# CHAPTER III

# BASIC THEORY

## 3.1 Concrete

Concrete is a building material that widely used. To construct buildings, bridges, highways and so forth, concrete is the required main materials. Making concrete is by mixing gravel or so-called coarse aggregate, sand or commonly known as fine aggregate, cement and water. All materials are stirred and mixed into one. Usually concrete is also added with other additives ingredients either chemically or physically. When all the material has been mixed, there will be a hardening process that occurs due to a chemical reaction between cement and water.

The good fresh concrete is concrete that can be stirred, can be transported, poured, can be solidified. There is no tendency for separation of gravel from the mixing and the separation of water and cement mixture. The good hard concrete is concrete that is strong, durable, waterproof, resistant to wear, and little change in volume (Tjokrodimulyo, 1996).

According Tjokrodimuljo, 1996; concrete has advantages and disadvantages. The advantages of concrete are as follows:

a. Concrete is able to resist the compressive strength, as well as having characteristic that resistant to corrosion and decay by environmental conditions.

b. Fresh concrete can easily be printed. The mold can also be used repeatedly, so it is more economical.
c. Fresh concrete can be sprayed on the surface of the cracked old concrete that cracked and can be fed into the concrete cracks in the repair process.
d. Fresh concrete can be pumped, making it possible to construct in difficult position.
e. Concrete is wear-resistant and fire-resistant, so the treatment is cheaper.

On the other hand, concrete also has disadvantages. Below are the disadvantages of concrete.

a. Concrete is considered unable to resist tensile force, so it is easy to crack. Therefore, it needs a reinforcement steel.
b. Hard concrete shrinks and expands when the temperature changes, so expansion joint needs to be made to prevent the occurrence of cracks due to temperature changes.
c. To get a perfectly watertight concrete, the making process must be done carefully.
d. Concrete that brittle (not ductile) should be examined carefully so after composited with the reinforcing steel it becomes ductile, especially on earthquake-resistant structures.

## 3.2 <u>Concrete Material</u>

Concrete is a structure element that has characteristic and constituent from materials, such as:

### 3.2.1 Portland Cement

Cement is one of the materials used to make concrete. If the cement react with water, it will make the concrete hard. There are many types of cements that divided by level of needs. One type of cements used in the construction process is Portland cement. Portland cement itself subdivided into five types.

Portland cement is hydrolase cement produced by grinding the Portland cement slag that consist of silicate calcium that has hydrolase characteristic, and grinding with one or more additional materials that have sulfate calcium crystal form and can be added with other material (SNI- 15-2049-2004).

Cement has several types based on its functions. The type of cement base on its function are as below.

1. Type I is Portland cement for general use and does not require any special requirements as required in other types.
2. Type II is Portland cement requiring the resistance towards sulfate or medium hydration heat.
3. Type III is Portland cement requiring the high resistance in the beginning state after the bond happens.
4. Type IV is Portland cement requiring the low hydration heat.
5. Type V is Portland cement requiring the high resistance toward sulfate (SNI-15-2049-2004).

The properties of Portland cement can be seen at Table 3.1.

Table 3.1 Portland cement materials

| **Materials** | **Percentage (%)** |
|---|---|
| Lime (CaO) | 60-65 |
| Silica ($SiO_2$) | 17-25 |
| Alumina ($Al_2O_3$) | 3.0-8.0 |
| Iron ($Fe_2O_3$) | 0.5-6.0 |
| Magnesia (MgO) | 0.5-4.0 |
| Sulphur ($SO_3$) | 1.0-2.0 |
| potash ($Na_2O$+$K_2O$) | 0.5-1.0 |

Source: *Tjokrodimuljo, 2009*

### 3.2.2 Water

Water and cement will react chemically so that the concrete becomes hard, easy to working and compact. The water used for concrete mixture must be clean and chemical free to make sure no contamination from other materials that can be reduced the quality of concrete mixture.

