Application of Value Engineering to Geotechnical Design for a Factory Structures on Soft Alluvial Flood Plain in Indonesia

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ABSTRACT: This paper aims at giving a framework on how value engineering can be applied to geotechnical design to improve the value of the project. Case history of such application on an alternative design to a palm oil mill over very soft alluvial flood plain in east coast of Sumatra of Indonesia is presented to demonstrate how a safe and cost effective geotechnical solution for the foundation treatment is developed. Innovative short floating pile design, piled raft foundation and inverted "T" arrangement retaining wall design have resulted in a cost saving of 30% and significant time saving. With the systematic approach and thoughtful brainstorming on design process, the final design turns up to be a successful showcase of value engineering in geotechnical design.

1 INTRODUCTION

Value engineering (VE), which is originated from the US military industry in the early 60 of this century, has been extensively applied in construction industry nowadays. Foo, T. H. (2002) and Chong, S. N. (2002) have given some useful frameworks on the application of VE. However, in Malaysia, VE is mostly associated to any alternative design with the intention of cost cutting exercise for a project, which is merely one of the initial intentions of the VE. This paper outlines the basic frameworks of VE and presents a case history showing the merits of VE in a palm oil mill project in Indonesia.

2 DEFINITIONS AND PROCESS OF VALUE ENGINEERING

Function is the purpose of a product. Value is the usefulness, importance, or worth of quality, use, life and aesthetics of a product. Sometimes, it can be as simple as client's requirements. Unnecessary costs are the costs that do not add value to the final product.

Value Engineering (VE) is a systematic and organized procedural decision-making process. It help people creatively generates alternative that secure essential functions at the greatest worth as opposed to costs. The following simple expression can demonstrate the relationship among value, function and cost.

$$Value = \frac{Function}{Cost}$$

The purpose of value engineering is to eliminate the unnecessary costs that do not contribute to functions of the product.

When value engineering is implemented for a project, some of the following side benefits may go along with the process.

- Cost Saving
- Quality Control
- Design Review
- Design Competency Review

There are three key components for a successful application of value engineering, namely:

- Involved and committed multidisciplinary team members
- Facilitator/Coordinator
- Job Plan for review

In value engineering, there are usually divided into 6 phases as shown in Figure 1. The activities in each phase are described hereafter:

A. Information
   - Gather related information
   - Identify potential areas to eliminate unnecessary costs

B. Function Analysis
   - Understand the intended function
   - Assess the achievement of the functions for respective elements of product
   - Focus on areas that add costs but not value & lead to seeking of alternative solutions

C. Creativity

- Explore alternative options
- Brainstorming on the options explored to achieve the intended function (Rethinking of problem in functional terms)
- Summarise outcome

D. Evaluation

- Assess pros & cons
- Review on impact & implication
- Estimate cost
- Prioritise options

E. Recommendation

- Define & qualify results
- Recommend to decision maker

F. Implementation

- Implement
- Monitor & follow up

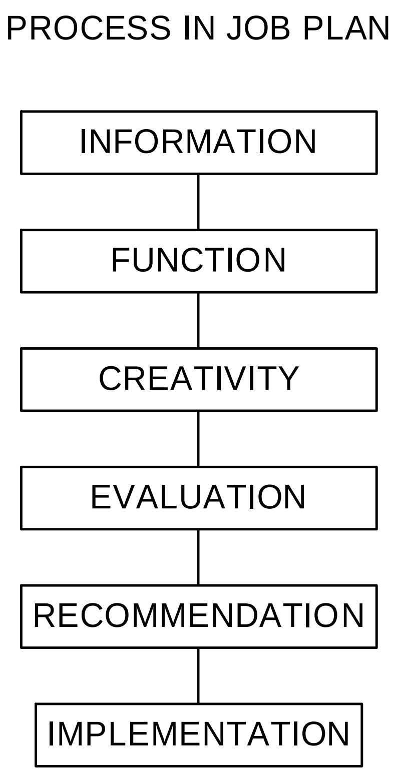

Figure 1 Phases of Value Engineering

There are some pitfalls to be bear in mind during value engineering as follows:

- Maintain an objective approach to prevent VE from degrading to design review
- Avoid habitual solution reestablished within VE (mind set effect)
- Avoid target percentage saving (potentially degrading design quality)
- Improve sale technique for VE solution
- Optimisation based on value and function
- Incentive to all parties to achieve ultimate objective of VE (win-win situation)

