CHAPTER I
INTRODUCTION

1.1. Background of Plant Design

Indonesia as a developing country is actively doing development in all fields in order to improve the standard of living of society, according to the ideals of the noble ideals of the nation that is just and prosperous society. One of the most expected development areas to replace the nation is the field of economy, and one of the economic fields is the industrial sector. This can be proved by the increasing number of development throughout the archipelago, both in rural and urban areas. With the increasing of physical development in Indonesia, hence requirement of cement and other building material like wallboard also increase. Required fountains and building materials in the manufacture of cement and building materials in the manufacture of wallboard.

Gypsum requirement in Indonesia is fulfilled with domestic production and import from abroad. Domestic gypsum production is still not sufficient to meet the needs of gypsum in Indonesia. Therefore, imports from foreign countries are still needed. By establishing the gypsum industry in Indonesia, it is expected to meet the needs of gypsum in Indonesia. Calcium sulfate dihydrate (gypsum) with the molecular formula CaSO4.2H2O is the most widely used materials as raw materials and auxiliaries in various types of industries.

Lateefee yangok
D500112001
Universitas Muhammadiyah Surakarta
Therefore, the gypsum plant needs to be established in Indonesia with the following considerations:

1. Can save the country's foreign exchange, with the gypsum factory in the country it can meet the needs of gypsum in the country so that imports can be reduced and if excess can be for export.
2. The process of technology transfer, with the existence of high technology industry is expected to increase the workforce of Indonesian workers, skills and skills so as to reduce dependence on foreign workers.
3. Opening employment around established industrial areas.
4. As a supplier of raw materials for the domestic industry using gypsum as raw materials and auxiliary materials so as to spur the development of industries using gypsum.

Based on the above considerations, the gypsum plant with limestone and sulfuric acid raw materials is expected to have good prospects.

1.2. Selection of Plant Capacity

The capacity of the industry is a very important factor in the establishment of the plant as it will affect the technical and economic calculations. Although theoretically, the greater the capacity of the plant, the more likely the profits will be gained, but in the determination of capacity it is also necessary to consider other factors, namely:

1.2.1. The Projection of Import Gypsum Demand.

Gypsum consumption is expected to increase per years. Based on the data demand import of gypsum from the BPS and the gypsum plant in Indonesia, the gypsum requirement is as follows:
1. The Import of Gypsum Demand In Indonesia

<table>
<thead>
<tr>
<th>No</th>
<th>Year</th>
<th>Capacity (Ton/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1995</td>
<td>230,180</td>
</tr>
<tr>
<td>2</td>
<td>1996</td>
<td>332,303</td>
</tr>
<tr>
<td>3</td>
<td>1997</td>
<td>513,604</td>
</tr>
<tr>
<td>4</td>
<td>1998</td>
<td>582,127</td>
</tr>
<tr>
<td>5</td>
<td>1999</td>
<td>507,791</td>
</tr>
<tr>
<td>6</td>
<td>2000</td>
<td>546,721</td>
</tr>
<tr>
<td>7</td>
<td>2001</td>
<td>1,036,124</td>
</tr>
<tr>
<td>8</td>
<td>2002</td>
<td>772,131</td>
</tr>
<tr>
<td>9</td>
<td>2003</td>
<td>660,491</td>
</tr>
<tr>
<td>10</td>
<td>2004</td>
<td>991,296</td>
</tr>
<tr>
<td>11</td>
<td>2005</td>
<td>962,282</td>
</tr>
<tr>
<td>12</td>
<td>2006</td>
<td>1,008,425.80</td>
</tr>
<tr>
<td>13</td>
<td>2007</td>
<td>1,188,047.68</td>
</tr>
<tr>
<td>14</td>
<td>2008</td>
<td>1,326,157.12</td>
</tr>
<tr>
<td>15</td>
<td>2009</td>
<td>962,723.19</td>
</tr>
<tr>
<td>16</td>
<td>2010</td>
<td>1,162,038.86</td>
</tr>
<tr>
<td>17</td>
<td>2011</td>
<td>1,533,424.50</td>
</tr>
<tr>
<td>18</td>
<td>2012</td>
<td>1,843,285.63</td>
</tr>
<tr>
<td>19</td>
<td>2013</td>
<td>1,966,207.01</td>
</tr>
<tr>
<td>20</td>
<td>2014</td>
<td>2,017,705.83</td>
</tr>
</tbody>
</table>

