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Utilization of Ceramic Waste as Coarse Aggregate and the effect on Concrete Compressive Strength

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***Keywords* — Ceramic Waste, Compressive Strength and Normal Concrete**

Abstract*— In accordance with the development of knowledge, ceramics are all items made from non-metallic inorganic materials with silicate rock soil materials whose manufacturing process is accompanied by a combustion process at high temperatures. Seeing the potential for clay soil in Indonesia is very large, of course, many industrial activities grow so that they can provide benefits for humans, but apart from the benefits there are also impacts from industrial activities. One of the impacts of industrial activities is the waste, there are industrial wastes that can damage the environment or are environmentally friendly. The method used in this study is an experimental method, namely an experiment that aims to investigate the relationship between the compressive strength of normal concrete and concrete that uses ceramic shards as a filler material for a portion of the weight of coarse aggregate. The test objects made in this experiment were 9 samples in the form of concrete cylinders with a size of 15 cm x 30 cm which would later be tested for the compressive strength of concrete using SNI 03-2834-2000 guidelines. The research objectives were to obtain the compressive strength of concrete using ceramic waste materials as an additional coarse aggregate and to obtain the results of a comparison of normal concrete compressive strength with the compressive strength of concrete using ceramic waste materials. The compressive strength of concrete using ceramic waste material as an additional coarse aggregate with a percentage of 15% and 20% ceramic waste is as follows: Trial mix with 15% ceramic gives a compressive strength of 23.91 MPa and trial mix with ceramic 20% days gives a compressive strength of 23 .89 MPa. From the results of this test the percentage of ceramic 20% has a greater compressive strength compared to the percentage of ceramic 15% and the comparison of the compressive strength values of normal concrete and concrete using ceramics proves that the compressive strength of concrete is greater than normal concrete. big. It can be seen from the compressive strength of concrete from 0% to 15% which has an increase of 0.59 MPa and the compressive strength of slate from 0% to 20% has an increase of 0.98 MPa.

I. INTRODUCTION

Technological developments in Indonesia are followed by problems that always arise, namely the problem of waste. Of course, this needs special attention because waste which is the residue of production, both liquid and solid, can have a negative impact on the environment. Soil pollution is also caused by the building materials industry, one of which is materials that are difficult to decompose such as ceramic waste. Ceramic waste buried in the ground is very difficult to decompose back into soil, unless it is destroyed first and even then it takes a long time for it to return to soil that can be used as agricultural land. It is very possible that polluted soil will grow unhealthy food for humans.

In accordance with the development of knowledge, ceramics are all items made from non-metallic inorganic materials with silicate rock soil materials whose manufacturing process is accompanied by a combustion process at high temperatures. Seeing the potential for clay soil in Indonesia is very large, of course, many industrial activities grow so that they can provide benefits for humans, but apart from the benefits there are also impacts from industrial activities. One of the impacts of industrial activities is the waste, there are industrial wastes that can damage the environment or are environmentally friendly. One example is the ceramics industry, because the availability of raw materials for making ceramics is very abundant, this industry will never die, instead it will grow because many industries produce unique and creative forms.In this researchceramic waste in the form of waste originating from the dismantling of building construction and also the work of finishing a building or a residential house, there are many items of work carried out, one of which is the work of finishing floors in the form of installing tiles. In carrying out this ceramic installation work, it tends to have leftover material (ceramic pieces) which cannot be used anymore if the amount of remaining material is large, it will cause waste. Visually, ceramic waste is a hard material like aggregate, but does ceramic waste also have characteristics equivalent to aggregate? If the characteristics of the ceramic waste comply with the specified requirements, the ceramic waste can be used for concrete mixtures.This is due to the fact that coarse aggregate materials are easy to obtain, but sooner or later the material is running out, so the cause is that material from year to year is getting more expensive, seeing the description above, in this study with the titleUtilization of Ceramic Fractional Waste as Coarse Aggregate and Effect on Concrete Compressive Strength

Purpose Study

1. Getcompressive strength of concrete using ceramic waste material as an additional coarse aggregate
2. Getresults of comparison of normal concrete compressive strength with concrete compressive strength using ceramic waste material

II. LITERATURE REVIEWS

2.1. Concrete

Concrete is a composite material (mixture) and several materials whose main ingredients consist ofmixturebetween fine aggregate, coarse aggregate, water and or without other added ingredients in a certain ratio. Because concrete is a composite, the ductility of concrete is highly dependent on the quality of each former. (Kardiyono Tjokrodimuljo: 2007). Sometimes one or more additives are added to produce concrete with certain characteristics, such as workability, durability and setting time (Mc Cormac, 2004). The basic ingredients for making concrete are factors that greatly support the quality of concrete.

Concrete has high compressive strength but weak tensile strength. Concrete compressive strength identifies the quality of a structure. The higher the desired structural strength, the higher the quality of the concrete produced. (Mulyono: 2004). The compressive strength value of concrete is obtained from standard tests with cylindrical specimens that are commonly used. The dimensions of the cylindrical test object are 300 mm high and 150 mm in diameter. The test procedures that are generally used are ASTM C39 – 86 standards. The compressive strength of each test object is determined by the highest compressive stress (f'c) achieved by the 28-day-old specimen due to the compressive load during the experiment. (Dipohusodo: 1996).

2.2. Portland cement

Portland cement is a hydraulic bonding material produced by pulverizing clinker which mainly consists of hydraulic silica calcium with gypsum as an additive (Department of Public Works, 1982).. The function of cement is to glue aggregate grains together to form a solid mass.

According to (Department of Public Works, 1982) regarding cement materials it is said that:

1. Cement that may be used for the manufacture of concrete must be of the type of cement specified in SII D013-81 or the General Standards for Indonesian Building Materials 1986, and must meet the requirements set out in these standards.
2. If using Pozzolan (Mixture of Portland Cement and Pozoland materials), the cement must comply with SII 0132 "Quality and Method of Testing Portland Pozzolan Cement" or ASTM C595 "Specification for Blended HidroulicCement".

In accordance with the intended use, Portland cement is divided into 5 types as follows (Tjokrodimuljo, 1996):

1. Type I : Portland cement for general use which does not require special requirements. This type of cement is most needed by the general public and can be used for all applications.
2. Type II: Portland cement which in use requires moderate resistance to sulfate and heat of hydration. This cement

is suitable for areas that have high temperature weather and drainage structures. Portland cement type II is recommended for use in buildings such as dams, wharves and heavy runways which are characterized by columns and where low hydration processes are also a major consideration.

3. Type III: Portland cement which in use requires high initial strength requirements after setting occurs. This type gains great strength in a short time, so it can be used for the repair of concrete buildings that need to be used immediately or where the reference needs to be removed immediately. Besides that, it can also be used in areas that have low temperatures, especially in areas that have cold winters. Use for making concrete roads, airfield runways, high-rise buildings, waterworks that do not require sulfate resistance.
4. Type IV: Portland cement which in its use requires low hydration heat requirements. This type of cement is used for construction purposes which require the amount and heat rise to be minimized. Therefore, this type of cement will gain concrete strength more slowly than Portland type I. This type of cement is used for massive concrete structures such as large gravity dams where the temperature rise due to heat generated during the curing process is a critical factor.
5. Type V : Portland cement which in its use requires very high sulphate resistance. It is suitable for making concrete in areas where soil and water have a high content of sulfate salts.