Water as the mixture to make concrete must fulfill the minimum requirement, but it does not mean that water as mixture must qualify as drinking water. According to Tjokodimuljo, 2007, the use of water as concrete mixture must fulfill the requirements as below.

a. Water must be clean

b. Water does not contain mud, oil, other flying things and not exceed 2 gram/liter

c. Water does not contain sodium that can be dissolved and can destroy the concrete, acid, organic substance more than 15 gram/liter

d. Water does not contain chloride or Cl > 0.5 gram/liter

e. Water does not contain sulfate substance > 1 gram/liter

### 3.2.3 Aggregate

Aggregates are granular materials, such as sand, gravel, crushed stone and slag furnace flare used together with a media binder to form a concrete or mortar hydraulic (SNI 03-2847 - 2002 Planning Procedures for Concrete Structure for Building), there are two types of aggregates, fine aggregate and coarse aggregate.

Aggregate is natural mineral gradation that has function as concrete mixture. 70% volume of concrete is aggregate. Even though it is just mixture, but it has important role toward the concrete characteristic. Therefore, the selection of the aggregate is important (Tjokrodimuljo, 2007).

#### 3.2.3.1 Coarse Aggregate

Coarse aggregate or called gravel is the result of natural des-integrase from rocks or in the form of crushed stone obtained from the quarry with a grain size more than 5 mm. Gravel, in its use, must meet the following conditions:

a. Grains of hard non-porous and its eternal meaning not broken due to weather influences, such as sun and rain.
b. Mud should be less than 1%; when exceeding, it must be washed before using.
c. It must not contain substances that could damage the rock; one example is reactive substance, such as alkali.
d. Coarse aggregate with grained flat can only be used if the amount does not exceed 20% of the overall weight.

The aggregate gradation is aggregate size distribution. When a grain aggregate has the same size (uniform), the volume of pore will be large. Conversely, if the size of the grains varies, the volume of the pore will be small. This is because the small grains fill the pores between the large grains, through just little pores.

According to SNI-03-2834-2000 (Procedure for Making Plans Mixed Concrete Normal), the gradation of coarse aggregate can be seen in Table 3.2.

Table 3.2 Coarse Aggregate Gradation

| Sieve size | | | | % Pass the sieve | | |
|---|---|---|---|---|---|---|
| mm | SNI | ASTM | inch | Max size 10 mm | Max size 20 mm | Max size 40 mm |
| 75 | 76 | 3 in | 3 | | | 100 - 100 |
| 37.5 | 38 | 1.5 in | 1.5 | | 100 - 100 | 95 - 100 |
| 19 | 19 | 3/4 in | 0.75 | 100 - 100 | 95 - 100 | 35 - 70 |
| 9.5 | 9.6 | 3/8 in | 0.375 | 50 - 85 | 30 - 60 | 10 - 40 |
| 4.75 | 4.8 | no. 4 | 0.187 | 0 - 10 | 0 - 10 | 0 - 5 |

**3.2.3.2 Fine Aggregate**

According to Neville (2003), fine aggregate is the aggregate with size not more than 5 mm. So, sand is include in fine aggregate. It can be either natural sand or sand from the quarry produced by rock breaker. The terms of fine aggregates in general according to SNI 03-6821-2002 are as follows:

a. Fine aggregate composed of grains of sharp and hard.
b. Fine grains are eternal, not broken or destroyed by the effects of the weather. The eternal nature of fine aggregate can be tested with a

saturated solution of salt. If used sodium sulfate maximum destroyed part is 10% by its weight.

c. Fine aggregate should not contain more than 5% mud (on dry weight); if the levels of mud exceed 5%, the sand must be washed.

According to SK SNI T-15-1990-03, sand roughness can be divided into four groups according to gradation, namely:

Zone 1 = rough sand

Zone 2 = rather coarse sand

Zone 3 = rather fine sand

Zone 4 = fine sand

The gradation of fine aggregate can be seen in Table 3.3.

Table 3.3 Sand Gradation Boundary Condition

| sieve hole (mm) | Comulative Passing Weight (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Zone 1 | | Zone 2 | | Zone 3 | | Zone 4 | |
| | bottom | above | bottom | above | bottom | above | bottom | above |
| 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 4.8 | 90 | 100 | 90 | 100 | 90 | 100 | 95 | 100 |
| 2.4 | 60 | 95 | 75 | 100 | 80 | 100 | 95 | 100 |
| 1.2 | 30 | 70 | 55 | 100 | 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 |

In this research, the author wanted to replace fine aggregate in the form of sand with red tile waste aggregate.

