# CHAPTER II
# LITERATURE REVIEW

## 2.1 Previous Research

One of the references used to add insight and knowledge about the topic in writing this final project is previous research. In this study some of the previous studies used are as follows.

**A. Mechanical Properties of Modified Coral Aggregate Seawater Sea-Sand Concrete: Experimental Study and Constitutive Model (Wang et al., 2023)**

In this study, concrete was made using sea sand, sea water. As well as using variations of 0%, 25%, 50%, 75% and 100% coral aggregate and modified coral as a substitute for gravel coarse aggregate. The coral aggregate used is the original coral and the modified coral obtained from the South China Sea. The modification was done by coating superfine cement on the coral with several steps, namely: soaking the coral aggregate in a slurry of superfine cement paste and stirring evenly. Next, the coral was removed and the remaining paste on the coral surface was filtered using a fine mesh, then placed evenly outdoors and dried for 24 hours. Finally, the coral aggregate was placed in a standard curing chamber with a temperature of 20±2 ºC and relative humidity of 95% for 28 days. From the results of the compressive strength test, it was concluded that the compressive strength of concrete using coral aggregate decreased linearly, indicating that the addition of aggregate has a direct effect on the compressive strength of concrete. The compressive strength of concrete with 100% coral as coarse aggregate is 40.2% lower than the compressive strength of concrete using 100% gravel. The compressive strength of concrete with modified coral aggregate decreased by 33.6% from that of gravel aggregate concrete. The increase in compressive strength of concrete due to modification is not very significant with an increase ratio of approximately 6%.

**B. Kuat Tekan Beton Ringan Non-pasir pada Pemanfaatan Batu Karang Simeulue sebagai Alternatif Agregat Kasar (Wesli et al., 2023)**

The title in English is “Compressive Strength of Non-sand Lightweight Concrete on the Utilization of Simeulue Coral as an Alternative Aggregate”. This research was conducted by making non-sand lightweight concrete and normal concrete using coral material as a substitute for coarse aggregate. The coral was taken directly from the coastal area of Matanurung village, Teupah Tengah District, Simeulue Regency. All variations, using a cement water factor of 0.40, a target compressive strength of 15 MPa, and compressive strength testing carried out at 28 days of concrete age. After obtaining the results of the mix design of lightweight non-sand concrete, then a variation of cement per aggregate whose weight is multiplied by ½ of the mix design results obtained. The test specimen variations made are: crushed gravel non-sand lightweight concrete (BNNP), coral non-sand concrete mix design (BKR1), coral non-sand concrete mix design + superplasticizer 0.6% (BKR1+SP0. 6%), lightweight non-sand concrete ½ mix design (BKR2 ½ BKR1), lightweight non-sand concrete ½ mix design + superplasticizer 0.6% (BKR2 ½ BKR1+SP0.6%), normal crushed gravel concrete (BN), normal coral concrete (BNBK), and normal coral concrete + superplasticizer (BNBK+SP1.5%). Based on the results of testing the compressive strength of non-sand lightweight concrete, the test specimens BNNP, BKR1, BKR1 + SP0.6%, BKR2 ½ BKR1, BKR2 ½ BKR1 + SP0.6%, produce sequential compressive strengths, namely: 11.86 MPa, 2.04 MPa, 2.3 MPa, 4.24 MPa, and 5.64 MPa. This shows that the compressive strength does not reach the plan quality of 15 MPa, the compressive strength of concrete with coarse aggregate coral does not meet the requirements for non-structural lightweight concrete which is 6.89 MPa. The results of testing the compressive strength of normal concrete, test specimens BN, BNBK, BNBK+SP 1.5%, produced a sequential compressive strength of: 20.52 MPa, 18.15 MPa, and 20.73 MPa. This shows that the replacement of coral as coarse aggregate makes the compressive strength decrease. However, the BNBK specimens met the compressive strength for structural concrete of 17 MPa, as well as meeting the planned compressive strength of 15 MPa. The addition of 1.5% superplasticizer makes the coral concrete increase by 1.01%.

