Pile defect quality control analysis on construction company in East Java

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Abstract. A production process has a possibility of product defects; the types of defects commonly found in pile products are porous concrete defects, dented joint plate defects, pile dimensions deviation defects, etc. The defect of the product needs to be controlled because it can cause losses to the company. Therefore, in this study, data processing was conducted on pile defect products using statistical process control. An analysis was then performed using the Pareto Chart to determine the types of defects that occur most often. After that, identifying the problems causes that occur in terms of man, machine, method, materials, money, and environment by using fishbone diagrams; so that recommendations for improvement can be given to the company. The results showed that, based on the Pareto principle, 80% of the defects types that occur include the type of porous concrete defects, the type of dented sheath plate defects, and types of joint plate dimension defects. The type of defect with the highest frequency is a porous concrete defects type. Recommendations for improvement that can be given include providing training to workers, maintaining machinery, improving product quality, and providing alternative electrical energy sources.

Keywords: quality control, product defects, piles, statistical process control.

1. Introduction
A company engaged in the field of construction has one of the products produced, namely piles. Pile foundation is part of the structure used to receive and transfer (distribute) the load from the upper structure to the supporting soil, located at a certain depth [1]. A production process has a possibility of product defects, which need to be controlled because it can cause losses. Defective products that occur require a process of repair, and this drives a greater cost [2,3]. When defective products reach consumers, most quality costs increase replacement costs due to complaints made [4]. The innovation of the product is also needed to maintain company capability in the competition [5]. Returned products are usually reworked or modified. This will also result in product sales, which will be influenced by the company's quality costs [6].

Therefore, in this study, data processing was carried out on pile defect products using Statistical Process Control. Statistical Process Control (SPC) is a method that can be used to control a sustainable production process and identify any unusual issue in the production process [7-9]. Some method like brainstorming to catch the cause of the problem for the critical to the product’s
quality is essential to build any improvement plan [10,11]. The results of the analysis conducted by SPC in the future can be used as a basis for measuring the products or services’ current quality and analyzing the existence of a variable in the production of goods or services experiencing changes that will affect quality [12,13]. Another use of SPC is to collect and analyze the sample’s monitoring results during the product’s quality control activities [14]. Some tools used to support SPC include the Pareto chart to determine the types of defects that occur most often. After that, identifying the causes of problems that occur is conducted using fishbone diagrams so that later improvements can be given to the company.

2. Material and Method

2.1. Material
This research was conducted at a construction company located in East Java. The company has several production lines, namely lines 1 to 6, and pile products are produced in lines 1, 2, and line 5. The data used are data of pile product defect produced at production line 1. The collection of the data had the purpose of finding the possible causes of the problem. Brainstorming and field analysis is the way used to generate information related to the problem.

2.2. Method
Statistical Quality Control using the SPC method can use seven main statistical tools that can be used to assist the quality control process. Quality control tools include check sheets, histograms, control charts, Pareto diagrams, fishbone diagrams, scatter diagrams, and process diagrams [14]. In this study, the quality control tools used are Pareto diagrams, control charts, and fishbone diagrams. The steps performed in this study are as follows:

a. Identify the visual types of defects on the defect pile, and brainstorm with the technical and quality responsible for Plant 1.

b. Construct a Pareto chart. Pareto chart is a bar chart that illustrates data with the highest percentage value to the lowest. Pareto charts are methods of organizing defectives, problems, or defects to assist focus on problem-solving efforts. Through the Pareto chart, we can find out the types of dominant defects that occur. An example of a Pareto chart is shown in Figure 1 below.

![Figure 1. Pareto Diagram](image-url)

Constructing a control chart, the p-chart is used to determine how big the proportion of defectives or defects in the sample or sub-group, or each time observations are performed [16]. The p-chart is used to determine whether the defects of the pile product produced are still within the required proportions or not. The following is the formula used in processing the P-chart [17].

\[
p = \frac{\sum d_i}{\sum n_i} = \frac{\sum n_i}{n_m}
\] (1)
Where:
\[ \bar{p} \] = the center line represents the proportion of defectives
\[ D_i \] = The proportion of defectives in each sample or sub-group in each observation
\[ N \] = sample size taken in each of observation performed
\[ UCL \] = Upper Control Limit
\[ LCL \] = Lower Control Limit

Possible causes for a problem /problems that occur [18]. In this study, fishbone diagrams are used to find the root causes of specific causes of defects in piles, which consist of 5M and 1E analysis, namely Manpower, Machine, Method, Materials, Money, and Environment. This stage is the final step to determine improvement recommendations given to companies based on an analysis of the causes of the previous defects. The figure of the fishbone diagram is shown in Figure 2.