2.3. Aggregate

Aggregate – Granular materials, such as sand, gravel, crushed stone, and blast-furnace slag, which are used with adhesive media to produce concrete or hydraulic cement mortar (SNI 2847:2013). According to Sagel et al, (1994) Aggregates are concrete mixture materials that are bonded together by cement adhesives. Commonly used aggregates are sand, gravel and crushed stone.

2.3.1 Fine Aggregate

Fine aggregate is aggregate with a maximum grain size of 4.75 mm. Fine aggregate is often also called sand. The fine aggregate quality requirements according to SK SNI S-04-1989-F are as follows:

1. The grains are sharp, strong and hard.
2. Eternal nature, not broken or destroyed by the influence of weather.
3. Eternal properties, when tested with a saturated solution of sulfate salt.
4. Fine aggregate should not contain more than 5% silt (that part that can pass through a 0.60 mm sieve). If more than 5% sand must be washed.
5. Must not contain organic substances.
6. Must have a variety of grain sizes (good gradation, so there are few cavities. Has a fineness modulus between 1.5 – 3.8. When sieved with the specified sieve arrangement, it must enter one of the grain arrangement areas according to zones 1, 2, 3, or 4 and must meet the following requirements:
   a. The remainder on the sieve is 4.8 mm, a maximum of 2% of the weight.
   b. Remaining on the sieve 1.2 mm, a maximum of 10% of the weight.
   c. Remaining on the 0.30 mm sieve, a maximum of 15% of the weight.
   d. Must not contain salt.

2.3.2 Coarse Aggregate

Becah stone is the main ingredient in forming concrete besides cement paste. Aggregate content in the mixture ranges from 70-75% of the total volume of concrete, therefore the quality of the aggregate affects the quality of the concrete. The requirements for crushed stone used in concrete mixtures according to the Ministry of Public Works (1982) are as follows:

a. Physical Requirements:
   1. The maximum aggregate grain size shall not be greater than 1/5 the smallest distance from the sides of the mould, 1/3 plate thickness or ¾ of the minimum spacing of the reinforcement.
   2. The hardness determined using a Rudellof vessel shall not contain more than 16% by weight of the crushed portion that passes through a 2 mm sieve.
   3. The crushed part when tested using a Los Angeles machine, should not be more than 27% by weight.
   4. The maximum sludge content is 1%.
   5. Long, flat grain portions, maximum 20% by weight, especially for high strength concrete.

b. Chemical Requirements:
   1. Conservation to Na2SO4 of the crumbling part, maximum 12 % by weight and conservation to the crushed part MgSO4, maximum 18 %.
   2. The ability to react to alkalis must be negative so that they are not dangerous.

2.4. Water

Water is an important basic ingredient for making concretethe price is the cheapest. Water is needed to react with cement, as well as to be a lubricating agent between aggregate grains so that it is easy to work with and compact. To react with cement, only about 25 percent of the weight of cement is required for water. However, in reality, the water-cement factor value used is difficult to be less than 0.35. This excess water is used as a lubricant. But it should be noted that the addition of water as a lubricant should not be too much because it can reduce the strength of the concrete will be low and the concrete will be porous.

(Tjokrodimuljo, 1996) According to (Department of Public Works, 1982), the use of water that meets the following requirements:

1. Water must be clean, not contain more than 2 grams/liter of mud, oil and other floating objects that can be seen visually.
2. Does not contain suspended matter more than 2 salts/liter.
3. Does not contain salts that can damage concrete more than 15 grams/liter.
4. Does not contain sulfate compounds of more than 1gram/liter.
5. Does not contain chloride (CI) more than 0.5 gram/liter.

2.5. Ceramic Waste

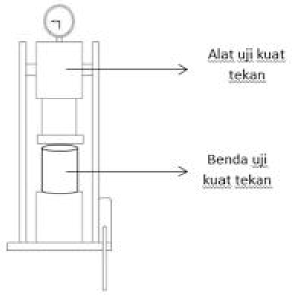
The development of the development sector in IndonesiauseConcrete bricks result in a high demand for cement and sand which will affect the increase in cement productivity. Cement production has resulted in significant CO2 emissions into the atmosphere. According to the International Energy Authority, World Energy Outlook, the amount of carbon dioxide produced in 1995 was 23.8 billion tons. Portland cement production contributes 7% of the total CO2 and is predicted to continue to increase (Akmalia et al. 2016).

The development of the ceramics industry in Indonesia continues to experienceThe increase also has an impact on the increase in ceramic waste that arises. The TMB Research and Development Center (2005) stated that Indonesia exported 122,367,973 m3 of ceramic stone in 2005. In addition, there has also been an increase in the demand for coal in power plants for the combustion process. This will increase the production of fly ash which is still little utilized, which is around 20-30% (Nurzal and Taufik 2016).

2.6. Concrete Compressive Strength

The compressive strength of concrete is the amount of load per unit area that causes the concrete to break. To determine the required compressive strength of hardened concrete, a concrete compressive strength test is carried out. The compressive strength test procedure refers to the Standard Test Method for Compressive of Cylindrical Concrete. The test steps are as follows:

a. The test object is weighed and the weight is recorded.



b. The test object is placed on the pressing machine and its position is adjusted so that it is right in the middle of the pressure plate.

c. Loading is carried out slowly continuously with a hydraulic machine until the test object is destroyed (the pointer stops then one of them moves down).

d. The maximum load indicated by the pointer is recorded.

Table.1: Scheme of Concrete Compressive Strength Testing.

Ditetapkan Oleh PBI	
UMUR BETON (Hari)	FAKTOR KONVERSI
3	0,4
7	0,7
14	0,9
21	1,0
28	1

e. The equation for calculating compressive strength is calculated by the formula, as follows:

$$f'c = \frac{P}{A} \quad (1.1)$$

Information :

f'c = concrete compressive strength (MPa)

P = Compressive Load (N)

A = Cross-sectional area of the specimen (mm^2)

2.7. Procedure for Making a Normal Concrete Mix Plan (SNI 03-2834-2000)

The general requirements that must be met are as follows:

1. The concrete mix proportions must produce concrete that meets the following requirements:
   a. Viscosity that enables concrete work (pouring, compaction, and leveling) to easily fill forms and cover surfaces homogeneously;
   b. Durability;

c. compressive strength;
d. Economical;

2. The concrete that is made must use normal aggregate without added ingredients.

The materials used in the planning must comply with the following requirements:

- If in different parts of the construction work different materials will be used, then each proportion of the mixture to be used must be planned separately;
- The materials for the trial mix must be representative of the materials to be used in the proposed work.
  Selection of concrete mix proportions
  a) The concrete mix plan is determined based on the relationship between the compressive strength and the water-cement factor;
  b) For concrete with an f'c value of more than 20 MPa, the proportion of the trial mix and the production process must be based on the weight ratio of the ingredients;
  c) For concrete with an f'c value of up to 20 MPa, the production implementation may use a volume ratio. Comparison of the volume of these materials should be based on the planned proportion of the mixture in weight which is converted into volume through the average unit weight between the loose and solid of each material.