**C. Studi Karang Mati sebagai Pengganti Agregat Kasar pada Adukan Beton (Putra & Sefrus, 2022)**

The title in English is “Study of Dead Coral as a Substitute for Coarse Aggregate in Concrete Mixes”. This study discusses the effect of using coral reefs in the Kaur area which is the southern coastal area of Bengkulu Province on compressive strength. The coral used is dead and is used as a substitute for coarse aggregate in concrete. Using the method by making a concrete mixture with a coarse aggregate composition of 60% coral. This study used cylindrical molded specimens with a diameter of 15 cm and a height of 30 cm with a composition ratio of 1 cement, 1.6 sand, and 2.5 coral. The compressive strength test of concrete was carried out at the age of 28 days. Testing resulted in the following conclusions. From the results of the study, it can be concluded that the use of 60% dead coral as a substitute for coarse aggregate is better than other concrete.

**D. Efek Penggunaan Limbah Terumbu Karang pada Komposit Beton (Fauzan & Suciati, 2022)**

The title in English is “Effects of Using Coral Reef Waste in Concrete Composites”. In this study discussed the effect of using split 2/3 coral in the Anambas Islands area of the Riau Archipelago Province as a substitute for 100% coarse aggregate in concrete composites on the compressive strength of concrete. In this study using the SNI 03-2492-2002 method by making the test objects printed in cubes measuring 15 cm x 15 cm x 15 cm with the quality of the K300 plan and tested on the $7^{th}$, $14^{th}$, $21^{st}$ and $28^{th}$ days. Testing resulted in the following conclusions.

- Testing the relative density of coral aggregates is 2.59 kg/dm$^3$
- After the research was carried out and the specimens arrived at the age of 28 days, the research resulted in the use of rock as coarse aggregate causing a decrease in the compressive strength of concrete by 62.34% compared to concrete using gravel as coarse aggregate.
- The resulting compressive strength ranges from 11.2 to 11.4 MPa. Therefore, concrete mixed with coral reef can be used for residential buildings, footpaths or small-scale buildings.

**E. Penggunaan Batu Karang, Tanah Sebagai Pengganti Agregat dalam Pembuatan Beton K-175 untuk Bangunan Sederhana (Pangaribuan & Narlis, 2015)**

The title in English is “The Use of Coral, Soil as a Substitute for Aggregate in Making K-175 Concrete for Simple Buildings”. This study discusses the use of local soil and coral materials on Enggano Island, Bengkulu Regency as a substitute for fine aggregate and coarse aggregate. Enggano Island water which is brackish as water in concrete with K-175 quality. The test was carried out using the try and error method and was carried out by making a cube test object (15 x 15 x 15) cm with the proportion or composition of the ingredients 9.220 kg of cement, 5.168 liters of water, 21.497 kg of sand, and 16.274 kg of coral.

- The unit weight test results in a higher density of fine aggregate than coarse aggregate, this indicates that the same volume of fine aggregate has a greater weight than coarse aggregate.
- Testing the relative density of coarse aggregate produces aggregate close to the relative density of light aggregate which has a limit of less than 2.5 gr/cm$^2$

- In the compressive strength test, the compressive strength of concrete aged 28 days was obtained, namely: Test Object 1 of 290.073 kg/cm$^3$. Test Object 2 is 203.17 kg/cm$^3$, and Test Object 3 of 177.773 kg/cm$^3$. Therefore, it can be concluded that the compressive strength is as desired, namely K.175.

## 2.2 Concrete

The word "concrete" is an English word that comes from Latin *concrete* which means "to grow together" or "to combine into one". Concrete is a mixture consisting of Portland cement or other hydraulic cement, aggregate, namely fine aggregate and coarse aggregate, and water in the presence of additional admixtures or without additional admixtures. Concrete is a composite material consisting of a coarse-grained material (fill aggregate) embedded in a hard matrix (cement or binder) that fills the spaces between the aggregate particles and binds them together (Li et al., 2022). Currently the definition of concrete is getting wider, where concrete can be made of various types of cement, aggregates and pozzolanic materials, fly ash, sulfur, fiber and others.