(BPS, 2014)
Graph 1.1 The Import Gypsum Demand in Indonesia

From the data of gypsum demand in Indonesia at the table above, will be obtained by the equation:

\[ y = mx + c \]

when from the graph

\[ y = \text{the capacity of gypsum} = 82,795x -2E+08 \]
\[ x = \text{different of year} \]
\[ m = \text{gradient} = 82,795 \]
\[ c = -2E+08 \]

So, that can be calculated the amount of gypsum demand in Indonesia at 2030 year.

\[ y = 8,2795x -2E+08 \]
\[ x = 2030-1995 = 35 \]

so, \[ y = 2, 897, 817 \text{ ton/year} \]

So that the demand of gypsum at 2030 year is 2, 897, 817 ton.
2. The List of Gypsum Plant in Indonesia

Table 1.2 The Plant of Gypsum in Indonesia

<table>
<thead>
<tr>
<th>No</th>
<th>Name of Plant</th>
<th>Capacity (Ton/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PT Smelthing Gresik, East Java</td>
<td>270,000</td>
</tr>
<tr>
<td>2</td>
<td>PT Siam Gypsum Cibitung, West Java</td>
<td>36,000</td>
</tr>
<tr>
<td>3</td>
<td>PT Tidar Jaya Magelang, Central Java</td>
<td>200,000</td>
</tr>
</tbody>
</table>

While the gypsum plant which has been established in abroad is Ukraina state production capacity reached 40,000 tons/year, Algeria country about 150,000 tons / year and Saudi Arabia reach 400,000 tons / year.

1.2.2. The Price Comparison

From the alibaba.com we can get the comparation price between the raw material and the product.

Table 1.3 The Price of Raw Material and Product.

<table>
<thead>
<tr>
<th>No</th>
<th>Material</th>
<th>Price ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CaCO₃</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>H₂SO₄</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>Gypsum</td>
<td>600</td>
</tr>
</tbody>
</table>

1.2.3. Availability of Raw Materials

The raw material to produce of gypsum (calcium sulfate dihydrate) are limestone and sulfuric acid. Limestone is a raw material obtained from PT. Bukit Batu Semesta that located at Payukumbuh, West of Sumatra. The production capacity of this plant are 2,500-3,500 tons/month with large 100 hectares of mine area (PT. Bukit Batu Semesta, 2015). While the sulfuric acid obtained from PT. Mahkota Indonesia that located in Pulo Gadung- Kelapa of Gading, North of Jakarta production capacity of 600,000 tons/year. Based on the data availability of raw materials, gypsum demand at The Central Bureau of Statistics (BPS), comparation of raw material and product, and plant...
capacity that have operated in Indonesia, so gypsum (calcium sulfate dehydrate) plant using limestone and sulfuric acid will be built at 2019 of year with capacity of 150,000 tons/year.

1.3. Selection of Plant Location

Selection of plant location is very important to establish of the plant, because it is directly related to the economic value of plant.

Based on several considerations, the gypsum plant will be established at Indarung City, West of Sumatra with the considerations are:

1.3.1. Primary Factors

The factors are directly affect to main process and economic value of plant operation. Primary factors are included:

a. Market Location

Indarung is a city passed a major transportation lines and near to other plant and building company like PT. Semen Padang and Universitas Sumatra Utara about 15-20 km. So that the market of gypsum product are placed. Supported by adequate transport is also close to the marketing area thus simplifying the distribution of the product.

b. Location of Raw Material Resource

The raw materials are limestone obtained from PT. Bukit Semesta that located about 50-100 km from Indarung City.

c. Transportation

The transportation at this location is easy to obtained by ship, bus and plant. Transportation used to support of this plant such as product sales, transporting raw materials by land and sea freight transport is sufficient.

d. Labor

The establishment of plant in this country will be created a new jobs to society so that will reduce the unemployment and pressing urbanization.

e. Utility
The water demand is main subject to support operation on this plant as water treatment that used as water process, drinking water, steam and other. So, we can obtained the water from Indarung River. While electricity can be supply from PLN that located over there.

1.3.2. Secondary Factors

Factors that are not directly involved in the process industry, but very influential to smooth the process construction of this plant.

Secondary factors are:

a. Expansion Area of Plant.

The expansion of plant location in this city is still allowed.

b. Permitting

The plant site selected in special areas for industrial areas, so as to facilitate permitting the establishment of the plant.

c. Infrastructure and Social Facilities

Infrastructure such as roads and other transport should be available, as well as social facilities as a means of education, worship, entertainment, banks and housing so as to improve the welfare and standard of living around the factory area.