The benefits of value engineering in design management are as follows:

- Organised design approach
- Understand project function/ requirements
- Avoid habitual solution & promote thorough and focused thought on design
- Focus on high cost areas

3 SOLUTIONS FOR SOFT GROUND

<u>GEOTECHNICAL SOLUTIONS FOR FACTORIES</u>

The project presented in this case study is a 120 Ton/hr palm oil mill to be constructed over the sand filled platform of about 83,000m^2 on soft compressible swampy ground. The location of the project site is about 50km away from the river mount of Sg. Guntung of Riau province of Sumatra, Indonesia. The total project cost for the earthworks, civil works, building works and ancillary works excluding the mechanical and electrical costs are about RM60 millions. This mill is strategically important, as it will serve to process the palm oil fruits from part of the surrounding 80,000 hectares oil palm plantation. As such, it is a great challenge to complete the mill in relatively short contract duration with difficult logistic conditions. However, value engineering has been carefully applied to this project and results in significant reduction in terms of construction costs and time.

<u>Subsoil & Geomorphology Conditions</u>

The site is generally underlain by recent alluvial soils, which are very weak in strength and highly compressible. Organic peat of about 1m thick can be found at the topsoil. Following the top peaty soil, 35m thick very soft compressible clay and subsequently 12m thick medium stiff clay can be found overlying the medium dense fine clayey sand at lower stratum. Figure 2 shows the schematic subsoil strata of this project site.

The geomorphology of the site is featured with typical extensive flood plain and high groundwater table. Due to nature of the overall ground condition of the region, canals become a convenient way for transportation of goods and passengers. With the recent rapid development of oil palm plantation at the area, more canals have been constructed for transporting the fruits and irrigation purpose. Due to the need of proper drainage and irrigation for the palm oil plantation, the water level in the canal system is then controlled by gated structures.

Figure 2 Subsoil Condition of Project Site

Client's Requirements

The primary requirements of the turn-key contractor are as follows:

- Innovative geotechnical design optimized for very difficult ground conditions.
- Use of locally available natural materials & reduce transported construction materials from outside.
- Reduce thickness of filled platform.
- Savings for construction cost and time.

Ground Treatment for Platform

Despite the water level in the canal system is controlled, there is a concern on the extreme flood condition in the vast canal system. Therefore, in the conventional design, platform above the expected flood level is to be constructed on very soft and highly compressible subsoil. It is a great challenge to construct the filled platform with provision to cater long-term settlement. This will result in thick fill and requires longer duration to reach the required platform using staged construction method to prevent bearing capacity failure.

In the proposed alternative design, thinner platform of 1.1m has been proposed to avoid instability and long-term settlement. In case of extreme flood event, provision of bund construction around the mill compound has been allowed to protect the mill. With the naturally available straight and long tree trunks during the site cleaning for the oil palm plantation project, wood piles of appropriate size and length were selected and installed in square grid pattern for supporting the 1.1m thick sand fill as shown in Figure 3. Woven geotextile fabrics were added over the grid of wood piles to spread the fill loading uniformly for better stability and reduce differential settlement. This is shown in Figure 4. Figure 5 shows a partially completed mill structure. The buoyancy of the wood-piles in grids and the stiffening effect of the soft subsoil by pile installation have also help in reducing the platform settlement.

Figure 3 Hardwood Blanket Piling

Figure 4 Hardwood Piled Foundations for Platform & Structures

Figure 5 Partially Completed Mill Structure

Foundations of Structures & Equipment

With the expected settlement of subsoil, negative skin friction developed on the originally designed end bearing piles is expected to very high and will require expensive slip coating to the piles. Similar floating concrete pile system is used to support heavy equipment, such as the crane system for FFB Reception Bay, Incinerators, Chimneys, Boilers and other processing stations. Figure 6 shows the floating concrete pile foundation. This floating pile system results in much shorter pile length of 36m as compared to the compliance design using end bearing piles of 50m penetration length. Most structural columns carrying light load are predominantly supported on hardwood piles.

