International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 10 (November 2014) www.ijirae.com

Application of Value Engineering in Slope Stabilization

Ting Jude M. H.
Department of Civil, UNIMAS

Afshar, N.R.
Department of Civil, UNIMAS

Selaman, O.S.
Department of Civil, UNIMAS

Taib, S.N.L.
Department of Civil, UNIMAS

Abstract— The removal of water from the subsurface is one of the most common remediation practices in slope stabilization. The use of horizontal drains has often proved to be an efficient and economical dewatering option for slope stability. Despite their frequent use, a comprehensive review of the state of the art which includes recent research, contributions from related fields and slope stability analysis, indicates that the optimal solution of horizontal drain has not been fully studied. The objective of this paper is to provide a summary of the current state of practice, including application of value engineering (VE) for slope stability. It has been shown from this study that the pipe being used in the initial design which is 75mm "Class D" UPVC can be replaced by HDPE Grade PN 10 which will increase the value as much as 13.42%. However, the recommended combination of the alternative design which gives the increase value as much as 15.77 % by replacement of slope degree from 25^o to 35^o and 75mm "Class D" UPVC to HDPE Grade PN 10. This study also found that with the increase of slope from 25^o to 35^o will cost 35.32 % more on vegetation which will only increase the value by 1.85%.

Keywords— Value engineering, Slope stability, horizontal drains, Function, Value

I. INTRODUCTION

Slope stability is the potential of soil to withstand and undergo movement. Stability is determined by the balance of shear stress and shear strength. A stable slope may be initially affected by preparatory factors, making the slope conditionally unstable. Triggering factors of a slope failure can be erosion, natural slope movement, human activity, overloading, transitory effect, removal of underlying materials, and increase in lateral pressure which makes a slope actively unstable, leading to mass movements. Mass movements can be caused by increases in shear stress, such as seepage forces. Alternatively, shear strength may be decreased by nature of the materials, weathering and physiochemical activity, effect of pore pressures and changes in structure.

According to (Guzzetti et al., 2007), continuous precipitation is one of the main causes for a landslide to occur. Slope failures due to heavy rain falls were observed in Hong Kong (Brand 1984), Singapore (Rahardjo et. al., 2001) and in Malaysia (Komoo & Lim, 2003) which have triggered public interest, particularly when they occur in urban areas and cause damage to public property. In practice, slope drainage is installed in slopes as a mean to reduce pore stresses, hence, improve its stability. Value engineering analysis is performed onto slope of various selected parameters (crucial to its stability) in order observe the effect on cost while maintaining the functionality of parameters in stabilizing the slope.

Value engineering is an organized process with an impressive history of improving value and quality. The VE process identifies opportunities to remove unnecessary costs while assuring that quality, reliability, performance and other critical factors will meet or exceed the customer's expectations. The main objective of VE is to improve value, and can overcome many of the roadblocks to achieving good value. Value Engineering follows the Job Plan and uses rational logic (a unique "how" - "why" and "when" questioning technique) and the analysis of function to identify relationships that increase Value.

II. CURRENT DESIGN PRACTICES

Horizontal drains are defined as holes drilled into a cut slope or embankment and cased with a perforated metal or slotted plastic liner (Royster, 1980). The function of horizontal drain in slope is to reduce the water table especially during heavy rainfall as a measure to reduce the failure in slope. Lau and Kenney (1984), described the parameters controlling the horizontal drainage design or evaluate the feasibility of using a system of horizontal drains to lower groundwater levels in hill- sides. Martin et al. (1994) suggested that a small number of drains installed at appropriate locations in accordance with a well-conceived conceptual groundwater model may be more effective than a large number of drains installed at uniform spacing over the slope. The effectiveness of the horizontal drainage system is a function of many factors including the drain location, length and spacing, as well as soil properties and slope geometry. Typically, effectiveness is described in terms of increase in slope's factor of safety as compared to factor of safety for the case without horizontal drains.