![Fishbone Diagram](image)

### Figure 2. Fishbone Diagram

### 3. Result and Discussion

#### 3.1. Result

The result obtained from the analysis is about the types of defects. The following are types of defects that can occur in pile products, and descriptions of each type of defect are shown in table 1. Strengthen the analysis, and there are also provided with the pictures of each defective product. Analyzing table 1, known that there is two major types of defect consist of variable and attribute. Considering 15 types of defects mentioned in Table 1, only two attribute defects consist of thin concrete and thick waste.
| No | Defect Types                                      | Picture |
|----|--------------------------------------------------|---------|
| 1  | Oval concrete/ corrugated visual inside/poor/thin | ![Picture](image1.jpg) |
|    | Description                                      | Oval visual inside, some of the pile inner diameter is thin and in the other part it thickens. |
| 2  | Hollow fin                                       | ![Picture](image2.jpg) |
|    | Description                                      | There are raffia or sponges in the fins or the side of the pile; it is where the upper and lower molds meet, so that it is cavities. |
| 3  | Porous fin                                       | ![Picture](image3.jpg) |
|    | Description                                      | The fins are where the upper and lower molds meet. Porous fins are parts of the fins that are not dense or have chip-off parts caused by water from the cement coming out so that there is no glue between the split. |
| 4  | Blow holes concrete                              | ![Picture](image4.jpg) |
|    | Description                                      | Blow holes concrete is a condition where there are air bubbles because the compaction process when spinning is less than perfect. |
| 5  | Broken/crack/chip-off/porous shoes               | ![Picture](image5.jpg) |
|    | Description                                      | Broken/crack/chip-off/porous shoes is a defect caused by shoe diameter dimensions being smaller/larger and less precise, or because the shoe storage time is less than 3 days before use. |
| 6  | Porous in connecting plate bolt-hole             | ![Picture](image6.jpg) |
|    | Description                                      | Porous in connecting plate bolt-hole is a condition where the bolt-hole is not fully filled by a slurry so that the inner part is porous. This is caused by a long slurry waiting time or because |
| No | Defect Types               | Description                                                                                                                                 |
|----|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| 7  | Thin concrete +/- 1 cm    | Thin concrete is a condition where the slurry inside diameter is uneven with the inner diameter of the connecting plate, this is caused by the pouring slurry is not suitable with the specifications. |
| 8  | Joint plate/dented sheath | Joint plate/dented sheath occurs because of improper tensile strength during stressing process.                                              |
| 9  | Framework Stickiness      | Framework stickiness is a condition where cement paste sticks to the framework.                                                              |
| 10 | Thick waste >10cm         | Thick waste is a condition where a dimension is measured on the inside of the pile, the inside diameter of the pile is greater than the diameter in the joint plate. This is because the waste is not completely disposed of. |
| 11 | Porous edge of the sheath plate | Porous edge of the sheath plate is a condition where porous concrete on the edge of the sheath plate.                                        |
| 12 | Broken heading            | Broken Heading is a condition where the head of the PC bar is disconnected from the PC bar. This is because the length of the pc bar is cut unevenly so that the shorter part receives a greater tensile load. |
No | Defect Types | Picture
--- | --- | ---
13 | Thick concrete (>\(+\)-1cm) | ![Picture](image)

Description
Thick concrete is a condition where the diameter of the pile exceeds the diameter of the joint plate. This is because the volume of the slurry is excessive or because of worn out dart root.

14 | Porous concrete | -

Description
Porous concrete is a condition where the concrete parts that do not blend well or porous on the inside, it is because the slurry is too dry when poured into the framework.

15 | Porous fins at segment joint | -

Description
Porous fins at segment joint due to uneven framework lip or it is not tightly closed.

Calculation example:
1. Percentage calculation of porous concrete defects.
   a. Defect percentage
      
      \[
      \text{Defect percentage} = \left( \frac{\text{Frequency of defect}}{\text{Total frequency of defect}} \right) \times 100\%
      \]
      
      \[
      = \frac{5}{8} \times 100\%
      \]
      
      = 53%

2. Percentage calculation of cumulative defects
   a. Percentage of dented joint plate
      
      \[
      \text{Percentage of dented joint plate} = 20\%
      \]

   b. Percentage of cumulative defect of dented joint plates
      
      \[
      \text{Percentage of cumulative defect of dented joint plates} = \text{Percentage of porous concrete defects} + \text{Percentage of joint plate defects}
      \]
      
      \[
      = 53\% + 20\%
      \]
      