## 3.3 Self-Compacting Concrete

Self-Compacting Concrete (SCC) is a concrete able to flow by itself and can be print on the formwork with or without vibrator. This concrete mixed leverage the aggregate size, aggregate portion and van admixture superplasticizer to achieve the specific viscosity that allows it to flow on their own without the vibrator. Once poured into a mold, the concrete can flow by itself and fill all space following the principle of gravity, including the casting of concrete with very narrow reinforcement steel. This concrete will flow into all the gaps in the casting place by utilizing its own weight of concrete mix.

According to Hela and Hubertova (2007) the ability to flow with the level of resistance to high segregation on Self Compacted Concrete is caused by two key recipe as follows:

a. The use of superplasticizer is adequate with a very strict set of aggregate composition of the mixture.
b. Water-cement ratio (w / c-ratio) is low by controlling the aggregate volume combined with 0,125 mm aggregate filler causing the concrete mix not prone to segregation.

On the composition of the concrete mix, the main difference between Self Compacting Concrete and conventional concrete is the large enough filler portion, approximately 40% of the total volume of the concrete mix. The filler material is fine-grained sand with a maximum grain size (dmax) ≤ 0.125 mm. The large portion causes the filler material mixed concrete tends to behave as a paste.

The adequate Superplasticizer usage, usually from polycarboxylate, allows the water consumption in the mixture to be reduced, but the reduction of workability and flow ability concrete mix can be maintained. Other additional filler materials used to produce Self Compacted Concrete are fly ash, silica fume, slag (blast furnace slag), metakaolin and others.

Mix design for self-compacting concrete must able fulfill the filling ability, passing ability and segregation resistance. Filling ability is the ability of self-compacting concrete to flow and fill overall the mold part by its own weight. Passing ability is the ability of self-compacting concrete to flow and pass the gap between the steel reinforcement or the narrow gap without segregation or blocking. Segregation resistance is the ability of the concrete to keep the composition still homogeny, during transportation until casting the concrete.

### 3.3.1 SCC Mix

SCC mix has several advantages, such as:

1. In terms of durability
   a. Homogenates increase of concrete
   b. Well reinforcement wrapping
   c. Low porosity
2. In term of productivity
   a. Fast to casting
   b. Easy to pump
   c. Not necessary anymore to compact

3. In term of labor
    a. Human error due to imperfect compacting; it can be in eliminate
    b. Minimized labor accident rate
    c. No noise pollution due to the vibrator.

### 3.3.2 SCC Requirement

Testing fresh concrete properties of self-compacting concrete types is carried out on three characteristics. There are flow ability/filling ability, viscosity, and passing ability by using several standard measurement tools, such as: Slump Flow, T500 Slump Flow, L-Shaped Box, J-Ring, and V-Funnel (EFNARC, 2002 and 2005).

According to The European Guidelines for Self-Compacting Concrete, SCC concrete testing requirement using several measuring devices are as follows (see Table 3.4):

Table 3.4 Self Compacting Concrete Requirement

| Test | Method | Unit | Limitations | |
|---|---|---|---|---|
| | | | Minimum | Maximum |
| Filling ability | Slump flow | mm | 550 | 850 |
| | V-funnel | second | 6 | 12 |
| Passing ability | L-shaped box | h2/h1 | 0.8 | 1 |
| | J-ring | mm | 0 | 10 |
| Viscosity | $T_{500}$ slump flow | second | 2 | 5 |
| | V-funnel | second | 0 | 25 |

## 3.4 Red Tile

Tile is an element of a building that serves as a roof. It is made of clay or without a mixture of other materials, and burned at high temperatures, so it cannot be destroyed when immersed in the water. The clay has the mineral silica and alumina so that when the clay is combusted at a particular temperature it will harden. The red tile waste can be used as fine aggregate to make concrete. However, before using it as concrete mixture, the tile fragment must be pounded first to get the fine aggregate size, less than 5 mm, and still retrained in sieve number 200.