Concrete Mix Design is needed to determine the proportion of each material needed to produce concrete compressive strength according to plan. Mix design is the process of selecting suitable and adequate concrete materials, and determining the proportions of each concrete ingredient to produce concrete that is economical and has good quality. Concrete design must comply with applicable design regulations and procedures. The design regulations and procedures are ASTM, ACI, JIS, or SNI (Indonesian National Standard). The methods that can be used are ACI (American Concrete Institute), SK.SNI-T-15-03 or DoE (Department of Environment) methods and trial and error methods. In designing concrete, there are several criteria that must be met, namely durable, inexpensive (economical), and wear-resistant.

Concrete has several advantages and disadvantages. Some of the advantages of concrete are the availability of basic materials for forming concrete that are more affordable, which can be obtained from the local area, in contrast to steel structures that must be produced in factories, low maintenance requirements, this is because concrete has a fairly high resistance, which is resistant to corrosion, Therefore, it does not need to be painted like steel structures. Some of the disadvantages of concrete are that the concrete that has been made will be difficult to change, the implementation of concrete work requires high accuracy, the concrete structure is heavy making it difficult to move, and the concrete has a large reflectivity.

There are many types of concrete, including the following:

1) Normal Concrete
   Based on (SNI 03-2847-2002) it is called normal concrete when the concrete has a volume weight between 2200 kg/m$^3$ up to 2500 kg/m$^3$ using natural aggregate or manufactured aggregate (stone crusher). Normal concrete made to withstand structural loads generally produces a compressive strength of concrete around 17.5 – 41 MPa. and concrete made to withstand non-structural loads has a compressive strength of less than 17.5 MPa at the age of the 28th day, produce normal concrete, namely portland cement, coarse aggregate in the form of natural gravel or crushed gravel, fine aggregate in the form of natural sand or the result of a stone crusher, and clean water.
2) Lightweight Concrete
   To produce lightweight concrete, lightweight aggregates are also used. Generally, use aggregate from burning shale, clay, slates, slag residue, coal residue, and other volcanic combustion products. Volume weight limit for light aggregate is 1900 kg/m$^3$, with a compressive strength at the 28th day of concrete age greater than 17.2 MPa (Mulyono, 2003). When compared to normal concrete, lightweight concrete is lighter, lightweight concrete is also more economical, and has a high level of fire resistance.
3) Weight Concrete
   Concrete can be categorized as heavy concrete when it has a content weight of more than 2500 kg/m$^3$ and produced by using aggregate with density above normal as concrete filler. Aggregate with a large relative density is needed, usually greater than 4 compared to the ordinary aggregate relative density which is only 2.6. The aggregate contained in concrete, both natural and synthetic aggregates, can reach up to 4485 kg/m$^3$, Concrete with a high weight is usually used for certain purposes such as withstanding radiation, withstanding collisions and others.
4) Mass Concrete
   Mass concrete is concrete in large quantities used for large constructions such as dams, canals, foundations or bridge pile caps and others. Concrete manufacture can use larger rocks than required up to 150 mm, and low slump can reduce the amount of cement. It takes a lot of vibrating tools and manpower in its implementation. Attention needs to be paid to the heat of hydration given the low slump value to prevent cracking. Pouring was done thinly layer by layer for several days. This was done to help overcome the cracks. Pipes were also provided for cold water flow as maintenance.

5) Fiber Concrete

   Fiber concrete is concrete that has fiber added to the mixture. Generally, the fiber used is rods measuring 5-500 µm which can be asbestos fibers, plastic fibers (poly-propylene), or pieces of steel wire. The addition of fiber to concrete aims to increase tensile strength, shear strength, flexural strength, crack reduction ability, shrinkage resistance ability, impact resistance ability, and fire resistance ability concrete. In order that, the quality of concrete also increases.