      = 73%

The pile produced by the company is 71,423 units. Throughout the year, several types of product defects occur. The following is a recapitulation of defective product data in the company's pile production process shown in table 2. Based on table 2, it can be known the types of defects that often occur in the process of producing piles in the company. To determine the type of defect that has a significant effect, a Pareto chart is made. Pareto charts are also used to show the problem from the highest priority to the lowest priority to determine the problem that must be addressed first. Problems that must be immediately addressed are problems from highest to lowest frequency and reaching 80% of the existing problems. The following is a Pareto chart of pile product defects types in the company shown in figure 3.
Table 2. Data on pile defect products

| No | Defect Types         | Frequency | Defect Percentage | Cumulative Defect Percentage |
|----|----------------------|-----------|------------------|-----------------------------|
| 1  | Porous concrete      | 8         | 53%              | 53%                         |
| 2  | Dented joint plate   | 3         | 20%              | 73%                         |
| 3  | Pile dimension       | 2         | 13%              | 87%                         |
| 4  | Framework stickiness | 1         | 7%               | 93%                         |
| 5  | Chip-off             | 1         | 7%               | 100%                        |
| 6  | Pile straightness    | 0         | 0%               | 100%                        |
| 7  | Fin width            | 0         | 0%               | 100%                        |
| 8  | Crack                | 0         | 0%               | 100%                        |
| 9  | Sign                 | 0         | 0%               | 100%                        |
| 10 | Joint plate position | 0         | 0%               | 100%                        |
| 11 | Pile shoe position   | 0         | 0%               | 100%                        |
| 12 | Pile shoe joint      | 0         | 0%               | 100%                        |
|    | **TOTAL**            | **15**    | **100%**         |                             |

Figure 3. Pareto Diagram of pile defects

Based on Figure 3, it can be seen that the most dominant type of defect to fulfill the Pareto chart principle is 80% due to 20% caused. There are three types of defects, including porous concrete, dented sheath plate, and pile dimensions. The type of porous concrete defects consists of 53%; the type of dented plate defect consists of 20%, and the type of pile dimensions defects consist of 13%. Thus, the three types of defects are added to 86%. This type of defect is a type of defect that must be tackled first to avoid any loss due to defective products.

3.2. Control chart analysis

a. Porous Concrete Defects Type

The proportion of porous concrete defects in November is above the control proportion because the value exceeds the upper control proportion of 0.000524, and the lower control proportion is
0, while the value of the defect proportion is 0.00118, so the data needs to be deleted and recalculate the UCL, CL and LCL values to revise control chart. After the calculation is revised, the UCL, CL, and LCL values are obtained. UCL value after revision is 0.00045, CL value after revision is 0.00009 and LCL value after revision is 0. After that, a control chart is made with the revised control limit so that the proportion of defect data from January to December (after November is deleted) is within the control limits, which means there is no data out of control. The influence of common causes fluctuations or variations in data. The control chart of porous defect proportions before and after revision can be seen in Figure 4.

![Figure 4. Control Chart of Porous Defects Proportion before (a) and after revision (b)](image)

b. Dented Joint Plate Defects Type

In the dented joint plate defects type, the data proportion of defects in January to December is within the control limit. The plate defect control limits include a UCL value of 0.00031, CL value of 0.00004, and LCL value of 0. Data on the proportion of defects is between the upper and lower control limits, which means there is no out of control data. The influence of common causes fluctuations or variations in data shown on the control chart of Dented Joint Plate Defect Proportion can be seen in Figure 5.

![Figure 5. Control chart of Dented Joint Plate Defect Proportion](image)
c. Pile Dimension Defects Type
In pile dimension defects Type, defect proportion data in January to December is within the control limits. The dented sheath plate defect control limits include a UCL value of 0.000249, CL value of 0.00003, and LCL value of 0. Data on the defects proportion is between the upper and lower control limits, which means there is no out of control data. The influence of common cause’s fluctuations or variations shown at the control chart of Pile Dimension Defects Type can be seen in Figure 6.

![Figure 6. Control chart of Pile Dimension Defects Type](image)

3.3. Fishbone diagram
A Fishbone diagram is constructed to determine the root causes that cause defective products. The following is a fishbone diagram of a pile defect in the company. The following is a fishbone diagram of a pile product defect in the company that can be seen in Figure 7. The fishbone analysis mentions four major causes of defective problems: man, machine, method, and material. Man, perspective gives information that human morals become a significant factor influencing the product defect. Careless, ignore the procedure, and fatigue is the factor that influences how the human does the job. Machine perspective mention that the failure of the process caused by the lifetime of the component. This cause informs that there are need some improvements related to maintenance or component replacement procedure. Last, for the method and material perspective, there are need to add some standard operating procedure to ensure that the material used in the process fulfill the requirement.

4. Conclusion
Based on the results of the analysis conducted in this study, several conclusions were obtained, namely:

1. Considering historical data of pile defect products in the company, can be seen that 80% of the defects types that occur include porous concrete defects, dented plate defects, and dimensional plate defects. The type of defect with the highest frequency is a type of porous concrete defects.

2. Recommendations for improvements that can be given is giving training programs for workers, checking every production process, maintaining machine maintenance periodically, ensuring the length of the PC bar cuts according to specifications, matching the slurry composition according to company capability and needs, slurry composition refers to predetermined specifications, tightening incoming quality inspections, carrying out work following work instructions, collaborating raw materials following customer requests, providing generators for anticipating power outages and designing a comfortable work environment.
Figure 7. Fishbone diagram of a pile product defect
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