According to Cai et. al. (1998), lengthening the horizontal drains is more effective than making the spacing smaller and increasing the number of the drains in a group in order to lower the ground water level and increase the slope stability. The study done by Rahardjo et al. (2001) shows that horizontal drains were found to be most effective when located at the base of a slope.

III. Application of Value Engineering

Value engineering (VE) is a systematic method to improve the "value" of goods or products and services by using an examination of function. Value, as defined, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost.

Value engineering is often done systematically following a multi-stage job plan. Larry Miles' (1961) original system was a six-step procedure which he called the "value analysis job plan." Depending on the application, there may be four, five, six, or more stages. Six basic steps in the job plan are information gathering, functional analysis, creative, evaluation, development and presentation.

Value engineering follows a structured thought process that is based exclusively on "function", i.e. what something "does" not what it is. This is the basis of what value engineering refers to as "function analysis". In value engineering "functions" are always described in a two word abridgement consisting of an active verb and measurable noun (what is being done - the verb - and what it is being done to - the noun). VE uses rational logic (a unique "how" - "why" questioning technique) and the analysis of function to identify relationships that increase value.

According to Mashayekhi and Afshar (1998), all phases of VE implemented in Iran since 1998, are accomplished at a reduced cost, but cost savings reduces as time progresses from beginning, to end of a project. The value engineering can be applied wherever cost and/or performance improvement is desired. That improvement can be measured in terms of monetary aspects and/or other critical factors such as productivity, quality, time, energy, environmental impact, and durability. VE can beneficially be applied to virtually all areas of human endeavor.

IV. Results and Discussion

A slope site located at Putra Jaya Precinct 9, Malaysia was selected to study the impact of horizontal drain for slope stabilization. Following the job plan and current conditions of the project which aims to lower groundwater table for slope stability, the main goal of the study was decided to be the application of value engineering in slope stabilization. The objective of functional analysis is to develop the most beneficial areas for continuing study. Project functions using active verb and measurable noun were defined which are summarized in the Table 1.

TABLE I
PROJECT FUNCTIONS

Project's function	Active verb	Measurable noun
Slope degree (25^o-35^o)	Resists	Failure
Pipe (UPVC "Class D", Galvanized Mild Steel Tubing "Class C", ABS Pressure Pipe "Class C"/Class "D"/Class "E" and HDPE Grade PN 10)	Drain	Water
Drainage filter (Poly felt "TS 20" and Poly felt "TS 30")	Filter	Fines
Vegetation (Pear Grass "P" and Axonopus Compressus "A")	Reduces or Holds	Erosion and Weathering or Soil
Soil Material	Indicates	Stability or Characteristics

To select functions for continued analysis, classify the functions as basic or secondary and expand the functions which have been identified. Function analysis system technique (FAST), displays the interrelationship of functions to each other in a "how-why" logic which is shown in Figure 1.