Calculation of Mixed Proportions:

a) The targeted average compressive strength is calculated from:

standard deviation obtained from experience in the field during concrete production according to the formula:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\overline{x})^2}{n-1}} \quad \text{...} (1.2)$$

With :

S = Standard Deviation

Xi = Concrete compressive strength that can be obtained from each test object

$\overline{x}$= Average compressive strength of concrete

$$\overline{x} = \frac{\sum_{i=1}^{n} Xi}{n} \quad \text{.. ...} (1.3)$$

With :

n is the number of test result values, which must be taken at least 30 pieces (one test result is the average test value of 2 test objects).

The two test results to be used to calculate the standard deviation should be as follows:

1. Represents materials, quality control procedures, and production conditions similar to the proposed work;
2. Represents the required concrete compressive strengthf'cwhose value is within 7 MPa of the specified fcr value;
3. A minimum of 30 consecutive test results or two batches of test results taken into production for a period of not less than 45 days;
4. If a concrete production does not have two test results that meet article a) point (i), but there are only 15 to 29 consecutive test results, then the standard deviation value is the multiplication of the standard deviation calculated from the test result data with a multiplier factor.

Table.2: Multiplier factor for standard deviation when data; available test results are less than 30

Jumlah Pengujian	Faktor Penggali Deviasi Standar
Kurang dari 15	Lihat Butir (v)
15	1,16
20	1,08
25	1,03
30 atau lebih	1,00

5. if the field test data to calculate the standard deviation that meets the requirements of article a) point (i), above is not available, then the targeted average compressive strengthf'cshould be taken not less than (f'c+12 MPa);

b) Value Added is Calculated According to the Formula:

M = 1.64 x sr ; .... (1.4)

With

M = added value

1.64 = statistical constant whose value depends on the percentagefailure of the test results by a maximum of 5%

Sr = plan standard deviation

The targeted average compressive strength is calculated according to the following formula:

fcr =f'c+ M... (1.5)

fcr =f'c+ 1.64 sr.. (1.6)

c) Selection of cement water factor

The cement water factor required to achieve the targeted average compressive strength is based on:

1. the relationship between compressive strength and water-cement factor obtained from field research according to the proposed material and working conditions. If research data is not available as a guide, Table 2 and Graph 1 or 2 can be used;
2. for special environments, the maximum cement water factor must comply with SNI 03-1915-1992 concerning specifications for sulfate-resistant concrete and SNI 03-2914-1994 concerning specifications for water-resistant reinforced concrete
3. Slump

   Slump is determined in accordance with the conditions of work implementation in order to obtain concrete that is easy to pour, obtain and level.
4. Maximum aggregate grain size

   The maximum aggregate grain size should not exceed:

   - One-fifth of the smallest distance between the side planes of the mould;
   - One third of the thickness of the plate;
   - Three-quarters of the minimum clear distance between bars or beams.
5. Free Moisture Content

   The free water content is determined as follows:

   - Unbroken aggregates and aggregates broken downused values in tables and graphs
   - Mixed aggregate (not broken down and broken down), calculated according to the following formula:

$\frac{2}{3}W_h + \frac{1}{3}Wk$.. (1.7)

with :

Wh is the approximate amount of water for fine aggregate

Wk is the approximate amount of water for coarse aggregate

Table.3: Estimated compressive strength (MPa) of concrete with Cement water factor, and coarse aggregate commonly used in Indonesia

Jenis semen	Jenis agregat Kasar	Kekuatan tekan (MPa)				
...		Pada umur (hari)				Bentuk
...		3	7	28	29	Bentuk uji
Semen Portland Tipe I	Batu tak dipecahkan	17	23	33	40	Silinder
	Batu pecah	19	27	37	45	
Semen tahan sulfat Tipe II, V	Batu tak dipecahkan	20	28	40	48	Kubus
	Batu pecah	25	32	45	54	
Semen Portland tipe III	Batu tak dipecahkan	21	28	38	44	Silinder
	Batu pecah	25	33	44	48	
	Batu tak dipecahkan	25	31	46	53	Kubus
	Batu pecah	30	40	53	60	

6. Aggregate Relative Specific Gravity

   The relative specific gravity of the aggregate is determined as follows:

   obtained from the test results data or if not available the value below can be used:

   - Aggregate is not broken down: 2.5
   - Aggregate broken down: 2.6 or 2.7
   - The aggregate specific gravity is calculated as follows:

   Specific gravity of combined aggregate = [% fine aggregate x BJ fine aggregate] + [% coarse aggregate x BJ coarse aggregate]

   - Concrete Mixing Proportions

   The proportions of the concrete mixture (cement, water, fine aggregate and coarse aggregate) must be calculated in kg per m^3 stir.
7. Mix Proportions Correction

   If the aggregate is not in a saturated state the surface dry proportion of the fine mixture is corrected for the water content in the aggregate. Correction of the proportion of the mixture must be made to the moisture content in the aggregate at least once a day and is calculated according to the following formula:

- Water = B – (Ck-Ca) x C/100 – (Dk –Da) x D/100... (1.8)
- Fine aggregate = C + (Ck-Ca) x C/100 .... (1.9)
- Coarse aggregate = D + (Dk-Da) x D/100.......... (1.10)

With:

b = Amount of water

c = amount of fine aggregate

d = amount of coarse aggregate

ca = Water absorption in fine aggregate (%)

da = Absorption of coarse aggregate (%)

ck = Water content in fine aggregate (%)

et al = Water content in coarse aggregate (%)

2.8. Previous Research

Daniyal and Ahmad (2015) examined the effect of adding crushed waste ceramic tiles as a substitute for natural coarse aggregate with substitutions of 10%, 20%, 30%, 40% and 50% and analyzed that, the optimum value of ceramic tile waste to be used in concrete mixes with a water/cement ratio of 0.5 is determined to be around 30%. The optimal compressive strength and flexural strength of concrete were found to be 5.43% and 32.2% higher than the reference concrete, respectively. The findings revealed that using lead waste ceramics to improve the properties of concrete.

According to Asri Mulyadi, 2019 with the results of the compressive strength test, namely on normal concrete (0% ceramic) with an immersion age of 28 days, the compressive strength of concrete is 200.78 kg/cm2, on concrete with a ceramic content of 20% with an immersion age of 28 days, the compressive strength is obtained. concrete of 194.74 kg/cm2, for concrete with a ceramic content of 40% with an immersion age of 28 days, the compressive strength of concrete is 188.70 kg/cm2, and for concrete with a ceramic content of 60% with an immersion age of 28 days, the compressive strength of concrete is 175 .12kg/cm2.

III. METHODOLOGY

3.1 Research sites

This research was conducted in Passo Village, Teluk Ambon District, Ambon City.

Fig.1: Research locations

3.2 Data Type

The types of data used in this writing are:

a. Primary data

Primary data is data obtained by researchers directly from the results of testing the physical properties of aggregates (examination of sieving analysis, moisture content, bulk density, silt content, specific gravity and absorption as well as mix design tests).

b. Secondary Data

Secondary data is data obtained by researchers from existing sources such as SNI 03-2834-2000.

