Application of life cycle cost in the construction of soil retaining wall replacing soldier pile with diaphragm wall (case study of Pejaten Apartment Projects)

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Abstract. In order to obtain efficient design, stable and optimal with a good characteristic of quality, one of the techniques that can be convinced is called life cycle cost. Life cycle cost is a process of determining the amount of costs related to an asset, including initial costs, maintenance costs, and repair costs. It was found that both relationships were significant and positive. The purpose of life cycle cost is to get the saving cost and time efficiency, which does not rule out its function and quality. In this life cycle cost analysis, the diaphragm wall is selected to replace the soldier pile. The cost savings obtained are 23% of the initial cost of the soldier pile’s retaining wall work. The process of diaphragm wall is a lot faster 2-3 times than the work of soldier pile retaining wall. Based on the results of the initial costs and maintenance costs, it can be interpreted that the method of diaphragm wall can allow much greater savings than using the soldier pile retaining wall method.

1. Introduction
In Indonesia, especially Jakarta, many tall buildings function as offices, hotels, and apartments. These tall buildings have basements. In the process of making a basement, there will be a process of excavating land which is the first step in the establishment of a tall building. The constraints faced in the basement excavation work are factors in the collapse of the vertical ground wall and the emergence of groundwater to the surface in the excavation. In the implementation of basement construction, three important things need to be considered, namely the construction method, retaining wall and dewatering. Basement constructions usually use a retaining wall that functions to keep the soil stable and not erupt or protected from erosion and to resist the lateral active force of soil or water. Retaining wall is used due to limited land so it is not possible to do an open cut method. Soil retaining walls either diaphragm walls or soldier piles function the same are built to hold the mass of land on the structure or building to be made. Different types of retaining walls depend on the planner and the availability of equipment owned by the implementing contractor. According to Coduto [1], a retaining wall is a structure designed to maintain and maintain two different ground elevation faces. The retaining wall serves to support the soil and prevent it from the danger of landslides. Both due to the burden of rainwater, the weight of the land itself and due to the burden of working on it. According to Donomartono [2], value engineering is an evaluation method that analyzes the techniques and values of a project or product involving owners, planners and experts who are experienced in their respective fields with a systematic and creative approach that aims to produce the lowest possible quality and cost, namely with functional limitations and the stages of the task plan that can identify and eliminate costs and efforts that are not needed or supportive. According to Fong [3], value engineering is an organized and directed function-oriented team approach to analyzing the functions of the product, system, or supply process, to increase its value by identifying and eliminating unnecessary costs and achieving the performance needed at the lowest
project life cycle costs. According to Fuller and Petersen [4], life cycle cost (LCC) is an economic method in evaluating projects for all costs incurred starting from the management, operation, maintenance, and disposal of a component of construction. According to Soeharto [5], cost estimation is the art of approximating, the possible amount of costs required for an activity based on information available at the time. According to Umar [6], the shorter the duration needed to complete a unit of work, the higher the productivity. The aims and objectives of this journal are obtain the number of costs associated with the method of retaining wall soldier pile and diaphragm wall after a life cycle cost comparison, and obtaining the value of cost efficiency, time and quality in the use of diaphragm wall retaining walls compared to soldier piles.

2. Method
This study uses primary data among other construction method and labor productivity studied from the Apartment Project in Pejaten for diaphragm wall retaining walls and from the Apartment Project in Cikarang for soldier pile retaining walls. Secondary data of this study are literature studies, soil data, shop drawings, and bill of a quantity that will be processed use Microsoft Excel. Primary and secondary data processing is performed to then be calculated life cycle cost soldier pile and diaphragm wall. One of the data collection directly in the project is looking for worker productivity in each method of retaining wall. the productivity of both methods is carried out in two apartment locations. Life cycle cost analysis of initial costs (C), maintenance and repair costs (M + R) and salvage value (S). Both methods of retaining wall have a salvage value of 0 because the retaining wall cannot be used in other projects.

3. Results and Discussions
Description of existing soil retaining walls:
1. Diameter : Soldier Pile Ø600; Soldier Pile Ø800; Bentonite Ø500-Bentonite Ø900
2. Concrete quality : Soldier Pile K-250
Planning structures that will be used on the diaphragm wall are:
1. Concrete quality : 25 MPa
2. Quality of reinforcement : 420 MPa
3. Vertical reinforcement diameter : 22 mm
4. Horizontal reinforcement diameter : 13 mm
5. The dimension of diaphragm wall:
   a. D-Wall thickness: 600 mm
   b. Wall length: 137 meters
   c. Wall height: 22 meters
This initial cost is obtained from the calculation of the budget plan of the available alternatives. Budget plan this fee is calculated based on wages and materials that will help complete the work of the retaining wall at the Pejaten Apartment Project.