Red tile compound from clay that combust with 1000°C temperature, so it is classified as earth ware. The chemical composition of the clay can be seen in Table 3.5.

Table 3.5 Chemical Composition in Clay

| No | Chemical Element | Total (%) |
|---|---|---|
| 1 | $SiO_2$ | 59.24 |
| 2 | $Al_2O_3$ | 15.34 |
| 3 | $Fe_2O_3 + FeO$ | 6.88 |
| 4 | CaO | 5.08 |
| 5 | $Na_2O$ | 3.84 |
| 6 | MgO | 3.49 |
| 7 | $K_2O$ | 1.13 |
| 8 | $H_2O$ | 1.15 |
| 9 | $TiO_2$ | 1.05 |
| 10 | others | 2.9 |

(Source:http://axzx.blogspot.com/2008/12/proses-pembentukan-tanah-liatsecara.html engkel keramik PPG Kesenian Jogja)

Red tile waste can become the substitution of normal aggregate, totally or partially. The value of concrete compressive strength with red tile fragment as aggregate with various percentage variation of normal aggregate is as much as 60% - 100% from compressive strength with normal aggregate. The red tile aggregate has high water absorption. Therefore, when mixing with the concrete, it will harden quickly after few minutes. To overcome this problem, red tile waste aggregate must be under SSD condition before using (As'ad and Agustina, 2012).

## 3.5 Viscocrete

Superplasticizer is chemical admixture type F (water reducing high range admixture) having the influence to increase the workability of concrete. Other alternative is this chemical addictive can be used to increase the concrete strength because it can be reduce the water consumption to keep the same workability (Murdock and Book, 1986).

Sika Viscocrete-10 is superplasticizer having brownish white color and can work with many different mechanisms. This superplasticizer is suitable for concrete mix needing long transport time and high workability. The advantage of Viscocrete-10 can reduce the water consumption until 30% (PT. Sika Indonesia, 2007).

### 3.5.1 Sika Viscocrete-10 Application

1. Concrete with water reduction in large amount (until 30%)
2. Concrete with high ability
3. Concrete in high weather needing long transport time and high workability
4. Watertight concrete
5. Ready mix concrete
6. Self-Compacting Concrete (SCC)
7. High strength concrete
8. Mass concrete

### 3.5.2 Advantages of Sika Viscocrete-10

1. The reduction of water in large amount will produce concrete with high density, high strength concrete and reduce permeability.
2. The effect of good water reduction will produce the good workability, easy to cast and curing. That is why it is suitable to use in self-compacting concrete.
3. It reduce the shrinkage and crack.
4. It reduce carbonation.
5. It increase the water proofing.

## 3.6 Workability

One of concrete characteristic before it hardens (fresh concrete) is workability. Workability is the level of ease to produce the concrete, such as mixing, stirring, pouring to mold and compaction without reducing homogenates of the concrete. In addition, there is no bleeding to achieve the desired concrete strength.

Characteristic of workability:

1. Mobility, easiness of concrete to flow into the mold.
2. Stability, ability of concrete mix to keep homogeny, coherent, and there are no segregation and bleeding.
3. Compatibility, ability of concrete mixing to compact, so the air pore can reduce.
4. Finishibility, easiness of concrete to achieve the final stage that is harden with good condition.

The elements that influence the properties of workability, are as follows:

1. The amount of water to make the mixing concrete. The more water used, the easier fresh concrete to make.
2. The increase of cement to the concrete mixing, it will make the work of mortar concrete easier, because the increasing of cement will affect the increase of water to make water cement ratio stable.
3. The gradation of fine and coarse aggregate. If the gradation of fine and coarse aggregate follow the gradation's requirement advised by the rules, then the concrete will be easy to make.
4. The using of round aggregate. It will ease the making of concrete.
5. The use of maximum gradation of coarse aggregate. It will affect the ease level to make concrete.
6. The different characteristics determined by the way to compact the mixing concrete. If the compaction is done with vibrator, it will need the different workability. Therefore, the amount of water is less if comparing with manual compaction (Tjokrodimuljo, 1996).

