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Life Cycle Cost Analysis of Geogrid Utilization for Landslide Management in Sentani-Waena Road, Jayapura, Papua

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Abstract

Life Cycle Costing (LCC) analysis of shotcrete and geogrid methods for slope reinforcement on the Sentani-Waena Jayapura road section has been studied. The topographical condition of Jayapura which is dominated by hills causes most of the roads to be built around hills or along the slopes of the hills such as the Sentani - Waena road segment. The purpose of this study was to analyze the cost of repairing the slopes that have been used on the Sentani - Waena km 15 to 25 km road section with the shotcrete method and the alternative method using geogrid and to analyze the efficiency of slope safety using the shotcrete method and using geogrid based on age and construction costs with LCC analysis. The research method used in this research was literature study and field survey, where the results of the field survey are obtained preliminary data which are then analyzed based on the type of construction used to calculate the value of life circle cost (LCC) based on the planned construction age until the construction cannot be used. The results showed that the cost of reinforcing slopes using geogrid requires less initial costs of Rp. 3.222.877.172.48, - then the shotcrete method and the current price (NPV) is less of Rp. 10.515.703.412.68, - compared to the shotcrete method. Cost maintenance for the shotcrete method is 14,524,629,029.64 with a construction service life of 50 years, while maintenance costs for the geogrid method are 14,992,621,120.87 with a service life of 100 years. Slope reinforcement using geogrid is more efficient by 69,35% compared to the shotcrete method.

Keywords : Life Cycle Costing, shotcrete, geogrid

1. Introduction

A slope is a land surface that has a certain slope to the horizontal plane. Slopes can form naturally due to geological factors such as river slopes, hillside, and mountain slopes, but can also be caused by human activities. Slope stability is influenced by soil structure, climate and weather, and human activities. Landslides on slopes often occur when the shear strength of the soil mass decreases.

The municipality of Jayapura, the capital of Papua province, is experiencing very fast and dynamic development. The topography of the city of Jayapura is in the form of hills with mountains, valleys, and rivers. The acceleration and dynamics of development are so fast, especially in the field of transportation infrastructure development in the form of roads built to reduce congestion. With the topographical conditions in the form of hills, most of the roads were built, circling the hills or tracing the slopes of the hills such as the Sentani - Waena road segment.

Jalan Sentani - Waena, which is the only road connecting Jayapura Regency - Jayapura City, has experienced an increase due to the large number of vehicles passing, and this road is built on fairly steep hillside slopes. This results in the slope conditions along the road prone to landslides and to overcome the landslides on the slopes, a safety reinforcement method has been carried out on the slopes in the form of Shotcrete / Cast slope surface. The slope of the shoulder of the road can be caused by soil conditions or roadside slope conditions that have low shear strength. Apart from geological factors, the causes of these landslides were caused by morphological and physical factors. One of the roads that have been repaired / safe slopes is the main road Waena - Sentani, especially at km 15 to km 25. With a large slope area, of course, it greatly affects the number of costs used, it is necessary to do alternative slope reinforcement such as the geogrid installation method.

Life Cycle Costing (LCC) analysis is conducted to obtain a quality and economical method of slope protection. LCC analysis is needed to determine the effectiveness of the method used for slope safety at km 15 to km 25 of the Sentani-Waena road. Research on LCC has been done a lot. An economic evaluation of the bridge to determine the priority of bridge handling

In this study, an LCC analysis will be carried out on the improvement/safety of the slopes of the Sentani-Waena road section (a case study of Jalan Waena Sentani km 15 to 25) Jayapura City, Papua. The purpose of this research is to analyze the cost of repairing the slopes that have been used on the Sentani - waena km 15 to 25 km road section with the shotcrete method and alternative methods using geogrid and to analyze the efficiency of slope safety using the shotcrete method and using geogrid based on age. and construction costs with LCC analysis.

2. Research Method

The research method used in this research is literature study and field survey, where the results of the field survey are obtained preliminary data which are then analyzed based on the type of construction used to calculate the value of life circle cost (LCC) based on the planned construction age until the construction cannot be used, and compared to find out the economic value of the construction used.