| Number. | DESCRIPTION ITEM       | AMOUNT          |
|---------|------------------------|-----------------|
| 1       | Preliminary Works      | 1,393,284.386   |
| 2       | Soldier Pile Works     | 11,468,971.468  |
| 3       | Retaining Wall Works   | 6,350,841.433   |
|         | **TOTAL AMOUNT**       | **19,213,097.287** |

Table 1. Bill of quantities of diaphragm wall
Table 2. Bill of quantities of diaphragm wall

| Number. | DESCRIPTION ITEM       | AMOUNT       |
|---------|------------------------|--------------|
| 1.      | Preliminary Works      | 1,627,284,386|
| 2.      | Guide Wall Works       | 395,730,684  |
| 3.      | Diaphragm Wall Works   | 12,703,901,656|
|         | **TOTAL AMOUNT**       | **14,726,916,725** |

The results of the initial costs show that the diaphragm wall retaining wall method is lower than the soldier pile method. This is because, the work of a retaining wall soldier pile requires reinforced concrete retaining walls to become a basement wall, while the diaphragm wall does not need a layer of walls anymore because the diaphragm retaining wall can be a basement wall (permanent retaining wall). When compared to the initial cost of the soldier pile method without a permanent retaining wall, the cost of making soldier pile is cheaper than the diaphragm wall. But, if the comparison of the two retaining walls serves as a basement wall, then the diaphragm wall is cheaper than a soldier pile.

Repairs to the retaining wall are carried out when the basement wall has leaked and seepage. Grouting is the most common way to repair a basement when a fine crack occurs.

Table 3. Maintenance and repair cost soldier pile method and diaphragm wall method

| Method      | 1 year (in Rupiah) |
|-------------|--------------------|
| Soldier Pile| 47,840,400,00      |
| Diaphragm Wall| 28,704,240,00    |

The results of maintenance and repair costs show that the diaphragm wall retaining method is lower than the soldier pile method.

Quality comparison of the results of the retaining wall method is seen when seepage occurs in the basement wall. Little water seepage is classified as a good quality retaining wall. In the initial design of the method of retaining walls, the soldier pile found a lot of seepage in the basement wall. This is because the soldier pile process is difficult to unite the primary pile and secondary pile so that the slope is vulnerable. The process of working the primary pile and secondary pile that is not suitable can cause slope and water seepage. The work of a retaining wall diaphragm wall in the process is easier because the diaphragm wall is done directly in large volumes so that the level of negligence in the work process is reduced. The degree of negligence and the depth of the wall is very deep which makes the diaphragm wall retaining walls rarely occur seepage. In the process, the diaphragm wall makes it easy for workers because of the standard work items such as reinforcement bar and concrete work, while the soldier pile needs to require difficulty in the process of combining primary pile and secondary pile.

Below is the quantity of work for each method of retaining wall.

1. Soldier pile method:
   - SP Ø 600 = 87 poles
   - SP Ø 800 = 87 poles
   - Bentonite Ø900 = 174 poles

2. Diaphragm wall method:
   - Panel = 5 meters
   - Depth = 22 meters
   - Roving = 137 meters

From the results of field observations on the Apartment project in Pejaten and Apartment project in Cikarang, the following time is needed to complete each of the retaining wall work items.

1. Soldier pile method
   a. 4 piles/day for soldier piles
   b. 5 piles/day for bentonite piles

2. The diaphragm wall method
a. 5 meters/day
From the quantity and standard time of work obtained the amount of time needed in each work of the retaining wall.
1. The soldier pile method takes 948 hours or 79 days with a productivity of 12 hours per day.
2. The diaphragm wall method takes 329 hours or 28 days with a productivity of 12 hours per day.

4. Conclusions and Recommendations
Based on the analysis, it was found that:
   a. Based on life cycle cost analysis, the most appropriate method in terms of cost, quality, and time is the method of retaining wall in the case study in Pejaten Apartment is a diaphragm wall.
   b. The diaphragm wall retaining wall can save an initial cost of 23%. The initial cost of a soldier pile is more expensive because it requires an additional reinforced concrete wall that functions as a basement wall while the diaphragm wall can be directly used as a basement wall. For maintenance costs, the diaphragm wall can save 40% compared to the maintenance costs of soldier piles. Savings due to the soldier pile retaining wall method cause smoother cracks and water seepage more than the diaphragm retaining wall.
   c. The retaining wall is of good quality when there is very little seepage. In the initial design of the method of retaining walls, the soldier pile found a lot of seepage in the basement wall. The depth of the wall is very deep which makes the diaphragm retaining wall rarely seepage occurs, so the quality produced by the diaphragm wall is better than soldier piles.
   d. In the implementation process, the diaphragm wall retaining wall is 2-3 times faster than the soldier pile retaining wall due to the fast process of starting excavation, reinforcement and concreting compared to the soldier pile which must wait for the time between working on the primary pile and secondary pile

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