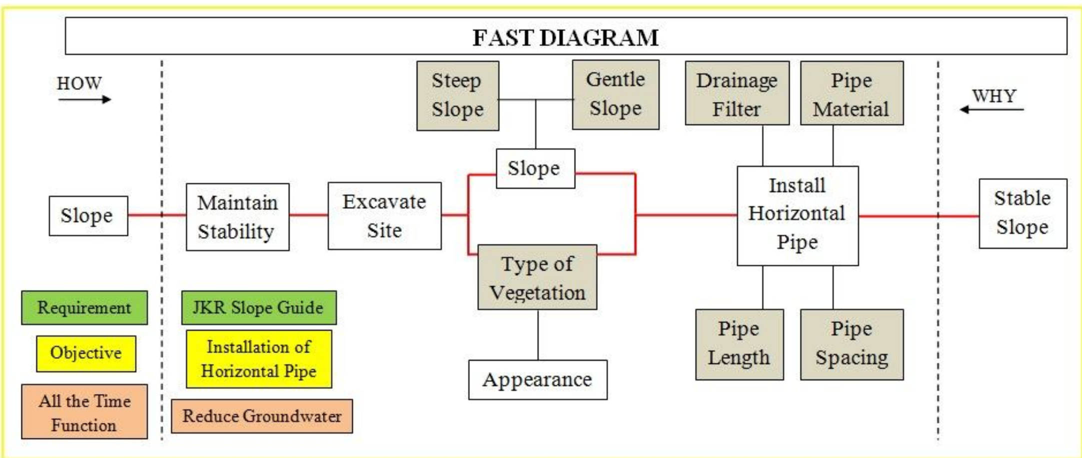

Fig. 1 Fast Diagram of Slope

Assign cost to functions and establish worth of functions by assigning the previously established user or customer attitudes to the functions. Then compare cost to worth of functions to establish the best opportunities for improvement. Assess functions in Table 2 indicates that, all the proposed alternatives have a value more than 1 which is worth to go for Performance considerations. Using the value analysis, the combination of the functions represents by 48 alternative designs in slope at Putra Jaya Precinct 9, Malaysia which is also summarized in Table 2. Table 2 indicates that all the proposed alternative have a value of more than 1 which is worth to go for.

TABLE 2
COST, SAVING AND B/C FOR ALTERNATIVES DESIGN

Alt No.	Slope Degree	Pipe Material	Drainage Material	Vegetation	Cost	Saving	B/C
1	25°	UPVC	TS20	P	380760.68	3729239.32	9.79
2	25°	UPVC	TS20	A	294735.08	3815264.92	12.94
3	25°	UPVC	TS30	P	381692.13	3728307.87	9.77
4	25°	UPVC	TS30	A	295666.53	3814333.47	12.9
5	25°	HDPE	TS20	P	348130.28	3761869.72	10.81
6	25°	HDPE	TS20	A	262104.68	3847895.32	14.68
7	25°	HDPE	TS30	P	349061.73	3760938.27	10.77
8	25°	HDPE	TS30	A	263036.13	3846963.87	14.63
9	25°	Galvanized Pipe	TS20	P	860823.08	3249176.92	3.77
10	25°	Galvanized Pipe	TS20	A	774797.48	3335202.52	4.3
11	25°	Galvanized Pipe	TS30	P	861754.53	3248245.47	3.77
12	25°	Galvanized Pipe	TS30	A	775728.93	3334271.07	4.3
13	25°	ABS Pipe "C"	TS20	P	527103.08	3582896.92	6.8
14	25°	ABS Pipe "C"	TS20	A	441077.48	3668922.52	8.32
15	25°	ABS Pipe "C"	TS30	P	528034.53	3581965.47	6.78
16	25°	ABS Pipe "C"	TS30	A	442008.93	3667991.07	8.3
17	25°	ABS Pipe "D"	TS20	P	578520.68	3531479.32	6.1
18	25°	ABS Pipe "D"	TS20	A	492495.08	3617504.92	7.35
19	25°	ABS Pipe "D"	TS30	P	579452.13	3530547.87	6.09
20	25°	ABS Pipe "D"	TS30	A	493426.53	3616573.47	7.33
21	25°	ABS Pipe "E"	TS20	P	761448.68	3348551.32	4.4
22	25°	ABS Pipe "E"	TS20	A	675423.08	3434576.92	5.09
23	25°	ABS Pipe "E"	TS30	P	762380.13	3347619.87	4.39
Alt No.	Slope Degree	Pipe Material	Drainage Material	Vegetation	Cost	Saving	B/C
24	25°	ABS Pipe "E"	TS30	A	676354.53	3433645.47	5.08
25	35°	UPVC	TS20	P	379359.88	3730640.12	9.83
26	35°	UPVC	TS20	A	289749.88	3820250.12	13.18
27	35°	UPVC	TS30	P	380291.33	3729708.67	9.81
28	35°	UPVC	TS30	A	290681.33	3819318.67	13.14
29	35°	HDPE	TS20	P	346729.48	3763270.52	10.85
30	35°	HDPE	TS20	A	257119.48	3852880.52	14.98
31	35°	HDPE	TS30	P	347660.93	3762339.07	10.82
32	35°	HDPE	TS30	A	258050.93	3851949.07	14.93