3.3 Research Variables

1. Percent variation (0 %, 15 %, 20 %)
2. Aggregate (coarse and fine)
3. Additives (Ceramic waste)
4. Concrete quality

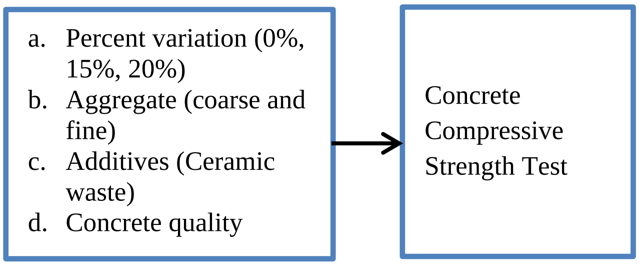


Fig.2: Variable Relationship

3.3 Data collection technique

The data collection technique used in this paper is as follows: Experimental, namely by experimenting with the manufacture of test objects directly.

3.4 Analysis Method

The method used in this study is an experimental method, namely an experiment that aims to investigate the relationship between the compressive strength of normal concrete and concrete that uses ceramic shards as a filler material for a portion of the weight of coarse aggregate. The test objects made in this experiment were 9 samples in the form of concrete cylinders with a size of 15 cm x 30 cm which would later be tested for the compressive strength of concrete using SNI 03-2834-2000 guidelines. The type of ceramic that I use isRefractory Ceramic which is a non-metallic inorganic solid material that is difficult to melt at high temperatures and is widely used in the high temperature industry as a refractory stone wall material.

3.5 Preparation Stages

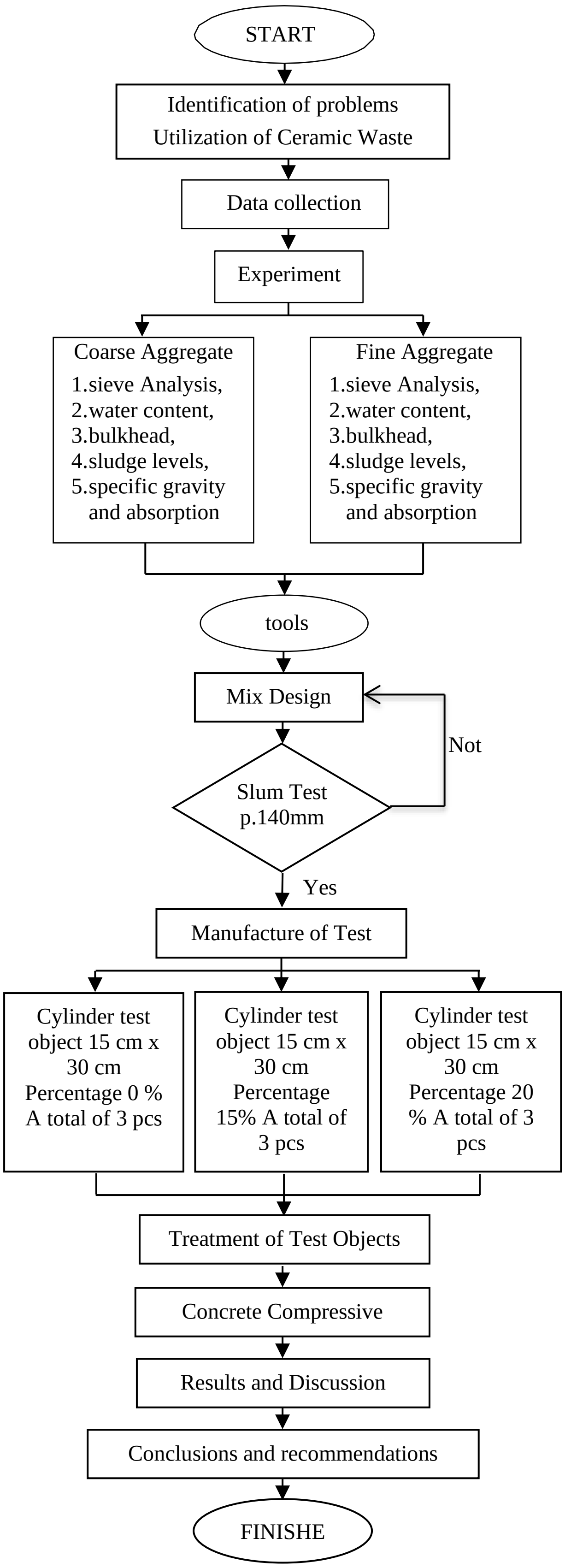


Fig.3: Preparation Stage

IV. ANALYSIS AND DISCUSSION

4.1 Results and Discussion of Material Testing

1. Aggregate gradation

Aggregate gradation is the grain size distribution of the aggregate. In aggregates for the manufacture of mortar or concrete, a grain with high compaction is desired, because the pore volume is small and this means that only a binder is needed.In Table.4, the results of the fine aggregate modulus are included in the specification 1.5 – 3.8 with an MHB value of 3.5128.

Table.4: Analysis of fine aggregate gradation

Hole Sieve (mm)	Heavy Left behind (grams)	Heavy Left behind (%)	Heavy Left behind Cumulative (%)	Pass Percent Cumulative (%)
40.00	0	0.00	0.00	100
20.00	0	0.00	0.00	100
10.00	0	0.00	0.00	100
4.80	17.58	1.75	1.75	98.25
2.40	23.86	2.38	4,13	95.87
1.20	69,36	6,94	11.07	88.93
0.60	399.62	39.96	51.03	48.97
0.30	409.75	40.98	92.01	7.99
0.15	30,77	3.08	95.09	4.91
0.075	10.46	1.05	96,14	3.86
pan	38,6	3.86	100	0
Total	1000	100		
			MHB =	3.5122

Information :

MHB : Grain Fine Modulus

Based on Table.4, the sand belongs to Zone II, because the cumulative pass percentage on a 0.60 (No30) sieve is 48.97 with an upper limit of 59 and a lower limit of 35. It can be seen in Fig.4:

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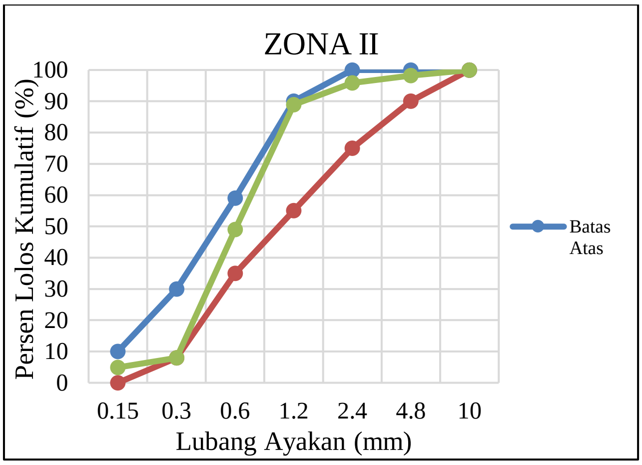

Fig.4: Graph of fine aggregate gradation

Table.5: The results of examining the characteristics of fine aggregate

Sample Type : Sand
Sample Source :Passo

No.	Uraian Pengujian	Hasil Pengujian	Spesifikasi	Standart Acuan
1	**Gradasi**			
	Zona Gradasi	Zona 2	Zona 1 - 4	SK. SNI T. 15-1990-03
	Modelus Kehalusan	3.51	1.5 - 3.8	SII 0052-80
2	**Berat Volume (gr/cm3)**		1.2 - 1.7	ASTM C-29
	Lepas	1.4318		
	Padat	1.6832		
3	**Berat Jenis dan Penyerapan**		2.4 - 2.9	BS 812
	Berat Jenis Bulk	2.45		
	Berat Jenis SSD	2.54		
	Berat jenis Semu	2.70		
	Penyerapa/ Absorsi (%)	3.85	< 5 %	PB - 0203 - 80
4	**Kadar Air (%)**	4.37	< 5 %	SII 0052- 80
5	**Kadar Lumpur (%)**	3.82	< 5 %	SII 0052- 80

2. Coarse aggregate yield

The results of the coarse aggregate fineness modulus are included in specifications 5 – 8 with an MHB value of 7.7603.