## 2.3 Structural and Non-Structural Concrete

### 2.3.1 Structural Concrete

Structural concrete generally produces a compressive strength of 17.5 – 40 MPa (Mulyono, 2015). According to SNI 2847-2013, all concrete used for structural purposes including plain and reinforced concrete, then the concrete is categorized as structural concrete. Structural concrete is concrete that is used to withstand loads. Generally, this concrete is used to make buildings, among others:

- Foundation
- Column
- Beam
- Plate

### 2.3.2 Non-Structural Concrete

Non-structural concrete is generally normal concrete without the use of reinforcement or other reinforcements including no additives. The concrete mixes used to produce normal non-structural concrete generally use by volume weight mixes, with a proportion of 1 cement: 2 sand: 3 crushed gravel/gravel (Mulyono, 2015). The compressive strength of non-structural concrete is less than 17.5 MPa at 28 days. Generally, this concrete is used to make buildings among others:

- Work floor and Sports field
- Neighborhood roads, village roads and concrete rabat roads
- Concrete panel fence foundation
- Carport floor and more.

## 2.4 Cement

Cement is a material consisting of a mixture of chemical substances that acts as a binder in concrete, cement also plays a role in filling the voids between coarse aggregate and fine aggregate grains. Because the manufacture of concrete from aggregates bound by hardened cement paste, the quality of concrete can be affected by the quality of cement (Nugraha & Antoni, 2007).

The most widely used cement as a construction material for concrete work is Portland cement. Portland cement is categorized as a hydraulic cement produced by grinding clinker consisting of hydraulic calcium silicate and generally containing one or more forms of calcium sulfate as an adjunct which is milled together with the main ingredient.

Portland cement is categorized into five types, namely:

1) Type I

   Type I Portland cement is used for general buildings that do not require special requirements.

2) Type II

   This type of cement contains high levels of $C_3A$ of not more than 8%, its use requires resistance to sulfate and moderate heat of hydration, this cement is used for building construction and concrete which is in contact with dirty water or groundwater continuously or for foundations embedded in soils containing aggressive water (sulfate salts) and sewage or buildings directly related to the swamp.

3) Type III

   This type of cement has a level of $C_3A$ and $C_3S$, the grains are ground very finely to speed up the hydration process. This type of cement is used in areas with low temperatures, especially in areas with winter.

4) Type IV

   This type of cement has a low heat of hydration $C_3S$ is limited to a maximum of about 35% and the $C_3A$ maximum is 5%. This type of cement is used for large and massive works such as large foundation dams or other large works.

5) Type V

   This type of cement is used for buildings that are in contact with seawater, industrial waste water, buildings that are affected by aggressive chemical gases or vapors, and for buildings that are in contact with groundwater that contains a high percentage of sulfates.

At the same conditions and temperature at the age of 90 days all types of cement will reach 100% strength. Meanwhile, at the age of 28 days, cement will produce different compressive strengths depending on the type of cement used.

## 2.5 Aggregate

Aggregate is a natural mineral in the form of granules, which functions as a filler in a mixture of concrete or mortar. Aggregate fills the concrete with a percentage ranging from 60%-70% by weight of the concrete. In the concrete mix using aggregates can be natural aggregates or artificial aggregates. Generally based on its size, aggregate can be divided into two types, namely fine aggregate and coarse aggregate.

Fine aggregate and coarse aggregate have different limitations between disciplines, the size limit between the size of coarse aggregate and fine aggregate is 4.8 mm according to the British Standard or 4.75 mm according to the ASTM Standard. Aggregate whose grain size is greater than 4.8 mm (4.75 mm) is categorized as coarse aggregate and aggregate whose grain size is smaller than 4.8 mm (4.75 mm) is categorized as fine aggregate. Fine aggregate is divided into several categories, namely fine sand when the grain size is smaller than 1.2 mm, silt when the grain size is smaller than 0.075 mm, and clay when the grain size is smaller than 0.002 mm. Aggregate whose grain size is larger than 4.8 mm is further divided into two, namely concrete gravel when the aggregate diameter is between 4.8-40 mm and coarse gravel when the diameter is greater than 40 mm.

In the concrete mix usually use aggregate smaller than 40 mm. While those that are larger than 40 mm are used for other civil works, such as road construction, retaining embankments, gabions, dams and others. Usually, the fine aggregate is called sand and the coarse aggregate is called gravel, split, and crushed gravel.