Figure 6 Floating Piles for Structures

Bulk Storage Structures

There are seven numbers of heavy steel tank structures for the storage of processing water and processed palm oil. The total weight of the tank structure is about 3500Ton including maximum storage capacity of 3000Ton for water or crude palm oil. The steel tanks are seated on 0.5m sand bed coated with bitumen strips in order to have uniform seating between the coned-down tank base and the reinforced concrete (RC) raft with thickness optimized to 500mm. This is rather thin as compared to the similar type of tank structures on floating piles. Figure 7 shows the completed tank structures and the tank raft. A total number of 137 of 350mm diameter hollow circular prestressed concrete (PC) spun piles with characteristic concrete strength of 60MPa have been designed and installed to support the tank through the RC raft. Figure 8 shows the installation of the tank foundation piles. To avoid the bowl shaped deflection profile of the raft as a result of the interaction effect of large floating piles group, the floating piles are designed with varying lengths to control the deflection profile of the raft as part of the design optimization for the raft. The central portion of the raft is supported with longer piles, in which the supporting stiffness is relatively higher than that of the short piles at outer rim of the raft. Figure 9 shows the schematic diagram of the pile foundation for tank structures. Detailed documentation on the performance of the tank foundation can refer to the technical paper by Liew S. S., Gue, S. S. & Tan, Y. C. (2002).

Figure 7 Completed Tank Structures

Figure 8 Piled Raft Foundation for Storage Tank

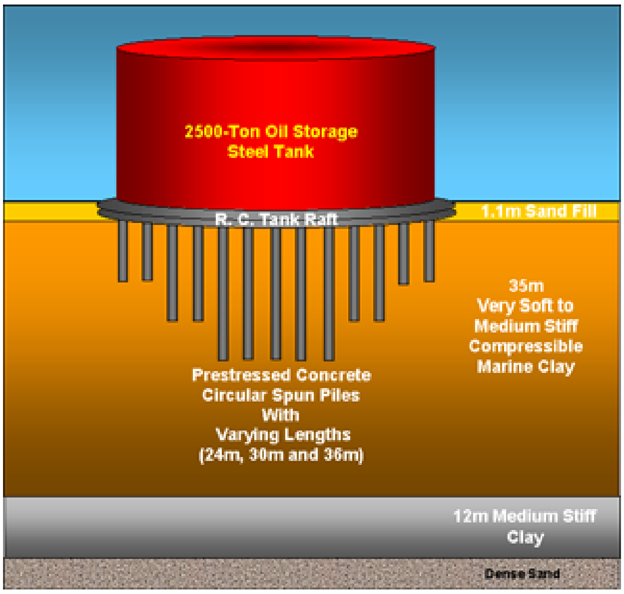

Figure 9 Schematic Piled Raft Foundation for Storage Tank

Retaining System for Wharf Structures

As the oil palm fruits are transported through canal, there is a need to construct a wharf structure for receiving the oil palm fruits. Because of the very weak subsoil, it is practically difficult to design a 3.6m high retaining wall facing the canal. An innovative concept in the retaining wall design for the FFB crane bay was used. The design concept used the sheetpiles in a successive "T" arrangement to act as a container for soil containment and, at the same time, to act as the primary supports for the wharf deck. Figure 10 and 11 show the plan view and schematic diagram of the retaining wall design. Only 12m long FSP IIIA sheetpile section has been used. This penetration length would not be possible to have adequate wall stability in the conventional retaining wall design in this type of soil condition. Figures 12 and 13 show the steel frame erection and the overview of the crane system.