Table.6: Analysis of Coarse Aggregate Gradation

Hole Sieve (mm)	Heavy Left behind (grams)	Heavy Left behind (%)	Heavy Left behind Cumulative (%)	Pass Percent Cumulative (%)
40.00	0	0	0	100
20.00	628.04	31,40	31,40	68,60
10.00	960,22	48.01	79,41	20.59
4.80	312.35	15,62	95.03	4.97
2.40	0	0	95.03	4.97
1.20	0	0	95.03	4.97
0.60	0	0	95.03	4.97
0.30	0	0	95.03	4.97
0.15	0	0	95.03	4.97
0.075	0	0	95.03	4.97
pan	99.39	4.97	100	0
Total	2000			
			MHB =	7.7603

Based on Table 6, crushed stone is classified as the Maximum Size of 40 mm. due to the percentage of cumulative passes on a 10 mm sieve (No.3/8 inches) which is 20.58% with an upper limit of 40 and a lower limit of 10. You can see in the image below.

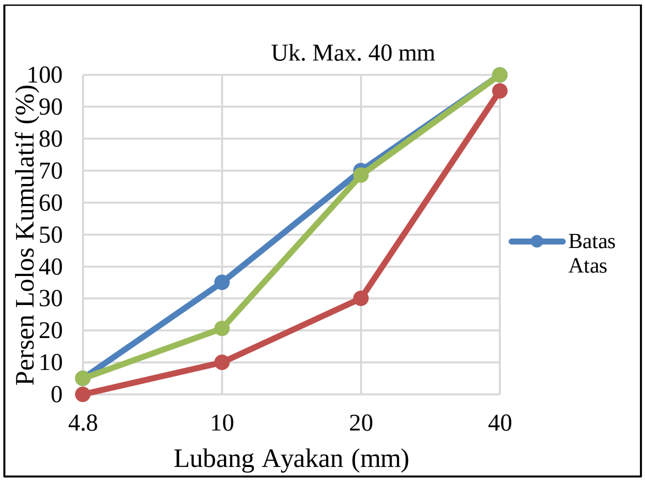

Fig.5: Graph of coarse aggregate gradation

Table.7: Results of examination of the characteristics of coarse aggregate

Sample Type : Broken stone
Sample Source : Passo

No.	Uraian Pengujian	Hasil Pengujian	Spesifikasi	Standart Acuan
1	**Gradasi**			
	Zona Gradasi	40 mm	Uk. Max 10 - 40 mm	SK. SNI T. 15-1990-03
	Modelus Kehalusan	7.76	5 - 8	SII 0052-80
2	**Berat Volume (gr/cm3)**		1.2 - 1.7	ASTM C-29
	Lepas	1.34		
	Padat	1.53		
3	**Berat Jenis dan Penyerapan**		2.4 - 2.9	BS 812
	Berat Jenis Bulk	2.63		
	Berat Jenis SSD	2.69		
	Berat jenis Semu	2.80		
	Penyerapa/ Absorsi (%)	2.30	< 5 %	PB - 0203 - 80
4	**Kadar Air (%)**	1.487	< 5 %	SII 0052- 80
5	**Kadar Lumpur (%)**	2.884	< 5 %	SII 0052- 80

3. Discussion

Based on the test results on the characteristics of fine and coarse aggregates, it can be discussed as follows:

a. Gradation of fine and coarse aggregate

The results of the gradation test show that fine aggregate (sand) meets the requirements because it is included in the zone II gradation category, while coarse aggregate (crushed stone) also meets the requirements because it is included in the specifications and is categorized in a maximum size of 40 mm.

b. Moisture content of fine and coarse aggregates

On testing the water content of fine aggregate (sand) an average value of 4.37% was obtained, for coarse aggregate (crushed stone) an average value of 1.487%. The aggregate moisture content value indicates that sand and crushed stone are within normal limits, where the requirement is 5%. The water content itself can affect the compressive strength value of concrete if the water content is high, then the aggregate absorption is higher and can affect the compressive strength value of concrete.

c. Specific gravity and absorption of fine and coarse aggregates

From the test results obtained the value of the specific gravity of fine aggregate surface dry (SSD) is 2.58, for coarse aggregate SSD is 2.69. while the absorption value of fine aggregate is 4.31% and coarse aggregate is 2.30%.

d. Fine and coarse aggregate silt content

From the results of testing the fine aggregate mud content, a value of 3.82% was obtained and that of coarse aggregate was 2.884% which is smaller than the specified value for the mud content in normal concrete, which is 5%.

4.2 Concrete Mix Design Mix Design

The calculation method used in planning the concrete mix design refers to the SNI-03-2834-2000 method. The steps in planning a mix design mix, as follows:

1. Determine the compressive strength of concrete (f'c) at the age of 28 days

The required concrete compressive strength (f'c) is defined as compressive strengthFc'18.67 MPa.

2. Set standard deviation value (S)

The standard deviation is calculated based on the volume of concrete made and the quality of the work. The standard deviation value used in the design of this mix is 7 MPa, which is the level of poor quality control due to lack of prior experience.

Table.8: Valuestandard deviation for various levels of job quality control

Level of Quality Control of work	SD (MPa)
Satisfying	2.8
Very good	3.5
Well	4.2
Enough	5.6
Bad	7.0
Without Control	8.4

3. Calculating Value Added (Margin)/(M)

M = 1.64 x S
= 1.64 x 7
= 11.48 MPa

4. Determine the Planned Average Compressive Strength (f'cr)

f'cr = f'c + M
= 18.67 MPa + 11.48 MPa
= 30.15 MPa

5. The specified type of cement is portland cement type I
6. Aggregate Type
   a) The fine aggregate used is natural, using sand from the land.
   b) The type of coarse aggregate used is crushed stone with a maximum size of 40 mm.
7. Determine the water-cement factor value (fas)

By using a graph of the relationship between compressive strength and fascicle of the cylinder test object. The steps for determining the fas value are as follows:

a) Determining the estimated compressive strength can be known from the type of cement, type of aggregate, shape of the test object used, and the age of the concrete in compressive strength (can be seen in table 9).

