. These test objects are made through the process of heating, stirring, and compacting [9]. The number of test objects can be seen in table 3.

There are several steps that must be taken to make the test object itself, including:

1. Pour the water into the mixing bowl, then slowly add the cement that has been determined, leave the two ingredients in the mixing bowl for 30 minutes.
2. Stir the water and cement mixture using a mixer for 30 seconds, the stirrer rotation speed is 140 ± 5 revolutions per minute, stirring is done using a mortar mixer.

Fig. 2. Mortar Mixer

3. Prepare the sand that has been determined then, enter it little by little into a bowl containing a mixture of cement and chili water, stir at the same speed for 30 seconds, then increase the speed of 285 ± 10 revolutions per minute.
4. Turn off the stirrer, clean the mortar that sticks to the top of the bowl then let it rest for 75 seconds in a closed mixing bowl.

5. Repeat stirring for 60 seconds with a stirring speed of 285 ± 10 revolutions per minute. All materials should be stirred using a mechanical mixer for one mixing with the maximum amount of water for 3 minutes to 5 minutes to produce an easy-to-work mortar consistency. The stiffened mortar must be stirred again by adding the required amount of water to restore the required consistency. Mortar that has been mixed for more than 2½ hours should not be used again (ASTM C305).
6. Then carry out the melting experiment in the following way:
   a. Fully fill the melting ring with mortar, filling is done in 2 layers, each layer should be compacted 20 times with a compactor.
   b. Smooth the top surface of the mortar in the melting ring and clean any mortar adhering to the outside of the melt ring.
   c. Figure the melting ring slowly, so that on the melting table the mortar forms a truncated cone.
   d. Vibrate the melting table 25 five times for 15 seconds at a height of ½ in.
   e. Measure the diameter of the mortar on the melting table at least in different places, otherwise calculate the average diameter.
   f. Repeat work 1 – 6 with the new mortar with several predetermined variations, so that the average diameter is 1 – 1.15 times the original diameter.
   g. Then after getting the results, mold the test object in the following order;
   h. Stir again the mortar in the mixing bowl with a stirring speed of 285 ± 10 revolutions per minute for 15 seconds.
   i. Put the mortar into the cube mold, fill the mold in 2 layers and each layer is compacted 32 times with 4 rotations in 10 seconds, the test object printing work must be carried out and started within 2 minutes after the initial stirring.
   j. Smooth the top surface of the cube, figure eight and block mold using a flattening spoon.
   k. Store the test object for 24 hours in a humid room.

Fig. 3. Mortar Mold

*B. Test Method*

The test of this mixed material is carried out on mortar with the aim of obtaining the appropriate mortar type specification and meeting the provisions of SNI 03-6825-2002 and SNI 6882:2014.

*C. Test Object Maintenance*

After the immersion process, the test object is removed from the water and placed in a damp place for 24 hours. At the age of 7 days and 28 days, the samples were tested for compressive strength.

*D. Speciment Testing*

*1. Testing the compressive strength of cement mortar*

The compressive strength test of cement mortar was carried out when the cement mortar was 7 days old and 28 days old. Test the compressive strength of the test object in the following order:

a. Remove the test object from the immersion place, then dry the surface by wiping and leave it for ± 15 minutes.
b. Weigh the cube of the test object, then record the weight of the test object.
c. Place the test object on the Cement Compression Machine, press the test object with a large increase in force until the test object breaks. Then record the results of the maximum compressive force acting.

Fig. 4. Compression Machine

*2. Testing the tensile and flexural strength of cement mortar*

Tensile and flexural strength testing of cement mortar was carried out when the cement mortar was 7 days and 28 days old. Test the compressive strength of the test object in the following order:

a. Remove the test object from the immersion place, then dry the surface by wiping and leave it for ± 15 minutes.
b. Weigh the test object, then record the weight of the test object.
c. Place the test object on the tensile and bending machine using the Tensile testing Machine, pull the test object with the addition of a large force until the test object breaks. Then record the results of the maximum tensile and bending forces acting.

*3. Testing elements of chemical compounds in mortar*

Testing of Chemical Elements to determine the Chemical Content contained in the test object. XRF is a tool used to determine the crystal structure in a solid or powder sample.

*4. Sample Requirement*

In this research, material requirement planning is used based on comparison/variation. In determining the planning needs of the comparison design made 6 variations, that is:

From the data from the test results for the chemical compounds produced, the dominant chemical compound elements will be taken including CaO, $SIO_2$, $Al_2O_3$, and $Fe_2O_3$ with mortar compressive strength results in a ratio of 1:1, 1:2, 1:3, 1:5, 1: 6, and 1:8 at the age of 28 days as in the sub-chapter

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above, then look for the relationship parameters that have been determined.

TABLE 1. Sample Requirement

| Ratio | Compresive Strength | Tensile Strength | Flexure Strength | chemical compound elements |
|---|---|---|---|---|
| 1 : 1 | 6 | 3 | 3 | 1 |
| 1 : 2 | 6 | 3 | 3 | 1 |
| 1 : 3 | 6 | 3 | 3 | 1 |
| 1 : 4 | 6 | 3 | 3 | |
| 1 : 5 | 6 | 3 | 3 | 1 |
| 1 : 6 | 6 | 3 | 3 | 1 |
| 1 : 7 | 6 | 3 | 3 | |
| 1 : 8 | 6 | 3 | 3 | 1 |
| Total | 48 | 24 | 24 | 6 |
| | 102 | | | |

Source: Calculation Results

TABLE 2. Test Results of Chemical Compound Elements and Mortar Compressive Strength

| Ratio | Al2O3 | SiO2 | CaO | Fe2o3 | Kuat Tekan |
|---|---|---|---|---|---|
| 1 | 4,7 | 17,1 | 58,1 | 13,9 | 51,2 |
| 2 | 3,2 | 10,8 | 64,5 | 16,4 | 29,73 |
| 3 | 4,8 | 19,9 | 47,4 | 21,5 | 20,4 |
| 4 | 4,4 | 17,8 | 52,6 | 18,6 | 5,73 |
| 5 | 5,2 | 19,2 | 52,6 | 17,3 | 4,27 |
| 6 | 3,9 | 16,3 | 52,6 | 22,5 | 2,27 |

From the test data then plotted into a quadritic graph showing the relationship between chemical compounds and the compressive strength at the age of 28 days.