1.4. The Process Selection

1.4.1. Kind of Process

1. Preparation of Gypsum from Rock

   The process of making gypsum from rock is by destroying the rocks gypsum obtained from mountain areas. Destruction of this rocks using a primary crusher. Then the rocks have to mesh to obtain a smooth stone. The process of destruction of rocks gypsum and meshing is done by several times to obtain the desired results. After meshing, the rocks is put into slink float to clean the stones from the dirty and then put into the secondary crusher that rocks from the dirty that has not been refined can be destroyed again and partly can into the fine grinding for milled into a fine grain.

   After fine grinding of grains are refined in calcination, the product will be produces board plaster, and part of this product after calcination will be enter into the ball mill to produce bagged plaster. This process, if viewed from the economic aspect is not favorable because it requires huge investment costs that are used for the mining process (Faith et al, 1957).

2. Preparation Gypsum from Limestone

   In this process, limestone (CaCO₃) is reacted with dilute sulfuric acid (H₂SO₄) in the reactor at the operating conditions of temperature at 93 °C and pressure at 1 atm. The resulting product from the reactor is then sent into a separator to remove its impurity.

   The reaction was as follows:

   \[
   \text{CaCO}_3 (s) + \text{H}_2\text{SO}_4 (l) + \text{H}_2\text{O} (l) \rightarrow \text{CaSO}_4.2\text{H}_2\text{O} (s) + \text{CO}_2 (g)
   \]

   Limestone    Sulfuric Acid    Water    Gypsum    Carbon Dioxide

   (US Patent 6,613,141 B2)
3. Preparation of Gypsum from CaCl$_2$ and H$_2$SO$_4$

This process is done by inserting CaCl$_2$ into the reactor with added H$_2$SO$_4$ at 50 °C - 80 °C and a pressure of 1 atm. Inside of the reactor occurs the neutralization reaction that produces CaSO$_4$ and HCl with the conversion reached 100%.

The reaction was as follows:

\[
\text{CaCl}_2 + \text{H}_2\text{SO}_4(\text{l}) \rightarrow \text{CaSO}_4(\text{s}) + 2\text{HCl}(\text{l})
\]

Calcium Chloride \quad Sulfuric Acid \quad Calcium Sulfate \quad Hydrochloric Acid

The separation process of CaSO$_4$ and HCl using absorber of CaSO$_4$ of vapor solution to produce CaSO$_4$.2H$_2$O then put in the dryer so that can produce gypsum with purity of 91% (Kirk & Othmer, 1978).

Before determining the choice of proper process is need for a study comparative to several alternative processes both from the technical and economic aspects.

**Table 1.4 Selection Process Based Technical and Economic**

<table>
<thead>
<tr>
<th>No</th>
<th>Parameter</th>
<th>Process I</th>
<th>Process II</th>
<th>Process III</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technical Aspects</td>
<td>Gypsum Rock</td>
<td>CaCO$_3$ and H$_2$SO$_4$</td>
<td>CaCl$_2$ and H$_2$SO$_4$</td>
</tr>
<tr>
<td></td>
<td>- Raw Material</td>
<td></td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>- Energy Consumption</td>
<td>Little</td>
<td>About 91 - 92%</td>
<td>About 90 %</td>
</tr>
<tr>
<td></td>
<td>- Purity of Product</td>
<td>Depend on Raw Material</td>
<td>Very big and easy to obtained</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Inventories of raw materials</td>
<td>Limited Source</td>
<td></td>
<td>Difficult to obtained</td>
</tr>
<tr>
<td>2</td>
<td>Economic Aspect</td>
<td>Big</td>
<td>Moderate</td>
<td>Big</td>
</tr>
<tr>
<td></td>
<td>- Investasion</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Aspects

Lateefee yangok
D500112001
Universitas Muhammadiyah Surakarta
From the table above, the best and most efficient in terms of technical and economical is the establishment of gypsum plant is by the second steps because the raw materials used accessible and plentiful.