## 3.7 Segregation

The tendency of coarse grains to be separated from the concrete mix is called segregation. This will cause the gravel nests on the concrete. Eventually, it will lead to porous concrete (Mulyono, 2004).

Segregation is caused by several things, such as:

1. The mix concrete that has less cement,
2. Too much water,

3. The gradation of coarse aggregate, more than 40 mm, and
4. Too rough aggregate coarse grain surface.

The tendency for this segregation can be prevented by:

1. The shortened high falls,
2. The using of water follow the requirement,
3. Enough space between reinforcement and references,
4. The size of aggregate that follows the requirement, and
5. Well compaction.

## 3.8 <u>Bleeding</u>

The tendency of water to rise to the surface at the newly compacted concrete is called bleeding. The water will rise to bring cement and fine grains, which at the time of the hardened concrete will form a membrane (laitance) (Mulyono, 2004). Bleeding is influenced by:

1. The composition of the grain aggregate. If the composition is follow the requirement, the possibility of bleeding will be small,
2. Too much water. It will lead to bleeding,
3. Hydration speed. The faster the concrete hardens, the smaller the occurrence of bleeding,
4. Excessive compaction process. It will cause bleeding.

Bleeding can be reduced by:

1. Giving a lot of cement,
2. Using little water as possible,
3. Using more refined grains,

4. Putting a bit of air in the mortar for special concrete.

## 3.9 Slump Flow

Slump flow value is used to measure the level of workability of mix concrete. The greater slump flow value, the more watery and easier concrete to work with. Conversely, the smaller the value of slump flow, the more viscous and more difficult concrete to make. Slump flow value varies between 600-725 mm (Lisantono, 2009).

According to Dehn, et al (2000), self-compacting concrete (SCC) requires good flow ability of the fresh concrete with a slump-flow value at a minimum of 60 cm and a very high general slump value achieved by SCC concrete (more than 20 cm). Figure 3.1 shown the procedure of slump flow test.

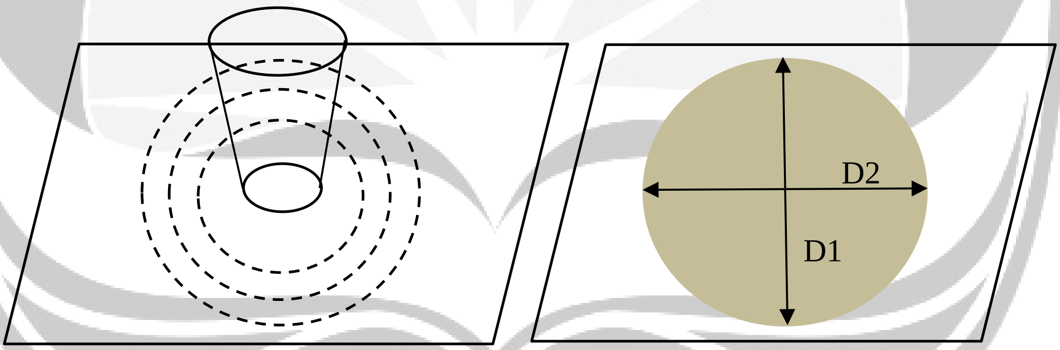


Figure 3.1 Slump Flow Test

## 3.10 L-shaped Test

In this research to test the slump value, the author used L-shape flow test. According to State of the Art report of RILEM technical Committee 174-SCC, the result of L-shaped flow test is well corresponded to the result of the slump flow test, i.e. reflecting the deformation capacity. The descent of the sample head has similar physical meaning with the slump value (descent of the sample head in the slump flow test or the slump test). In other words, the slump flow test evaluates the 2-dimentional flow-ability of sample concrete under free condition and this type of L-shaped flow test evaluate the one-dimensional flow-ability under directionally restrained condition.

However, if that the sample concrete has strong tendency, segregate and/or the amount of coarse aggregate in the mixture is relatively large. Therefore, it is possible that the concrete flowing is stopped by the blocking at the open gate. When this phenomenon occurs, the result of the L-flow value does not correspond to the result of the slump flow. L-shaped box shown in Figure 3.2.