### 2.5.1 Fine Aggregate

Based on (SNI 1970-2008), Fine aggregate is natural sand produced from the natural disintegration of rocks or in the form of crushed sand originating from the stone crushing industry. Sand has a grain size of 0.15 mm to 5 mm. In the concrete mix, use sand which must meet the following paragraphs:

1) The grain fines modulus should be 2.3 to 3.1
2) Mud content or parts smaller than 70 microns or 0.074 mm (sieve No.200) in weight percent maximum.
    - In concrete that has an abrasion of 3%
    - In other types of concrete by 5%
3) The maximum content of clay particles and clumps that are easily tidied up is 3%
4) Charcoal and lignite content
    - Maximum 0.5% where visible concrete surface is considered important (concrete will be exposed).
    - Maximum 1% for other types of concrete.
5) The organic matter content was determined by mixing the coarse aggregate with $NaSO_4$ (sodium sulfate) of 3% produces a color that is not darker than the standard color. If the resulting color is darker then it is rejected except for the

following provisions:

- The appearance of a darker color due to the presence of little lignite charcoal or the like
- When tested with a comparison test of concrete compressive strength made with standard silica sand the results showed a value greater than 95%.

6) Should not be reactive to alkalis when used for concrete in contact with wet and damp or in contact with materials that are active towards alkali cement, where the use of cement containing not more than 0.6% sodium oxide.
7) The stability of the sand when tested with sodium sulfate is a maximum of 15%, and a maximum of 10% when tested with magnesium sulfate.
8) Based on (ASTM C-33), the requirements are as shown in the following table, where fine aggregate may not contain more than 45% of the part that passes through one set of sieves and is retained on the next sieve.

Table 2.1 Grading of Fine Aggregate Sieve

| Sieve Hole (mm) | Grain weight passing through the sieve (%) | | | |
|---|---|---|---|---|
| | Rough | A bit rough | A bit smooth | Smooth |
| 10 | 100 | 100 | 100 | 100 |
| 4.8 | 90-100 | 90-100 | 90-100 | 95-100 |
| 2.4 | 60-95 | 75-100 | 85-100 | 95-100 |
| 1.2 | 30-70 | 55-90 | 75-100 | 90-100 |
| 0.6 | 15-34 | 35-59 | 60-79 | 80-100 |
| 0.3 | 5-20 | 8-30 | 12-40 | 15-50 |
| 0.15 | 0-10 | 0-10 | 0-10 | 0-15 |

*(Source : Tjokromuljo in Silalahi, 2021)*

Before being used for mixing concrete, fine aggregate must be tested first, this is done to determine the properties contained in the fine aggregate. In this study, fine aggregate testing will be carried out, including:

a) Sand Sieve Analysis Test

$$\text{Percentage of Retained} = \frac{\text{Retained Sand Weight}}{\text{Initial Sand Weight}} \times 100\% \quad \text{........} \quad 2.1$$

b) Sand Volume Weight Test

$$\text{Volume weight} = \frac{(\text{Cylinder Weight+Sand Weight})\text{-Cylinder Weight}}{\text{Volume Cylinder}} \quad \text{........} \quad 2.2$$

c) Sand Moisture Test

$$=\frac{\text{Wet Sand Weight-Oven Dry Sand Weight}}{\text{Weight of Oven Dry Sand}}\times 100\% \quad (2.3)$$

d) Sand Absorption Test

$$=\frac{\text{Sand Weight SSD-Oven Dry Weight of Sand}}{\text{Oven Dry Weight}}\times 100\% \quad (2.4)$$

e) Test Weight Type of Sand

$$\text{Type Weight}=\frac{\text{W3-W1}}{(\text{W5+W2})\text{-W4}} \quad (2.5)$$

Information: W1 = Weight of Pycnometer
W2 = Weight of SSD Sand
W3 = Weight of Sand + Pycnometer
W4 = Weight of Pycnometer + Sand + Water
W5 = Weight of Water + Pycnometer

f) Sand Volume Development Test

$$=\frac{\text{V1(Initial Sand Volume)-V2 (Volume of sand in water)}}{\text{V2 (Volume of sand in water)}}\times 100\% \quad (2.6)$$

g) Test Cleanliness of Coarse Aggregate Against Mud with Dry Method

$$=\frac{\text{Mud Sediment Height}}{\text{Sand Sediment Height}}\times 100\% \quad (2.7)$$

