Analysis of Worker Productivity at Construction Projects in Highlands: A Case Study from the Development of Penanjakan Viewpoint at Bromo Tengger Semeru National Park in East Java

Kusnul Prianto[1] and Mega Ayundya Widyastuti[1]
[1]*Department of Architecture, Universitas Islam Negeri Sunan Ampel Surabaya*

Keywords: Standard Time, Worker Productivity.

Abstract: One of the leading tourist destinations in East Java is Mount Bromo. This destination is included in the top 10 tourist channels that have received support from various parties including UNESCO and administratively under the Balai Besar of Bromo Tengger Semeru National Park. The increasing number of tourists has also increased the need for public facilities supporting the tourist area. The construction of the viewing tribune is a form of attention to the increasing number of tourists every day. The major work of this tribune is stone masonry, which is nearly 40 percent of the total work done. From the field observational data, the calculation of the standard completion time for each m3 of river-stone foundation is 202.086 minutes/m3 or 3.3681 hours/m3, meaning that the productivity of 2 workers and 3 workers in one day is 2.375 m3. Based on the calculation of the unit price of river-stone foundation installation in the contract, it is obtained the price of wages for installing river-stone foundation/m3, which is Rp 365,125.-. According to observations in the field, the installed price is the amount of wages in 1 day (8 hours), which is Rp 1,010,000.-. For 1 m3, it takes 3,3681 hours, so in 1 m3, direct costs in the field is (Rp. 1,010,000 / 8 hours) x 3.3681, or Rp 425,222. There is a difference as many as Rp 60,097.- in wages for every m3 of river-stone foundation.

1 INTRODUCTION

President Joko Widodo once said that countries which are able to survive nowadays are most visited countries by tourists, such as Singapore and Malaysia. These two countries are more advanced because they are supported by the tourism sector. Every year, 25 million tourists visit Malaysia, while there are 40 million tourist visits in Singapore (Rutmawati, 2017).

One of the leading tourist destinations in East Java is Mount Bromo. Mount Bromo is included in the top 10 tourist channels that have received support from various parties including UNESCO (Tourism Canal, 2017). Mount Bromo is part of Bromo Tengger Semeru National Park (TNBTS), so administratively, the development of Mount Bromo is under the work unit of the National Park.

One of the destinations in the area of Mount Bromo is Mount Penanjakan. It is the best viewpoint to see sunrise over Mount Bromo and is very crowded at night and before the morning.

1.1 Research Problems

1. How to calculate worker productivity in constructing river-stone foundation per one cubic meter?
2. How to calculate the cost of river stone, cement, and sand in one-cubic-meter construction at the work location?

1.2 Research Purposes

The purposes to be achieved in this research are:
1. To calculate worker productivity in constructing river-stone foundation per one cubic meter
2. To calculate the cost of river stone, cement, sand in one-cubic-meter in one-cubic-meter construction at the work location.

1.3 Research Limitations

a. Parameters in this research are worker productivity in constructing foundation and the

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installed price of the foundation material at the work location.
b. The data used are primary and secondary data. Primary data are from direct observation on location, while secondary data are based on literature studies.

1.4 Significance of the Research

This research is quite urgent, especially to find real fixed unit price of river-stone foundation construction job in work project located at highlands. It is expected to be able to be used as a reference for proposals or planning for similar jobs and locations.

This research is also important for the development of science and technology within Islamic higher educational institutions, which have been converted into universities for only several years and has begun to concern in science and technology.

1.5 Theoretical Framework

Real fixed unit price analysis is a price analysis conducted by direct observation of work in the field by considering various aspects, such as worker productivity, the use of work aids, material procurement on work site, and other aspects related to the work.

2 THEORETICAL STUDY

Research on the productivity of workers in many construction works has been previously conducted. One research has been conducted by Yorristia Adelia Layzanda, Robert J. M. Mandagi, and Pingkan A. K. Pratasis from the Faculty of Engineering, Department of Civil Engineering, Sam Ratulangi University in Manado. The research has stated that a calculation basis, such as Indonesian National standard (abbreviated SNI), is needed. Whereas from the real application in the field, it can be seen that real fixed unit price is the real cost of the work.

This study compares real fixed unit price for wages. The results of SNI analysis and real fixed unit price are compared using power index, direct observation at masonry and plastering work sites of projects in the city of Manado.

Research on worker productivity has been also conducted by Jan Tamamengka, Pingkan A. K. Prastasis, and D. R. O. Walangitan from Faculty of Engineering, Department of Civil Engineering, Sam Ratulangi University, Manado. The research has stated that in the implementation of project analysis, a very important role in employment is labor or workers.

2.1 Productivity

Productivity has different meanings for each individual. In general, productivity is defined as the relationship between tangible and physical output (of goods or services) and actual input. One of the highest potentials in increasing productivity is by reducing ineffective working hours. The main opportunity in increasing human productivity lies in individual abilities, individual attitudes in work, and work management and organizations. Meanwhile, factors that affect productivity are identified as follows:

1. Weather conditions
2. Physical condition of work site
3. Supporting facilities
4. Supervision, planning, and coordination
5. Composition of the working group
6. Overtime
7. Project Size
8. Hiring options (employees or subcontractors)
9. Experience curve
10. Labor density

2.2 Research Development Plan of Balai Besar of Bromo Tengger Semeru National Park

Research development plan is to analyze the concept of development and product item that will be implemented to maximize the potentials in Bromo region and Mentigen. The plan has been listed in the Short-Term Planning of Balai Besar of Bromo Tengger Semeru.