Table.9: Estimated Compressive Strength (MPa) of concrete with fas 0.5

Jenis semen	Jenis agregat Kasar	Kekuatan tekan (MPa)				
...		Pada umur (hari)				Bentuk
...		3	7	28	29	Bentuk uji
Semen Portland Tipe 1	Batu tak dipecahkan	17	23	33	40	Silinder
	Batu pecah	19	27	37	45	
Semen tahan sulfat Tipe II, V	Batu tak dipecahkan	20	28	40	48	Kubus
	Batu pecah	25	32	45	54	
Semen Portland tipe III	Batu tak dipecahkan	21	28	38	44	Silinder
	Batu pecah	25	33	44	48	
	Batu tak dipecahkan	25	31	46	53	Kubus
	Batu pecah	30	40	53	60	

b) From the table above, the compressive strength is 37 MPa. After that, it will be described on the graphThe relationship between the cement water factor and the average compressive strength of concrete cylinders (can be seen in Fig. 6)

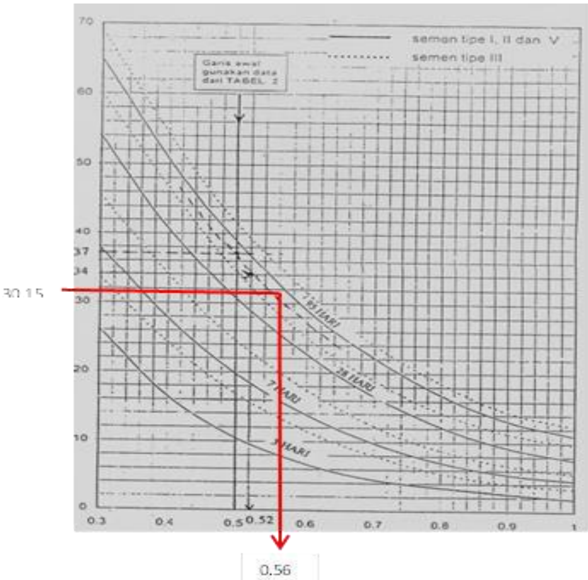

Fig.6: Relationship between compressive strength and cement water factor

c) The determination of the fas value of 0.56 is obtained from the meeting of the compressive strength value of 37 MPa with the fas value of 0.5 based on table 9. then the meeting point is drawn proportionally with a dashed curved line, after that on the y axis (average compressive strength) which is planned to be f'cr = 30.15 MPa. Drag the 32.23 MPa value line on the graph until it touches the dotted line, then drag it downwards to the fas value to get a fas value of 0.56.

8. Determine the maximum water-cement factor value

For concrete that is inside the building space with a non-corrosive circumferential condition, it is obtainedmaximum cement water factor 0.52.

Table.10: Requirements for the minimum amount of cement and maximum water-cement factor for various types of concrete in special environments

Construction Type	Amount of Cement min./m3 Concrete (kg)	Max. Fas Value
Concrete in the building space:		
a. Non-corrosive circumstance	275	0.60
b. The corrosive circumstance is caused by condensation or corrosive vapors	325	0.52
Concrete outside the building:		
a. Not protected from rain and direct sun	325	0.55
b. Protected from rain and direct sun	275	0.60
Concrete that goes into the ground:		
a. Experience alternating wet and dry conditions	325	0.55
b. Under the influence of alkaline sulfates from the soil or groundwater	375	0.52
Continuous concrete in contact with water:		
a. Freshwater	275	0.57
b. Sea water	375	0.52

9. Sets the slump value

The planning slump height is set at 60 – 180 mm.

10. Sets the maximum aggregate grain size

The maximum aggregate grain size used is 40 mm.

11. Set the value of free moisture content

To determine the free water content, see table 11 for the combined aggregate of natural sand and crushed stone, thenfree water content must be taken into account 175 Kg/m3 and 205 Kg/m3 withslump value of 60 – 180 mm and a maximum aggregate line of 40 mm.

Table.11: Estimated free water content (Kg/m3) required for several levels of concrete mix workability

Size Max. Gravel (mm)	Rock Type	Slumps (mm)			
		0 - 10	10-30	30-60	60 – 180
10	Experience	150	180	205	225
	Crushed Stone	180	205	230	250
20	Experience	135	160	180	195
	Crushed Stone	170	190	210	225
40	Experience	115	140	160	175
	Crushed Stone	155	175	190	205

Based on the table above, the estimated water needs per cubic meter of concrete include:

W = 2/3 Wh + 1/3 Wk
= 2/3 (175 kg/m3) + 1/3 (205 kg/m3)
= 185 Kg/m3

So from the calculation, the free water content value is 185 Kg/m3

12. Calculating the Need for Cement

The amount of cement needs is calculated based on the equation

W cement $= \frac{W\ air}{fas}$
$= \frac{185}{0.52}$
= 355.76 Kg

From the calculation above, it is obtained that the amount of cement needed is 355.76 Kg.

13. Set minimum cement

Based on table 11, a minimum of 325 kg of cement is obtained with the condition that the concrete is in a non-corrosive circumferential building space.

14. Determine the need for cement to be used

Based on table 11, a minimum cement of 275 kg is obtained, from the calculation of the cement requirement of 355.76 kg. Of the two values of cement requirement used is the greatest value of 355.76 Kg.

15. Determine the percentage of fine and coarse aggregates

The percentage of aggregate quantity is determined from the maximum size of coarse aggregate, slump value, cement water factor (fas) and fine aggregate gradation area. For fine aggregate, it can be seen in the figure below using a maximum grain size of 40 mm, slump of 60-180 mm, and zone II gradation from the results of the Fine Aggregate Modulus of Fineness (MHB) test.

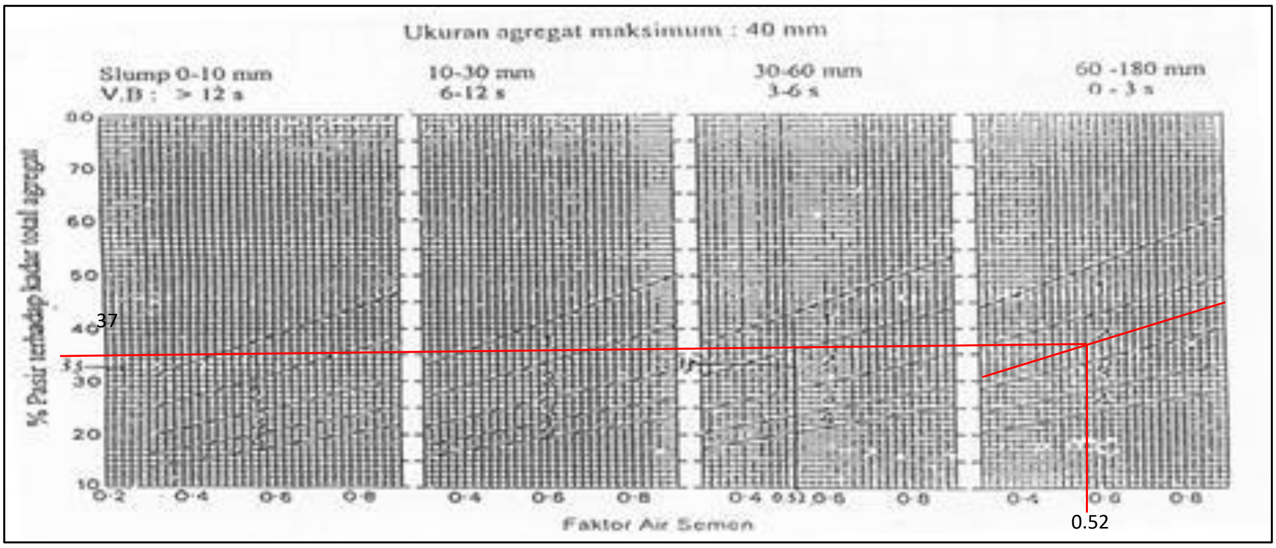

Fig.7: Graph of the percentage of fine aggregate to overall aggregate for a maximum grain of 40 mm