### 2.5.2 Coarse Aggregate

Coarse aggregate is gravel produced from the natural disintegration of rock or in the form of crushed gravel originating from the stone-breaking industry, coarse aggregate having a grain size between 4.75 mm (sieve No.4) to 40 mm (sieve No.1½ inches) (SNI 1970-2008). Based on its relative density, coarse aggregate is divided into 3 types, namely:

1) Normal Aggregate
Normal aggregate is an aggregate that has a relative density between 2.5 and 2.7 grams/cm$^3$. Normal aggregates are produced from breaking rock by quarrying or directly from natural sources. Normal aggregates usually come from granite, basalt, quartz, and others.
2) Lightweight Aggregate
Lightweight aggregate to make lightweight concrete. It is called light aggregate when the specific weight of the aggregate is less than 2 grams/cm$^3$. Lightweight aggregates are commonly used to make non-structural concrete
3) Heavy-weight Aggregate
Aggregate with a relative density of more than 2.8 gram/cm$^3$ categorized as heavy aggregate. The concrete produced has a high relative density of up to 5 grams/cm$^3$. Usually used as a protective wall or X-ray radiation.

To make a concrete mix, use coarse aggregate which must meet the following requirements:

a) The grain size of the coarse aggregate must be greater than 5 mm
b) Fineness modulus of coarse aggregate between 6 to 7.1
c) Maximum mud rate 1%
d) The hardness of the coarse aggregate is tested using a Los Angles machine where the loss in weight does not exceed 50%.
e) Must not be active against alkalis, substances that can damage concrete.
f) Does not contain flat and long grains of more than 20% of the total weight.
g) Coarse aggregate must consist of a variety of grains and when sifted, must meet the requirements such as the residue above the 31.5 mm sieve must be 0%, the residue above the 4 mm sieve must range between 90-98%, the difference between the cumulative sieve is a maximum of 60% and a minimum of 10 %.

The sieve grade proportion requirements for concrete mixtures are as follows:

Table 2.2 Coarse Aggregate Sieve Grade Table

| Sieve Diameter (mm) | Percentage of Passed Grains | | |
|---|---|---|---|
| | Maximum 10 mm | Maximum 20 mm | Maximum 40 mm |
| 75 | | | 100 – 100 |
| 37.5 | | 100 – 100 | 95 – 100 |
| 19 | 100 – 100 | 95 – 100 | 35 – 70 |
| 9.5 | 50 – 85 | 30 – 60 | 10 – 40 |
| 4.75 | 0 – 10 | 0 – 10 | 0 – 10 |

(*Source: SNI 03-2834-2000*)

Before being used for mixing concrete, coarse aggregate must be tested first, this is done to determine the properties contained in the coarse aggregate to be used. In this study, coarse aggregate testing will be carried out, including:

- Coarse Aggregate Sieve Analysis Test

$$\text{Retained Percentage} = \frac{\text{coarse agg. Weight Retained}}{\text{initial Gravel Weight}} \times 100\% \quad \text{.................................} \; 2.8$$

- Coarse Aggregate Volume Weight Test

$$\text{Volume weight} = \frac{\text{(Cylinder Weight+Gravel Weight)-Cylinder Weight}}{\text{Volume Cylinder}} \quad \text{.........................} \; 2.9$$

- Coarse Aggregate Relative Density Test

  Type Weight $= \frac{W1}{W1-(W3+W2)-W4}$ .............................................................. 2.10

  Information : W1 = Gravel Weight
  W2 = Weight of Gravel in Water
  W3 = Basket Weight
  W4 = Weight of Basket in Water
- Coarse Aggregate Moisture Test