33	35°	Galvanized Pipe	TS20	P	859422.28	3250577.72	3.78
34	35°	Galvanized Pipe	TS20	A	769812.28	3340187.72	4.34
35	35°	Galvanized Pipe	TS30	P	860353.73	3249646.27	3.78
36	35°	Galvanized Pipe	TS30	A	770743.73	3339256.27	4.33
37	35°	ABS Pipe "C"	TS20	P	525702.28	3584297.72	6.82
38	35°	ABS Pipe "C"	TS20	A	436092.28	3673907.72	8.42
39	35°	ABS Pipe "C"	TS30	P	526633.73	3583366.27	6.8
40	35°	ABS Pipe "C"	TS30	A	437023.73	3672976.27	8.4
41	35°	ABS Pipe "D"	TS20	P	577119.88	3532880.12	6.12
42	35°	ABS Pipe "D"	TS20	A	487509.88	3622490.12	7.43
43	35°	ABS Pipe "D"	TS30	P	578051.33	3531948.67	6.11
44	35°	ABS Pipe "D"	TS30	A	488441.33	3621558.67	7.41
45	35°	ABS Pipe "E"	TS20	P	760047.88	3349952.12	4.41
46	35°	ABS Pipe "E"	TS20	A	670437.88	3439562.12	5.13
47	35°	ABS Pipe "E"	TS30	P	760979.33	3349020.67	4.4
48	35°	ABS Pipe "E"	TS30	A	671369.33	3438639.67	5.12

Table 3 shows the difference of value compared to the initial design (Alternative No. 2). The negative value shows that the alternative proposed have lower value as compared to the initial design.

TABLE 3
VALUE DIFFERENT WITH INITIAL DESIGN

Alternative Number	Slope Degree	Pipe Material	Drainage Material	Vegetation	B/C	Value Difference
30	35°	HDPE	TS20	A	14.98	2.04
32	35°	HDPE	TS30	A	14.93	1.98
6	25°	HDPE	TS20	A	14.68	1.74
8	25°	HDPE	TS30	A	14.63	1.68
26	35°	UPVC	TS20	A	13.18	0.24
28	35°	UPVC	TS30	A	13.14	0.19
2	25°	UPVC	TS20	A	12.94	Initial Design
4	25°	UPVC	TS30	A	12.9	-0.04
29	35°	HDPE	TS20	P	10.85	-2.09
31	35°	HDPE	TS30	P	10.82	-2.12
5	25°	HDPE	TS20	P	10.81	-2.13
7	25°	HDPE	TS30	P	10.77	-2.17
Alternative Number	Slope Degree	Pipe Material	Drainage Material	Vegetation	B/C	Value Difference
25	35°	UPVC	TS20	P	9.83	-3.11
27	35°	UPVC	TS30	P	9.81	-3.13
1	25°	UPVC	TS20	P	9.79	-3.15
3	25°	UPVC	TS30	P	9.77	-3.17
38	35°	ABS Pipe "C"	TS20	A	8.42	-4.52
40	35°	ABS Pipe "C"	TS30	A	8.4	-4.54
14	25°	ABS Pipe "C"	TS20	A	8.32	-4.62
16	25°	ABS Pipe "C"	TS30	A	8.3	-4.64
42	35°	ABS Pipe "D"	TS20	A	7.43	-5.51

44	35^o	ABS Pipe "D"	TS30	A	7.41	-5.53
18	25^o	ABS Pipe "D"	TS20	A	7.35	-5.59
20	25^o	ABS Pipe "D"	TS30	A	7.33	-5.61
37	35^o	ABS Pipe "C"	TS20	P	6.82	-6.12
39	35^o	ABS Pipe "C"	TS30	P	6.8	-6.14
13	25^o	ABS Pipe "C"	TS20	P	6.8	-6.14
15	25^o	ABS Pipe "C"	TS30	P	6.78	-6.16

Table 4 shows with the changing of the degree of slope from 25^o to 35^o, the cost of vegetation will increase with 35.32% which will only increase the value by 1.85%. Besides that, it is found that the replacement of pipe material will have increase of 13.42% in value. However, the combination of replacement of degree of slope and pipe will give the highest increase in value of 15.77 % although the increase of slope will cost more to the vegetation area.