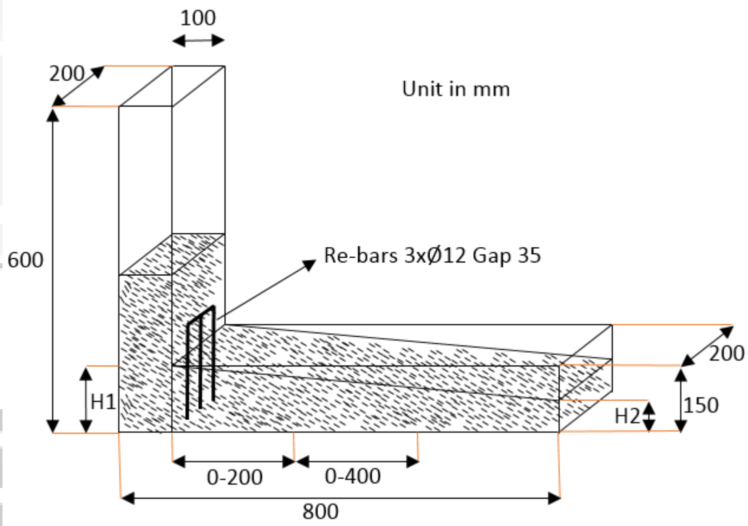


Figure 3.2 L-shaped Box

### 3.11 Concrete Age

The compressive strength of concrete improves with the increasing age of the concrete. Concrete strength will rise rapidly (linear) until the age of 28 days, but the increasing will be small after that. The compressive strength of concrete in some cases will continue to grow until a few years in advance. Usually the compressive strength of concrete plans is calculated at 28 days. For structures that require high initial, the mixture is combined with a special cement or chemical added with additive while using this type of cement type I (OPC-1). The rate of increase in the concrete depends on the use of constituent materials. The most important thing is the use of cement because cement tends to directly improve the performance of compressed (Mulyono, 2004).

Meanwhile, according to Tjokrodimuljo (2007), concrete compressive strength increases with age. What it means here is the age calculated from the concrete began to pour in the mold. The rate of increase in compressive strength of concrete at first is rapid, and then will be slower and the rate of increasing will be relatively small after 28 days. As standard concrete compressive strength (if not mentioned specifically age) is the compressive strength of concrete at 28 days.

The rate of increase in concrete is influenced by several factors: the type of Portland cement, concrete circumference temperature, water-cement ratio and other factors similar to the factors that influencing the compressive strength of concrete. The relationship between age and the compressive strength of concrete can be seen in Table 3.6.

Table 3.6 Concrete Compressive Strength Ratio at Different Age

| Concrete Age | 3 | 7 | 14 | 21 | 28 | 90 | 365 |
|---|---|---|---|---|---|---|---|
| General Portland cement | 0.4 | 0.65 | 0.88 | 0.95 | 1 | 1.2 | 1.35 |
| Portland cement with high strength at initial | 0.55 | 0.75 | 0.9 | 0.95 | 1 | 1.15 | 1.2 |

Source: PBI 1971, NI-2, in Tjokrodimuljo, 2007

## 3.12 Concrete Compressive Strength

The compressive strength of concrete is the ability to receive a compressive force per unit area. The strength of concrete identifies the quality of a structure. The higher the strength of the desired structure, the higher the quality of concrete produced (Mulyono, 2004).

The compressive strength of concrete obtained from standardized testing with specimen commonly used are cylindrical. The dimension of the specimen is 300 mm for its height and 150 mm for its diameter. The commonly used procedure for testing is the standard ASTM C39-86. Compressive strength of each specimen is determined by the highest compressive stress (fc'), which reached specimen 28 days due to the compressive load during experiment (Dipohusodo, 1996). The cylinder specimen shown in Figure 3.3.