Initial data from this study are primary data and secondary data. Primary data includes descriptions of shotcrete activities, documentation of implementation, typical cross-sectional images of shotcrete execution, and shotcrete planning RAB. While the secondary data is the geographic unit price data and the alternative Budget plan (RAB) for reinforcing slopes with geogrids.

Research Procedure

a. From the data obtained, the initial cost is calculated which is the RAB for the implementation of slope reinforcement using the shotcrete method and the alternative geogrid method.

b. Calculating the net present value (NPV) for each slope strengthening method with the equation

$$NPV = \sum_{t=1}^{N} \lfloor (c)t : (1+i)^t \rfloor \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

With NPV is the net present value, (c) t is the t-th year cash inflows, (c0) t is the t-th year cash inflows, N is the economic age of the project, i is the applicable interest rate, t is the time.

c. Calculating the annual cost or operational and maintenance costs of the slope reinforcement method with shotcrete and geogrid with equations

$$A = P\frac{i(1+i)^N}{(1+i)^N - 1} \qquad (2)$$

Where A is annual cost, P is present cost, I is bank interests rest, dan N is project service life.

d. Calculating Life Cicle Cost (LCC) use the equation

$$\boldsymbol{LCC = C + M + O + R - S} \qquad (3)$$

Where C is the initial cost (present cost, rupiah), M is the maintenance cost (annual cost, rupiah / year) and O is the operational cost (consisting of energy costs and staff costs, annual cost, rupiah / year).

3. Analysis And Discussion

The Life Cycle Cost (LCC) analysis of slope reinforcement in this study will be calculated with 2 (two) alternatives. The first alternative is calculated using the shotcrete method, then the second alternative is using the Geogrid method of slope reinforcement. Operational costs are assumed to be 20% of maintenance costs while maintenance costs are 2% per year of the total building costs, (Permen pupr no.24 / prt / m / 2008). The economic life of the slope repair/safety building for the shotcrete method is 50 years where shotcrete is included in large building structures such as other important buildings, and for alternative reinforcement using the geogrid method is 100 years according to the geographic material property data, namely Environment, PH ＜ 11 at 120 years design life)

Interest rates in 2020 based on the interest rate index of several banks in Table 1 show the average interest rates each year. For the calculation of the analysis, an average interest rate of 5.48% was taken.

Table 1. Bank Interest Rest

No	Bank	Interest Rest 12 Months
1	Bank BI	5.00%
2	Bank BCA	5.13%
3	Bank Mandiri	5.50%
4	Bank BRI	5.63%
5	Bank BNI	6.13%
	Average	5.48%

Source: PIPU per 6 September 2020

3.1. Analysis of Life Cycle Cost LCC slope safety with the shotcrete method

The initial budget for the implementation of slope repair/maintenance on the Sentani - Waena road section km 15 to km 25 using the shotcrete project method is Rp. 7,965,598,000 (seven billion nine hundred and sixty-five million five hundred and ninety-eight thousand rupiahs). These costs include preliminary work, mobilization and demobilization work, excavation and earthworks, concrete work and pairing, final work, and construction safety management costs (SMKK). From Figure 1 and Table 2 it can be seen that the value of the shotrete method building has decreased in value. The closer to the end of the service life, the smaller the construction value.

Table 2 cash flow NPV shotcrete

Cash Flow NPV Shotcrete		
Periode	**NPV shotcrete**	
	(Rp)	Tahun
I	4,672,154,265.05	10.00
II	2,740,412,644.03	20.00
III	1,607,365,903.08	30.00
IV	942,786,901.82	40.00
V	552,983,698.70	50.00