TABLE 4
COMPONENT WHICH INCREASE THE VALUE

Alternative Number	Slope Degree	Pipe Material	Drainage Material	Vegetation	Increase in Value	Increase in Value (%)
30	35^o	HDPE	TS20	A	2.04	15.77
Changes (%)	22.13	65.78	0	-12.08		
32	35^o	HDPE	TS30	A	1.98	15.32
Changes (%)	21.73	64.57	-1.84	-11.86		
6	25^o	HDPE	TS20	A	1.74	13.42
Changes (%)	0	100	0	0		
8	25^o	HDPE	TS30	A	1.68	12.99
Changes (%)	0	97.22	-2.78	0		
26	35^o	UPVC	TS20	A	0.24	1.85
Changes (%)	64.68	0	0	-35.32		
28	35^o	UPVC	TS30	A	0.19	1.5
Changes (%)	61.32	0	-5.2	-33.48		

V. CONCLUSION AND RECOMMENDATIONS

Slope is one of the crucial design along with the rapid urbanization. Designing of slope is not an easy task which requires a lot of considerations and also huge investment. Value engineering is a new kind of managing technology which integrates function, cost, technology and economy from its basic concepts and principles. Value Engineering focuses on value rather than cost and seeks to achieve an optimal balance between time, cost and quality.

It has been shown that, the pipe being used in the initial design which is 75mm "Class D" UPVC can be replaced by HDPE Grade PN 10 which will increase the value as much as 13.42%. However, the recommended combination of the alternative design which give the increase value as much as 15.77 % by replacement of slope degree from 25o to 35o and 75mm "Class D" UPVC to HDPE Grade PN 10. This study also found that with the increase of slope from 25o to 35o will cost 35.32 % more than vegetation which will only increase the value by 1.85%.

ACKNOWLEDGMENT

The authors wish to acknowledge the Ministry of Education Malaysia for the financial support ERGS/TK03(01)/1008/2013(05) of the project.

REFERENCES

[1] Brand, E.W. (1984). Landslides in Southeast Asia: A state-of-art report. Proceedings of 13th International Conference on soil Mechanics and Foundation Engineering, New Delhi, India, pp. 1013-1016.
[2] Cai,F. et al., (1998). Effects of horizontal drains on slope stability under rainfall by three-dimensional finite element analysis. Computers and Geotechnics. Volume 23. Issue 4. Pages 255–275.
[3] Guzzetti et al., (2008). The rainfall intensity–duration control of shallow landslides and debris flows. Journal of the International Consortium on Landslides, Volume 5. Issue 1. pp 3-17.
[4] Komoo, I & Lim, C.S., (2003). Taman Hillwiew landslide tragedy. Bulletin of the Geological Society of Malaysia. 46, 93-100.
[5] Lau, K.C. & Kenny, T.C. (1984). Horizontal Drains to Stabilize Clay Slopes. Canadian Geotechnical Journal 21(2): 241-249.
[6] Martin, R.P., et al (1994). Review of the Performance of Horizontal Drains in Hong Kong. Special Project Report, SPR 11/94. Geotechnical Engineering Office. Civil Engineering Department. Hong Kong. p. 106.
[7] Mashayekhi. Rostam Afshar,N. (1998). Thesis. Power and Water university of technology, Tehran-Iran.
[8] Miles, L.D., (1961). Techniques of Value Analysis and Engineering. McGraw Hill. Inc. New York.
[9] Rahardjo, H., et al (2001)..The Effect of Antecedent Rainfall on Slope Stabilit. Journal of Geotechnical and Geological Engineering. Special Issue on Unsaturated and Collapsible Soils. 19(3–4). 371 - 399.
[10] Royster, D. L. (1980). Horizontal drains and horizontal drilling: an overview. Transportation Research Record. (783).
[11] SAVE, (1998). Value Methodology Standard. SAVE International.