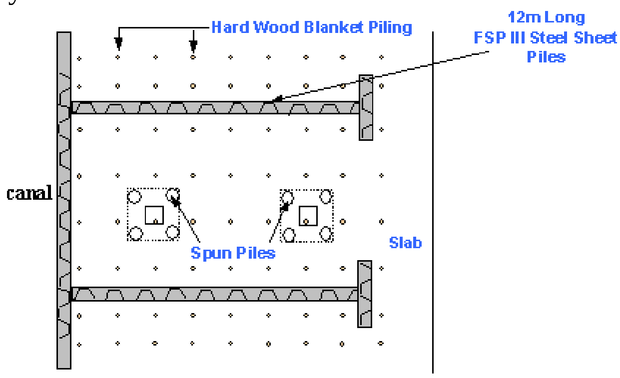

Figure 10 Schematic Diagram of Crane Bay

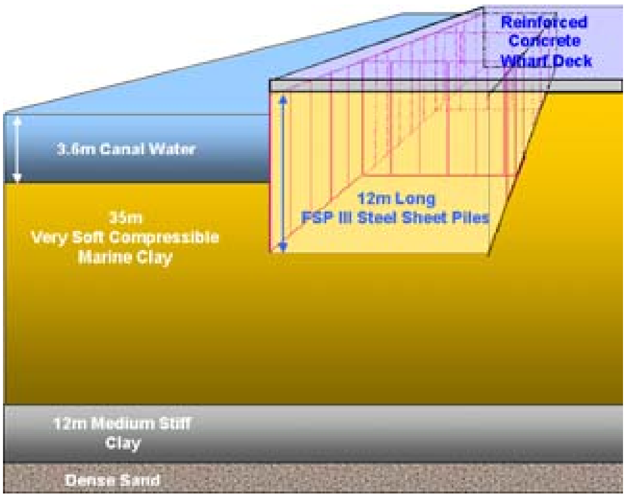

Figure 11 Schematic Diagram of Crane Bay

Figure 12 Erection of Steel Frame of FFB Crane Bay

Figure 13 Overview of FFB Crane Bay

Design Feedbacks from Instrumentation Results

Instrumentation and load tests have been implemented to validate the actual performance against the design expectation. The monitoring results show very convincing and satisfactory outcome. The maximum settlement on the monitored structural columns and stumps, floor slab and sand fill platform is less than 30mm at the time of handing over. The maximum settlement of the storage tank with full water storage is also only about 18mm, which is well within the tolerance of 75mm. Figure 14 shows the instrumentation results of the tank structure during the water test. The view of the completed mill is shown in Figure 15.

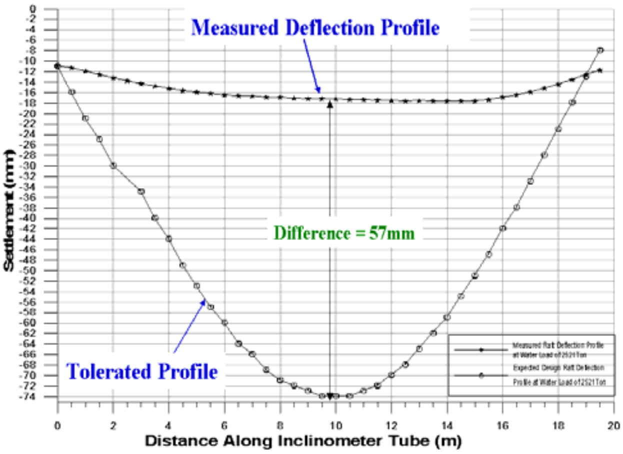

Figure 14 Instrumentation Result of Tank Structure

Figure 15 Overview of Completed Mill Structures

<u>Achievements in Value Engineering</u>

The proposed alternative geotechnical designs have satisfied the four design criteria demanded by the turnkey contractor. There are remarkably cost savings in the geotechnical design and the construction time. The objective to utilise the local resources rather than transporting from outside has been well satisfied as the water transportation is not as effective as land transport. The uses of less sand fill, optimized thinner tank raft, successive 'T' sheet piles as wharf structure, local wood-piles for platform construction and floating piles system of shorter length have cut down significant amount of the construction materials and time. In the original design, the total cost of earthwork and foundation are about 75% of the total civil and structure costs. The alternative design has a cost saving of more than 30% on the total costs and significant time saving. The performance of the proposed system has been verified by instrumentation and the alternative foundations performed better than expected. From the instrumentation results, it appears that further design optimization is possible.

4 CONCLUSION & RECOMMENDATION

The following conclusions can be drawn:

a. The short floating piles can be very effective to support structures on very soft compressible alluvium soil.
b. Varying concrete floating pile lengths underneath the piled raft has successfully supported the 2500 Ton storage tank with negligible raft distortion.
c. The sheetpiled retaining wall with inverted "T" arrangement as a container box to reinforce the retained soil has proven to be an effective retaining solution in soft ground.
d. The monitoring results have shown a very satisfactory performance in this alternative geotechnical design.
e. Application of value engineering in this case history has successfully fulfilled the requirements by the project client.

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