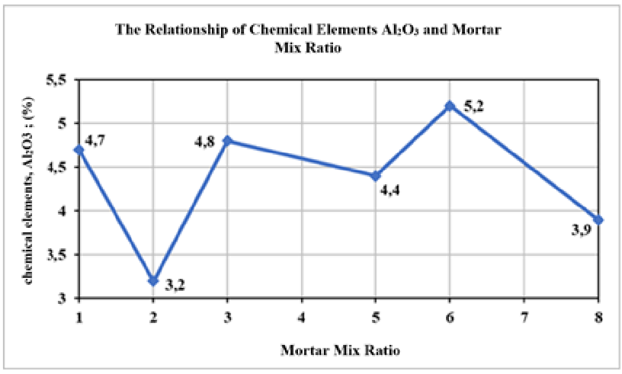


Fig. 5. Graph of Relationship Between Elements of Chemical Compound $Al_2O_3$

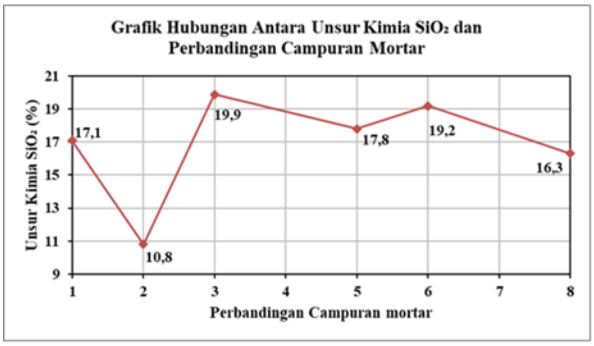


Fig. 6. Graph of Relationship Between Elements of Chemical Compound $SiO_2$ against Mortar Mix Comparison

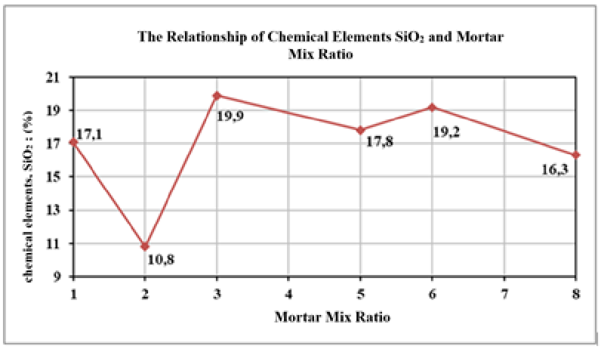


Fig. 7. Graph of Relationship Between Elements of Chemical Compound CaO against Mortar Mix Comparison

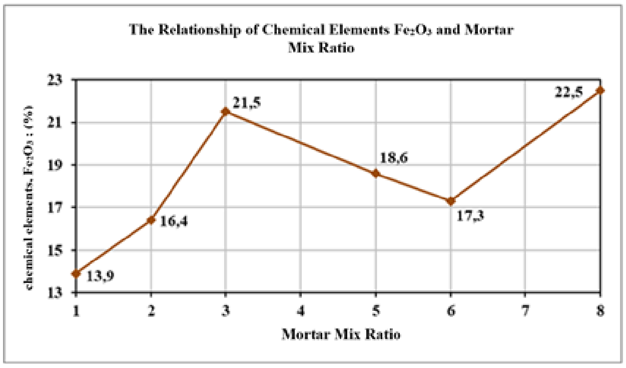


Fig. 8. Graph of Relationship Between Elements of Chemical Compound $Fe_2O_3$ against Mortar Mix Comparison

## III. Conclusion

From the test results of elements of chemical compounds obtained percentage values based on the ratio of the mixture, among others;

a. Comparison 1Pc : 1Ps
$Al_2O_3$ 4.7%, $SiO_2$ 17.1%, CaO 58.1%, $Fe_2O_3$ 13.9%.
b. Comparison 1Pc : 2Ps
$Al_2O_3$ 3.2%, $SiO_2$ 10.8%, CaO 64.5%, $Fe_2O_3$ 16.4%.
c. Comparison 1Pc : 3Ps
$Al_2O_3$ 4.8%, $SiO_2$ 19.9%, CaO 47.4%, $Fe_2O_3$ 21.5%.
d. Comparison 1Pc : 5Ps
$Al_2O_3$ 4.4%, $SiO_2$ 17.8%, CaO 52.6%, $Fe_2O_3$ 5.73%.
e. Comparison 1Pc : 6Ps
$Al_2O_3$ 5.2%, $SiO_2$ 19.2%, CaO 53.1%, $Fe_2O_3$ 17.3%.
f. Comparison 1Pc : 8Ps
$Al_2O_3$ 3.9%, $SiO_2$ 16.3%, CaO 52.6%, $Fe_2O_3$ 22.5%.

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