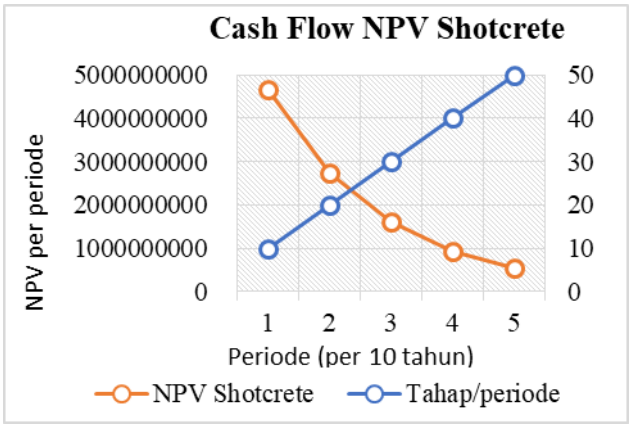

Figure 1 NPV shotcrete cash flow to construction service life

Table 3 cash flow annual cost shotcrete

Cash Flow Annual Cost Shotcrete		
Periode	**Annual Cost Shotcrete**	
	(Rp)	Tahun
I	2,062,885,233.00	10.00
II	2,388,819,398.22	20.00
III	2,800,086,699.02	30.00
IV	3,315,374,615.94	40.00
V	3,957,463,083.46	50.00

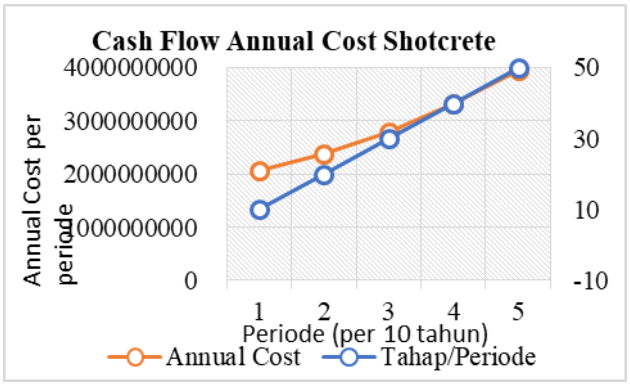

Figure 2 Graph of annual cost shotcrete cash flow to construction service life

From Figure 2 and table 3 it can be explained that the longer the construction life, the greater the maintenance costs.

Table 4 LLC Shotcrete cash flow

Cash Flow LCC Shotcrete		
Period	**LCC Shotcrete**	
	(Rp)	Year
I	6,735,039,498.05	10.00
II	5,129,232,042.25	20.00
III	4,407,452,602.10	30.00
IV	4,258,161,517.76	40.00
V	4,510,446,782.15	50.00

LCC shotcrete cash flow in table 4 shows that the total construction costs are inversely proportional to the construction service life where the longer the construction life, the smaller the construction value. LCC flow chart shotcrete method can be seen in Figure 3.

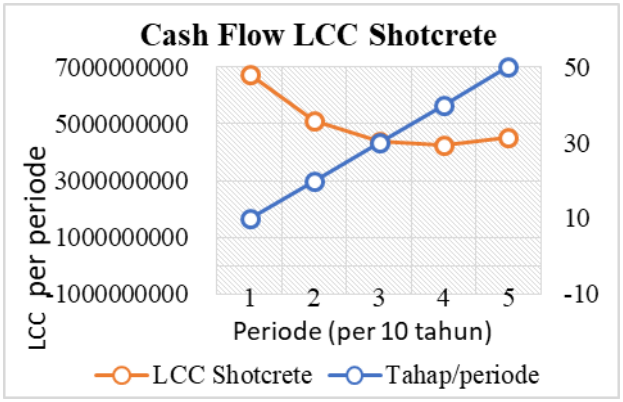

Figure 3 LCC shotcrete cash flow to construction service life

3.2. Life Cycle Cost Analysis of LCC slope safety by geogrid method

The initial cost of the alternative geogrid method for the implementation of slope improvement/slope improvement on the Sentani - Waena road section km 15 to km 25 using the geogrid method is planned with a project value of Rp. 2,282,837,000 (two billion two hundred eighty-two million eight hundred and thirty-seven thousand rupiahs). These costs include preliminary work, mobilization and demobilization work, excavation and earthworks, geogrid work, final works, and construction safety management costs (SMKK).