  $= \frac{\text{Weight of Wet Gravel-Weight of Oven Gravel}}{\text{Weight of Oven gravel}} \times 100\%$ .......................................... 2.11
- Coarse Aggregate Water Absorption Test

  Absorption $= \frac{\text{SSD Gravel Weight-Oven Dry Gravel Weight}}{\text{Dry weight of Oven Gravel}} \times 100\%$.......................... 2.12
- Test the Mud Rate of Coarse Aggregate by dry method

  $= \frac{\text{Gravel Weight Before Washing-Gravel Weight After Washing}}{\text{Gravel Weight Before Washing}} \times 100\ \%$ ........................ 2.13
- Coarse Aggregate Toughness/Abrasion Test

  $= \frac{\text{Initial Gravel Weight-Retained Gravel Weight No. Sieve. 12}}{\text{Initial Gravel Weight}} \times 100\%$ ........................... 2.14

## 2.6 Water

To trigger the chemical process of cement as an adhesive, water is needed. In general, potable water can be used in concrete mixes. The quality of concrete will decrease or even change in character when using water containing harmful compounds, which is contaminated with salt, oil, sugar or other chemicals. The ratio of water to cement which is called the Water Cement Factor (water cement ratio) is very important because the cement paste itself is the result of a chemical reaction between cement and water. The amount of water needed for the cement hydration process must be sufficient, if there is too much water in the concrete mixture it will result in lots of water bubbles after the hydration process is complete, whereas if the water is too little it will cause the hydration process not to be fully achieved in order that it will affect the compressive strength of the concrete.

To make a concrete mixture, water must meet the following requirements:

- Water must be clean, colorless and odorless.
- Does not contain mud, oil, and other floating objects that can be seen visually. The substance cannot be more than 2 grams/liter.
- Does not contain more than 15% of salts which can dissolve and damage concrete, for examples acids, organic substances, and others.
- Does not contain more than 0.5 gram/liter of chloride
- Does not contain more than 1 gram/liter of sulfate compounds.

## 2.7 Coral reefs

The skeletons of tiny animals known as corals or rocks make up natural coral reefs (education.nationalgeographic.org/reef, accessed in 2024). Hard corals or reef-building corals that can produce calcium carbonate are the type of corals responsible for making reefs. Seawater is the source of calcium carbonate, which hard corals use to form a strong, protective exoskeleton for their soft, sac-like bodies (www.livescience.com/coral-reefs, accessed in 2024). The dead coral reefs will be carried by the waves to several locations on the beach and over time will form a pile of coral fragments.

Figure 2.1 Coral Reefs

*(Source: Wikipedia.org/coral reefs, accessed in 2024*)

Figure 2.2 Dead coral from Kampung Lobuk

(*Source: Author, 2024*)

According to Yamin (2011) aggregates originating from coral reefs have the largest chemical content in the form of CaO, in order that they are included in the limestone rock group. Hendra in Kurniawan et al. (2016) has conducted research on the composition of chemical compounds contained in coral reefs. Analysis of chemical compounds produces the following table.

Table 2.3 Coral Chemical Compound Composition

| No. | Parameter | Amount (%) |
|---|---|---|
| 1 | $SiO_2$ | 2.37 |
| 2 | $MgO_2$ | 24.80 |
| 3 | $Fe_2O_3$ | 0.24 |
| 4 | $Na_2CO_3$ | 1.27 |
| 5 | $CaCO_3$ | 73.76 |

(*Source: Hendra in Kurniawan et al., 2016*)

Coral reefs contain $CaCO_3$ If the rock is very large. Then the rock is classified as limestone (limestone).