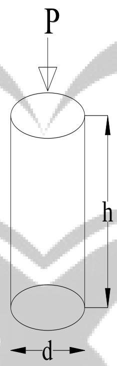


Figure 3.3 Cylinder Specimen

The formula used in the equation (3-1) to get the value of concrete compressive strength based on laboratory experiment are as follows (Antono, 1995):

$$fc' = \frac{P}{A} \tag{3-1}$$

where:

*fc'* = compressive strength (MPa)

P = load (N)

A = area of the specimen ($mm^2$)

Concrete will have a high compressive strength if composed with local materials having good quality. Concrete compiler material needing attention is the aggregate, because the aggregate reaches 70-75% of the concrete volume (Dipohusodo, 1996). Therefore, the aggregate strength influences on the strength of concrete. Thus, the things that need to be considered in the aggregate are:

a. surface and form of aggregates,
b. aggregate gradation, and
c. maximum size of aggregate.

### 3.13 Concrete Modulus of Elasticity

Different from steel, modulus of elasticity of concrete varies according to strength. Modulus of elasticity also depends on the age of the concrete, the properties of aggregates and cement, loading speed, type and size of specimen. Usually modulus compressive at 25% to 50% of the compressive strength (fc') is taken as the modulus of elasticity (Wang dan Salmon, 1986).

According with SK SNI T-15-1990-03 Section 3.1.5, use the formula modulus of elasticity of concrete as follows (Dipohusodo, 1996).

$$Ec = 4700 \times \sqrt{fc'} \qquad (3\text{-}2)$$

where:

Ec = modulus of elasticity (MPa)

fc' = concrete compressive strength (MPa)

## 3.14 Concrete Modulus of Rupture (Flexural Strength)

Beam flexural strength is the value of tensile stress resulting from the bending moment divided by the cross section of specimen holder moment. Beam flexural strength is an important factor in determining the mechanical properties and characteristics of the concrete itself. The components affecting the strength of concrete are water cement ratio, the degree of density, concrete age, type of cement, the amount of cement and aggregate quality.

Distance from the sides of the beam until the end of the beam is very important to determine the formula used. One of method that used to test the flexural strength of the beam is a beam bending test with one loading point. Beam sample can be seen in Figure 3.4 and simple beam flexural strength was calculated by the following equation:

$$\sigma = \frac{3\,P\,L}{2\,b\,h^2} \tag{3-2}$$

where:

σ = flexural strength (MPa)

P = maximum load that resulted in the collapse of the beam specimen (N)

L = span length between the two beams pedestal (mm)

b = average width of the beam cross-section collapses (mm)

h = average high beams at the cross collapse (mm)

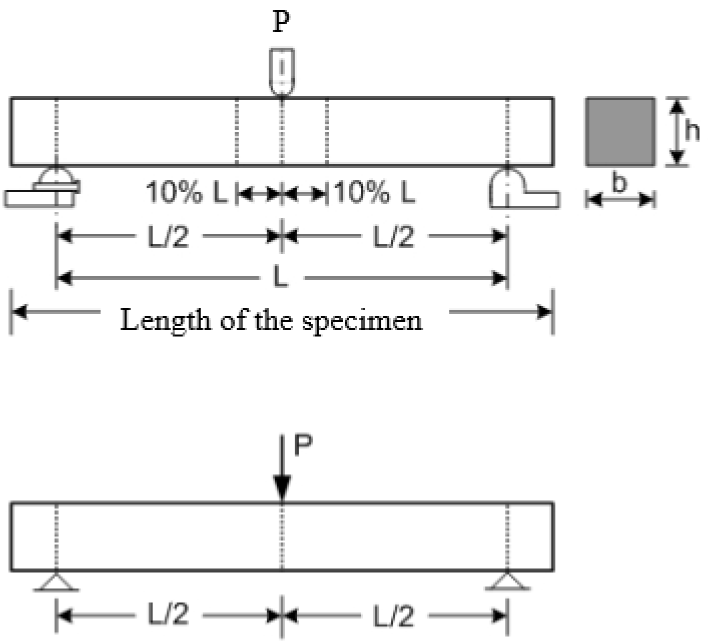


Figure 3.4 Beam Sample

Where:

b = 100 mm

h = 100 mm

L = 450 mm