Table 5 cash flow NPV geogrid

Cash Flow NPV Geogrid		
Period	**NPV Geogrid**	
	(Rp)	Year
I	1,338,978,771.71	10.00
II	785,366,695.52	20.00
III	460,650,205.56	30.00
IV	270,190,489.48	40.00
V	158,477,950.78	50.00

Cash Flow NPV Geogrid		
Period	NPV Geogrid	
	(Rp)	Year
VI	92,953,904.23	60.00
VII	54,521,327.86	70.00
VIII	31,979,024.61	80.00
IX	18,757,026.93	90.00
X	11,001,775.81	100.00

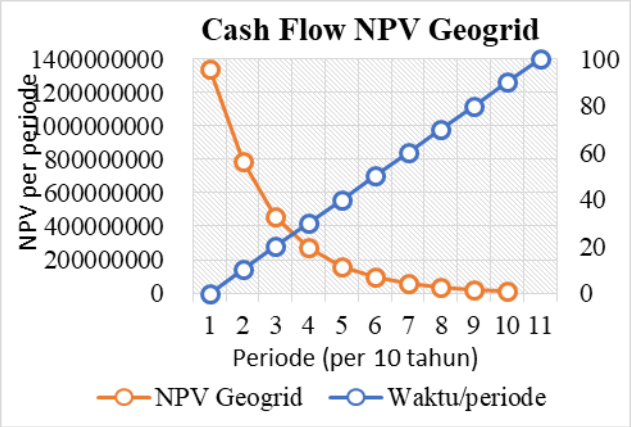

Figure 4 Geogrid NPV cash flow graph to construction service life

Geographical NPV value when seen from Table 5, it can be seen that the construction value is getting smaller with the increasing age of the construction service. The decrease in the value of the construction can be illustrated in graphical form on figure 4.

Table 6 cash flow Annual cost geogrid

Cash Flow Annual Cost Geogrid		
Period	Annual Cost Geogrid	
	(Rp)	Year
I	596,218,374.65	10.00
II	698,758,224.05	20.00
III	825,753,442.56	30.00
IV	982,559,619.54	40.00
V	1,175,705,188.56	50.00
VI	1,413,148,273.70	60.00
VII	1,704,589,783.81	70.00
VIII	2,061,855,072.65	80.00
IX	2,499,359,180.47	90.00
X	3,034,673,960.88	100.00

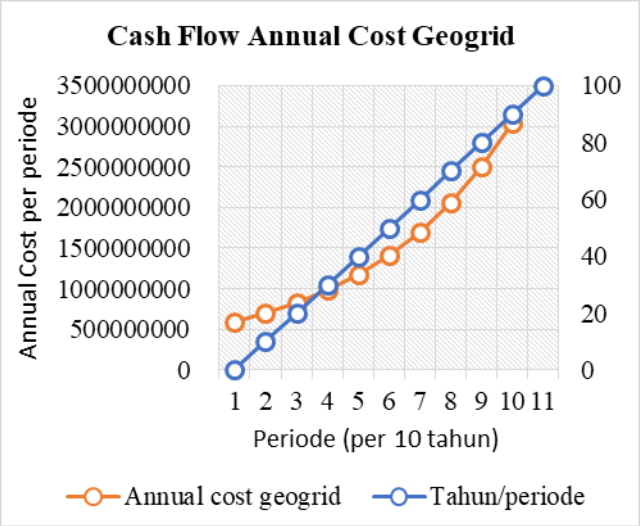

Figure 5 Graph of annual cost geogrid cash flow to service life of construction

From Figure 5 and Table 8, it can be seen that the value of geogrid maintenance is directly proportional to the construction age where the longer the construction service life, the greater the costs incurred for its maintenance.

Table 7 LLC geogrid cash flow

Cash Flow LCC Geogrid		
Period	**LCC Geogrid**	
	(Rp)	Year
I	1,935,197,146.36	10.00
II	1,484,124,919.57	20.00
III	1,286,403,648.11	30.00
IV	1,252,750,109.01	40.00
V	1,334,183,139.34	50.00
VI	1,506,102,177.93	60.00
VII	1,759,111,111.67	70.00
VIII	2,093,834,097.26	80.00
IX	2,518,116,207.40	90.00
X	3,045,675,736.69	100.00

Geographical LCC cash flow from table 7 and figure 6 shows that the total LCC value is inversely proportional to the service life of the construction where the longer the construction, the smaller the construction value.