## 2.8 Slump

Slump concrete is the viscosity or plasticity and cohesiveness of fresh concrete. The slump test has the objective of monitoring the homogeneity and workability of fresh concrete mix with a certain thickness expressed by the slump value (SNI-1972-2008). Based on SNI-1972-2008, the slump value can be calculated using the equation below:

$$\text{Slump Value} = H1\text{-}H2 \quad \text{...... } 2.15$$

Where:

H1 = Height of slump tool

H2 = Height of concrete after settlement

## 2.9 Unit Weight

A unit weight test is carried out to determine the value of the relative density of the concrete to be used. Based on SNI 1973-2008, unit weight is the weight per unit volume which is calculated using the following formula:

$$D=\frac{M_c-M_m}{V_m} \quad \text{...... } 2.16$$

Where:

D = Unit weight (kg/m$^2$)

$M_c$ = Weight of measuring container filled with concrete (kg)

$M_m$ = Weight of measuring container (kg)

$V_m$ = Volume of the measuring container ($m^3$)

## 2.10 Water Absorption

To find out the water content or how much the absorption rate is in the concrete test object, a water absorption test is carried out. To find out the water content in concrete, it can be calculated using the formula based on SNI 03-6433-2000 as follows:

$$\text{Absorption} = \left(\frac{B\text{-}A}{A}\right) \times 100\% \quad \text{......................................} \ 2.17$$

Where:

A = Weight of dry test object (g)

B = Weight of the test object after immersion (g)

## 2.11 Concrete Compressive Strength

The quality of a structure is identified by the compressive strength of concrete. If the desired structural strength is higher, the quality of the concrete produced will also be higher. The compressive strength of concrete is the ability of the specimen to withstand loads with a certain force applied by the compression testing machine until the specimen is crushed. The following is the formula for determining the compressive strength value based on SNI 1974:2011 on concrete:

$$\text{Concrete compressive strength} = \frac{P}{A} \quad \text{.............................} \ 2.18$$

Where:

P = Axial compressive load

A = Cross-sectional area of the test object

The unit for compressive strength of concrete (MPa) or ($N/mm^2$)

The cross-sectional area of the test object has units ($mm^2$)

Unit for compressive load (N)

In order to produce a required average compressive strength, the proportion or composition of the concrete must be designed. At the construction implementation stage, the concrete mixture that has been designed must be produced in such a way as to minimize the frequency of occurrence of concrete with a compressive strength lower than the required f'c. There are a number of factors that can affect the compressive strength of concrete, including:

1. Cement Water Factor
   The water-cement factor is the ratio of water to cement. In planning concrete mixes, the water-cement factor is a very important indicator, this is because cement paste itself is the result of a chemical reaction between cement and water. It is generally known that the higher the water-cement factor value, the lower. However, this does not necessarily mean that the lower the water-cement factor value, the stronger the concrete will be. A low water-cement factor value will cause difficulties in carrying out compaction in concrete work and will eventually reduce the quality of the concrete. In general, the minimum value of the water-cement factor is about 0.4 and the maximum value is 0.65.
2. Cement Type
   When the concrete is 90 days old, all types of cement under the same conditions and temperature will reach 100% strength. At the age of 28 days, cement will produce different compressive strengths depending on the type of cement used.
3. Aggregate
   The decrease in concrete compressive strength can be caused by changes in grade without changing the maximum size of coarse aggregate and water-cement ratio. Therefore, the consistency of the use of grading in accordance with the provisions of the concrete mix design must be maintained routinely against irregularities.
4. Water
   A decrease in compressive strength can occur due to the use of less clean water. Therefore, it is necessary to check the chemical content in the water first or to do a test to find out whether the water to be used in the concrete mix is appropriate or not.
5. Additional Materials
   Materials added to the concrete mixture in the form of powder or liquid are called added ingredients. The purpose of adding additives is to change the properties of the concrete mix to make it suitable for certain jobs and save costs. The effect of additives on the strength of concrete depends on the type of additives.
6. Concrete Treatment (Curing)
   After the concrete has reached its final setting, which means the concrete has hardened, curing is carried out by placing the concrete in a pool filled with water. This treatment is carried out in order that there is no disturbance in the subsequent hydration process. If this happens, the concrete will crack due to

the rapid loss of water. This concrete treatment aims to obtain high compressive strength in concrete, to improve the quality and durability of concrete, impermeability to water, resistance to wear, and stability of the dimensions of the structure.

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