1.4.2. Product Uses

The usefulness of gypsum in the industrial world as follows:

a. To soils either as a source of nutrients or to modify and improve soil properties.
b. The primary use of gypsum is for building materials (such as plaster and wallboard). For construction purposes, gypsum is ground and heated (calcined) to remove most of the bound water, resulting in hemi-hydrate plaster (plaster of Paris)
c. Ceiling tiles, paints, joint compound
d. Calcined gypsumused as plaster
e. plasterof Paris and Plaster board
f. Stucco additive
g. Cement
h. Kitty Litter
i. Animalbedding
j. Dietary supplement in foods for nutrition or a flavor additive that controls tartness in wines.
k. Water treatment
l. Sludgedrying for stability and odor control
m. Cementproduction (reduce setting time)
n. Flea powder- Recycled gypsum makes up over 90% of the inert ingredients in flea powders.
1.5. Theory Description

1.5.1. Physical and Chemical Properties

a. Raw Material

1. Calcium Carbonate

- Physical Properties.
  - Molecule Structure : CaCO$_3$
  - Phase : Solid
  - Composition :
    - CaCO$_3$ : 97.89%
    - MgCO$_3$ : 0.95%
    - SiO$_2$ : 0.36%
    - Al$_2$O$_3$ : 0.17%
    - Fe$_2$O$_3$ : 0.25%
    - CaSO$_4$ : 0.08%
    - H$_2$O : 0.3%

- Chemical Properties
  - It is not flammable and stable.
  - Can be obtained naturally in the form of minerals such as limestone.
  - Represents a precipitate which can be obtained from the reaction between calcium chloride and sodium carbonate.

\[ CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl \]

- React with water

\[ CaCO_3 + 2H_2O \rightarrow Ca(OH)_2 + H_2O + CO_2 \]

- React with sulfuric acid and make free of CO$_2$

\[ CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2 \]

(Patnaik, 2002)
2. Sulfuric Acid

- **Physical Properties**
  - Molecular Structure : $\text{H}_2\text{SO}_4$
  - Molecular Weight : 98.08 (g/mol)
  - Phase : Liquid
  - Density : 1.837 g/cm$^2$
  - Boiling point : 338 °C
  - Specific gravity : 1.834

(Perry & Green, 1999)

- **Chemical Properties**
  - Reaction with base can formed salt and water.
    
    $\text{H}_2\text{SO}_4(\text{l}) + 2\text{NaOH}(\text{s}) \rightarrow \text{Na}_2\text{SO}_4(\text{s}) + \text{H}_2\text{O}(\text{l})$
  - Reaction with alcohol can formed ether and water.
    
    $2\text{C}_2\text{H}_5\text{OH}(\text{l}) + \text{H}_2\text{SO}_4(\text{l}) \rightarrow 2\text{C}_2\text{H}_5\text{OH}(\text{l}) + \text{H}_2\text{O}(\text{l}) + \text{H}_2\text{SO}_4(\text{l})$
  - Corosif with all of metals
  - React with NaCl formed NaSO$_4$
    
    $\text{NaCl} + \text{H}_2\text{SO}_4(\text{l}) \rightarrow \text{NaSO}_4 + 2\text{HCl}$
  - React with MgCO$_3$ will be formed MgSO$_4$
    
    $\text{MgCO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{l}) \rightarrow \text{MgSO}_4(\text{s}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

(Perry & Green, 1999)
b. Product

Gypsum

- Physical Properties
  - Molecular formula: CaSO$_4$.2H$_2$O
  - Molecular weight: 172.17
  - Phase: White powder
  - Purity: 92%
  - Specific gravity: 2.32 – 2.96
  - Mohs hardness: 1.5-2.0
  - Water content: 8 %

  (Kirk-Othmer, Jed, Vol 24, 1978)

- Chemical Properties
  - At temperature 170°C will be forming anhydrate

  \[
  \text{CaSO}_4.2\text{H}_2\text{O}_{(s)} + \text{heat} \rightarrow \text{CaSO}_4.\frac{1}{2}\text{H}_2\text{O}_{(s)} + \frac{3}{2}\text{H}_2\text{O} \text{ (steam)}
  \]

  (www.wikipedia.org)

1.5.2. General Description Process

Gypsum is production from the reaction between limestone (CaCO$_3$) with sulfuric acid solution (H$_2$SO$_4$) 50% of weight in Continuous Stirred-Tank Reactor (CSTR) with the general reaction as follows like below:

\[
\text{CaCO}_3 (s) + \text{H}_2\text{SO}_4 (l) + \text{H}_2\text{O} (l) \rightarrow \text{CaSO}_4.2\text{H}_2\text{O} (s) + \text{CO}_2 (g)
\]

(US Patents 6,613,141 B2)