The steps for determining the aggregate percentage are as follows:

a) Make a straight line on each edge of zone II, then a line in the middle on the edge of zone II

b) Draw a straight line up through the cement water factor that was previously obtained at 0.52 until it intersects the midline in zone II
c) then drag it towards the Y axis (sand percentage) so you get a sand percentage of 37%
d) The percentage value of fine and coarse aggregate can be calculated using the formula below:

%AK = 100% - A.H
= 100% - 37
= 63%

From the calculation above, the percentage value of fine aggregate (% AH) is 37% and the percentage of coarse aggregate (% AK) is 63%.

16. Calculates the combined aggregate SSD specific gravity

The specific gravity of fine aggregate and coarse aggregate can be known from the SSD specific gravity test, including: for the specific gravity of fine aggregate (BJAH) of 2.58 and the specific gravity of coarse aggregate (BJAK) of 2.69.

Then the combined aggregate specific gravity can be calculated using the equation below:

Combined BJs = (% AH x BJAH) + (% AK x BJAK)
= (37 % x 2.58) + (63 % x 2.69)
= (0.954) + (1.694)
= 2.64

From the calculation above, the combined aggregate specific gravity (Bj combined) is 2.64

17. Determine the concrete unit weight

The wet concrete unit weight is determined based on the graph in Figure 4.5 by entering the combined aggregate specific gravity and free water content. The steps to determine the concrete unit weight from the picture above are as follows:

a) Create a new curve according to the combined aggregate specific gravity proportionally taking into account the existing upper and lower curves
b) Draw a perpendicular line upwards from the grade value used, which is 185 kg/m3, until it intersects the new curve for the combined specific gravity
c) Then from the point of intersection, draw a horizontal line to the left until it intersects the vertical axis
d) From the drawing of the line, the value of the concrete unit weight is 2399 kg/m3

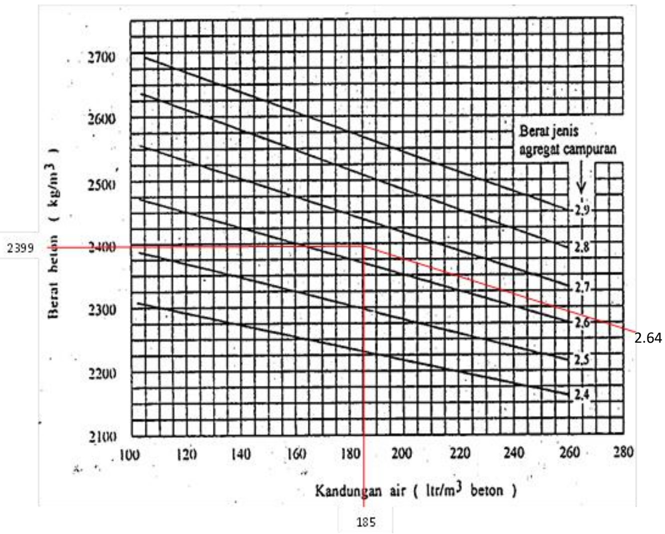

Fig.8: Estimated wet concrete unit weight that has been obtained

18. Calculate the combined aggregate weight

Combined = Wisi wet concrete – Cement – Wair
= 2399 Kg/m3 – 355.76 Kg/m3 – 185 Kg/m3
= 1858.24 Kg/m3

From the calculation above, we get a combined aggregate weight of 1858.24 Kg/m3

19. Calculate the weight of fine aggregate

WOW = (Wisi concrete –Wcement – Wair) x % AH
= (2399 – 355.76 – 185) x 0.37
= 687.54 kg/m3

From the calculation above, the fine aggregate weight is 87.54 Kg/m3

20. Calculate the weight of coarse aggregate

WAK = (Wisi concrete –Wcement – Wair) x % AK
= (2399 – 355.76 – 185) x 0.62
= 1170.69 kg/m3

From the calculation above, the weight of coarse aggregate is 1170.69 Kg/m3

21. Calculates the proportions of the mixture

From the results of the calculation of the mix design, it is obtained that the proportion of ingredients to make 1 m3 of concrete mixture with a design target of compressive strength f'c = 18.67 MPa (225 Kg/cm2), is:

a) Cement : 355.76 Kg/m3
b) Water : 185 Kg/m3
c) Fine aggregate : 687.54 Kg/m^3
d) Coarse aggregate :1170.69 Kg/m3

From the data from the calculation of the proportions of the mixture of the basic ingredients, the mixture ratio is obtained as follows:

1 PC : 0.52 Water : 1.93 Fine aggregate : 3.29 Coarse aggregate

Table.12: Mix design calculations refer to SNI 03-2843-2000

NO	DESCRIPTION	INSTRUCTIONS	SCORE	UNIT
1	Required compressive strength (f'c)	planned	18.67 MPa	
2	Standard Deviation (Sr)	Defined	7 MPa	
3	Value Added (M)	1.64 x Sr	11.48 MPa	
4	Targeted average compressive strength	F'c + M	30.15	
5	cement type	Defined	Portlands Type 1	
6	Aggregate type - coarse – fine			
	Rough	Defined	Crushed Stone	
	Fine	Defined	Sand	
7	Free water-semen factor	Graphic 1 SNI 2000	0.56	
8	Maximum cement water factor	Table 4 SNI 2000	0.52	
9	Slumps (mm)	Defined	Slumps 60-180	Mm
10	Maximum aggregate size	Defined	40	Mm
11	Free water content (kg/m3	Table 3	185	Kg/Ltr
12	The amount of cement	11:8	355.76	kg/m3
13	Minimum amount of cement	Table 4 SNI 2000	325	kg/m3
14	The amount of cement used	The amount of cement used	355.76	kg/m3
15	The percentage of fine aggregate : coarse aggregate	sister	37:63	
16	Combined relative density (sand and crushed stone)	Based on Graphic 15 of SNI 2000	2.64	kg/m3
	Relative density of Sand SSD conditions	Test result	2.58	kg/m3
	Relative density of crushed stone SSD condition	Test result	2.69	kg/m3
17	Concrete weight kg/m3	Based on Graphic 16 of SNI 2000	2399	kg/m3
18	Combined aggregate weight	No.(17 - 12 - 11)	1858,24	kg/m3
19	Fine aggregate weight	= % Ag. Smooth x No. 18	687,54	kg/m3
20	Coarse aggregate weight	= % Ag. Coarse x No. 18	1170.69	kg/m3
21	Mixed proportions			
	Cement (Kg)	**WATER (Kg/Ltr)**	**FINE AGGREGATE**	**COARSE AGGREGATE**
	Each m3 355.76	185	687,54	1170.69
22	**1 PC : 0.52, WATER : 1.93, AG. FINE : 3.29, AG. ROUGH**			