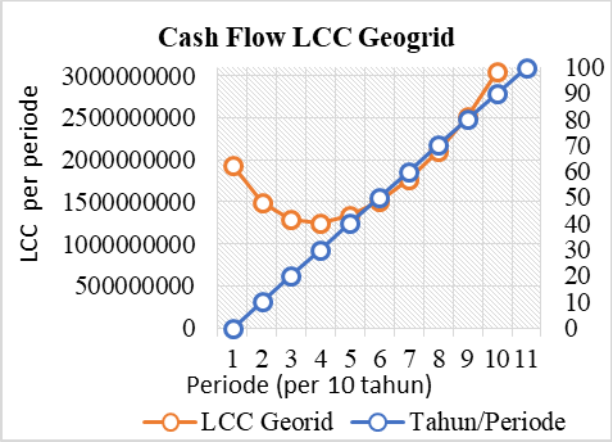

Figure 6 Graph of LCC geogrid cash flow to construction service life

3.3. Comparison of the LCC analysis of the shotcrete method with the geogrid method.

The comparison of the LCC analysis with the shotcrete method and the geogrid method which consists of a comparison of the initial cost, annual cost and LCC value can be seen in table 8.

Table 8 Comparison between the LCC value of the shotcrete method and the geogrid method

Comparison between the LCC value of the shotcrete method and the georid method				
Phase	Description	Alternative II	Alternative I	deviation
		shotcrete	Geogrid	
	Initial cost	7,965,598,000	2,282,837,000	5,682,761,000
10	I	4,672,154,265	1,338,978,772	
20	II	2,740,412,644	785,366,696	
30	III	1,607,365,903	460,650,206	
40	IV	942,786,902	270,190,489	
50	V	552,983,699	158,477,951	
60	VI		92,953,904	
70	VII		54,521,328	
80	VIII		31,979,025	
90	IX		18,757,027	
100	X		11,001,776	
	NPV	10,515,703,412.68	3,222,877,172.48	7,292,826,240.20
	Annual Cost	14,524,629,029.64	14,992,621,120.87	467,992,091.23
	LCC	**25,040,332,442.32**	**18,215,498,293.35**	**6,824,834,148.97**

From table 8 it can be calculated the value of efficiency (E) from the geogrid method as follows.

E =69,35 %

Table .8 is a comparison of the LCC values based on the calculation results. From the table it can be seen that the cost or initial investment that must be provided for the second alternative, namely slope reinforcement using geogrid (Rp. 2,315.83,000, -) is smaller as much as Rp. 5,649,761,000, - compared to the shotcrete method. Likewise for the current cost (NPV), if the planned age of the georid method is 100 years, the total cost of the alternative geogrid work is smaller,

amounting to Rp. 7,292,826,240.20, - compared to the first alternative with a construction age of 50 years of Rp. 10,515,703,412. 68, -

Meanwhile, the maintenance costs every year periodically decrease per period where the amount of maintenance for the shotcrete method is Rp. 14,524,629,029.64, with a construction service life of 50 years, while the maintenance costs for the geogrid method are Rp. 14,992,621,120.87, - with a service life. 100 years. When viewed from the maintenance costs of the shotceret method, it is Rp. 467,992,091.23 less than the shotctere method. However, when compared with the service life between 50 years of shotcrete and 100 years of geogrid method, it can be said that the geogrid method is more effective than the shotcrete method when viewed from the annual cost. And from the total it can be seen that there is a cost savings of Rp. 7,292,826,240.20, - for reinforcing slopes using geogrids. The efficiency value of reinforcing slopes using geogrid is 69.35%. This shows that the use of geogrids in slope reinforcement is more efficient based on cost and construction age compared to slope reinforcement using the shotcrete method.

4. Conclusion

Conclusion of the research are

a. The cost of reinforcing slopes using geogrid requires less initial costs and current costs (NPV) compared to the shotcrete method of Rp. 3,222,877,172.48 and Rp. 10,515,703,412.68, respectively. shotcrete for Rp. 14,524,629,029.64 with a construction service life of 50 years, while the maintenance costs for the geogrid method are Rp. 14,992,621,120.87, - with a service life of 100 years.

b. Slope reinforcement using geogrid is 69.35% more efficient than the shotcrete method.

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