From the results of Table 12, the required m3 will be calculated with a cylindrical test object with a diameter of 150 mm and a height of 300 mm. then for the volume of 3 test objects, namely:

V = ¼ x Π x d xd x t

= ¼ x 3.14 x 0.15 m x 0.15 m x 0.3 m

= 0.0053 m^3+ (10% x V (Safety Factor))

= 0.00583 m^3x 3 pcs

= 0.0175 m^3

The proportion of material requirements for 3 test objects:

1. Cement =W. Cement x Volume
   = 355.76 Kg/m3 x 0.0175 m3
   = 6,225 kg

Table.13: Proportions of mixed concrete materials

No	Material	Jumlah masing – masing material untuk campuran beton dengan bahan keramik sebagai tambahan agregat kasar (KG)		
		0%	15%	20%
1	Semen	6.225	6.225	6.225
2	Air	3.238	3.238	3.238
3	Batu Pecah	20.487	17.414	16,390
4	Pasir	12.031	12.031	12.031
5	Keramik	-	3,073	4,097

Table.14: Data of Cylindrical Concrete Compressive Strength Test Results

HASIL PERHITUNGAN KUAT TEKAN BETON SILINDER

N	Benda Uji	Tanggal		Umur Beton	Dimensi Silinder		Berat Sampel	Beban	Konversi	Beban	Luas	Kuat Tekan Hancur	Koef. Umur 7 Hari	Kuat tekan hancur umur 28 hari	Rata-rata Kuat Tekan Hancur Umur 28 Hari
		Dicor	Diuji		D (Diameter)	T (Tinggi)									
				(Hari)	(Cm)	(Cm)	(Kg)	(KN)		(Kg)	(cm^2)	(Kg/cm^2)		(Kg/cm^2)	
a)	b)	c)	d)	e)	f)	g)	h)	i)	j)	k) =i)* j)	l)	m) = k) : l)	n)	o)=m) : n)	
A.	Sampel 0%														
1	Sampel 1	30-Nop-21	08-Des-21	7	15	30	12,16	270	101,97	27531,9	176,625	155,878	0,7	222,682	226,806
2	Sampel 2	30-Nop-21	08-Des-21	7	15	30	11,97	270	101,97	27531,9	176,625	155,878		222,682	
3	Sampel 3	30-Nop-21	08-Des-21	7	15	30	12,00	285	101,97	29061,45	176,625	164,538		235,054	
B.	Sampel 15%														
1	Sampel 1	30-Nop-21	08-Des-21	7	15	30	11,99	270	101,97	27531,9	176,625	155,878	0,7	222,682	232,305
2	Sampel 2	30-Nop-21	08-Des-21	7	15	30	11,89	285	101,97	29061,45	176,625	164,538		235,054	
3	Sampel 3	30-Nop-21	08-Des-21	7	15	30	11,92	290	101,97	29571,3	176,625	167,424		239,177	
C.	Sampel 20%														
1	Sampel 1	30-Nop-21	08-Des-21	7	15	30	11,93	285	101,97	29061,45	176,625	164,538	0,7	235,054	236,428
2	Sampel 2	30-Nop-21	08-Des-21	7	15	30	11,94	285	101,97	29061,45	176,625	164,538		235,054	
3	Sampel 3	30-Nop-21	08-Des-21	7	15	30	12,01	290	101,97	29571,3	176,625	167,424		239,177	

*Table.15: Average cylinder compressive strength test **F'c** = 18.67 MPa*

No	Test Objects	Average crushing strength 28 Days (Kg/cm2)	Average crushing strength 28 Days (MPa)
1	Sample 0%	226,806	22.68
2	Sample 15%	232,305	23.23
3	Sample 20%	236,428	23.64

From the test above, there are three comparisons, namely:

1. Normal concrete with an average compressive strength of 22.68 MPa
2. 15% ceramic waste concrete with an average strength of 23.23 Mpa
3. 20% ceramic waste concrete with an average strength of 23.64 MPa

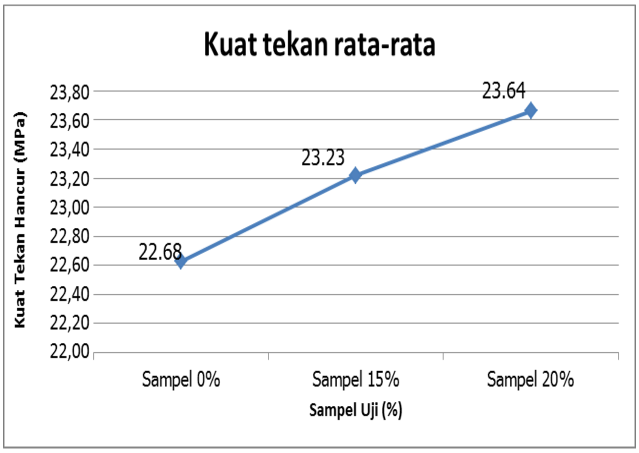

Fig.9: Graph of the average compressive strength of concrete aged 28 days

The graph above shows that the greater the percentage of ceramics, the higher the compressive strength of concrete. This can be seen in the average compressive strength graph above for the 0% sample with a crushed compressive strength of 22.68 MPa to a 15% sample with a crushed compressive strength of 23.23 MPa, so that it has a difference increase of 0.55 MPa. Likewise the 0% sample with a crushed compressive strength of 22.68 MPa to a 20% sample with a crushed compressive strength of 23.64 MPa so that it has a difference increase of 0.96 MPa

V. CONCLUSIONS AND SUGGESTIONS

5.1. Conclusion

Based on the results of the research in testing, the analysis and discussion that has been carried out on concrete with the addition of some ceramics with normal concrete is as follows:

1. The compressive strength of concrete using ceramic waste material as an additional coarse aggregate with a percentage of 15% and 20% ceramic waste is as follows: Trial mix with 15% ceramic gives a compressive strength of 23.91 MPa and trial mix with ceramic 20% days gives a compressive strength of 23 .89 MPa. From the results of this test the percentage of 20% ceramic is greater in compressive strength compared to the percentage of 15% ceramic
2. Comparison of the compressive strength values of normal concrete and concrete using ceramics proves that the compressive strength of concrete is greater than that of normal concrete. The more percentage of ceramics, the greater the compressive strength of concrete. It can be seen from the compressive strength of concrete from 0% to 15% which has an increase of 0.59 MPa and the compressive strength of slate from 0% to 20% has an increase of 0.98 MPa.

5.2. Suggestion

Based on the conclusions above, it can be suggested as follows:

1. Further research needs to be done on larger numbers in order to get significant results.
3. For further research in the hope of reducing environmental pollution.
4. For future researchers, it is necessary to find other alternatives so that the process of refining ceramic waste can produce even more volume.

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