2.3 Worker

This study calculates worker productivity, work quality and quantity, efficiency of work plans, working hours, environmental conditions, and others. The following are the functions and tasks of workers based on their expertise:
1. Construction supervisor, is a person who has expertise in certain field according to certain type of work.
2. Chief builder, is a person who has expertise in the field of building.
3. Builders, are people who directly do work of building according to the instructions of chief builder.
4. Workers, are people who help builders or chief builder with all types of work without having to have expertise in certain field.

2.4 Indonesian National Standard (SNI) for Unit Price Analysis

Analysis of unit prices in Indonesia is based on analysis of SNI that has been updated at certain period of time. This study compares the analysis of real fixed unit price for wages with the analysis of price according to SNI on the construction of river-stone foundation.

The SNI analysis in this research is according to the 2013 SNI analysis. Details of the construction of river-stone foundation can be seen in Figure 4.

2.5 Time study using the Work Sampling Method

According to Barnes (1980), time study is an activity to determine the time needed by an operator (who averagely has good skills and is well-trained) in doing work activity in normal working conditions and time.

2.6 Working Time Method of Work Sampling

Work sampling is a technique for conducting a large number of observations on the activities of a machine, process, or worker/operator (Wignjosoebroto, 2003).

3 RESEARCH METHOD

In this study, several research stages are conducted as follows:

Stage 1. Problem Identification.
At this stage, the steps taken are to search for topics and then to study those topics. This stage also involves the process of searching literature related to research material.

Stage 2. Data Collection.
At this stage, data for this research are collected. The data are as follows:
a. Data on worker productivity and data of installed price of foundation material. These data are taken by observing and retrieving data directly at the work location.
b. Data from the Balai Besar of Bromo Tengger Semeru National Park in the form of Budget Estimating and Cost Planning and supporting documents for the development of the viewpoint area for the 2017 budget year.

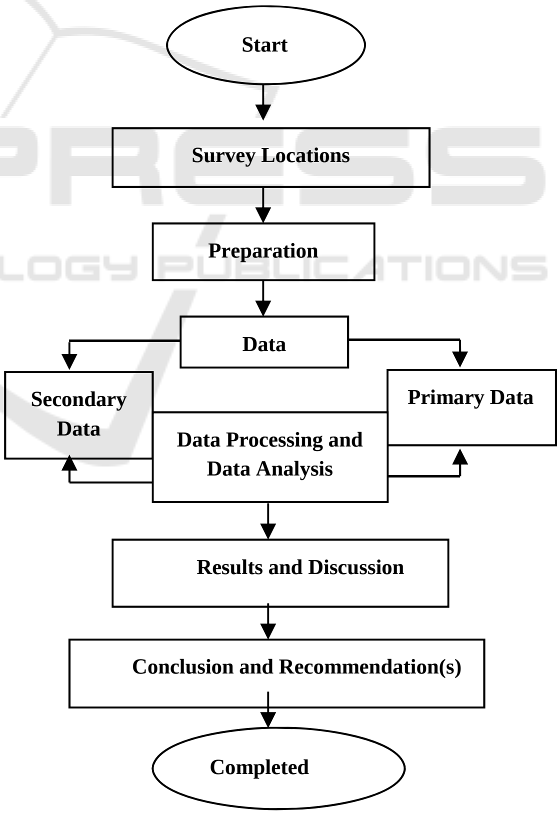
Stage 3. Calculation of Worker Productivity.
At this stage, calculations are made on productive and unproductive work times.

Stage 4. Data Processing Using Work Sampling Model.
This is the stage where the data on productivity are processed using work sampling method.

Stage 5. Material Price Calculation.
At this stage, material costs, from the supplier of initial purchasing to the work location, are directly calculated by taking into account the cost of repayment.

Stage 6. Analysis and Discussion.
At this stage, the results of data processing using work sampling methods are analysed and discussed.

Stage 7. Report Writing.
This is the stage where documentation of research results is conducted.
The research flow is as follows:



4 DISCUSSIONS

We give some result and can be discuss.

4.1 Existing Condition of Pakis Bincil - Dingklik Block (PTN Penanjakan Resort)

Pakis Bincil-Dingklik block is located at coordinates 112 ° 55 '17 "- 112 ° 56' 02" E and 7 ° 55 '03' '- 7 ° 56' 02 " S. This block has an area of 95 Ha and is located at Penanjakan Resort.

Renovation of Stairs of Penanjakan Viewpoint.

Pananjakan viewpoint is crowded-tourist destination at Bromo Tengger Semeru National Park (TNBTS). This place is the concentration point of tourists at Bromo Tengger Semeru National Park. Tourists gather at this viewpoint to enjoy the beauty of sunrise over Mount Bromo. Some of stairs at Pananjakan viewpoint are currently damaged so renovations are urgently needed.

Renovation of Penanjakan Viewpoint Tribune.

The current capacity of Pananjakan viewpoint is still considered to be low for the high number of tourists coming to Bromo Tengger Semeru National Park. Moreover, some facilities have been damaged. Therefore, renovation is needed so that the utilization of Pananjakan viewpoint can be optimal and representative as a service to tourists.

Construction of Penanjakan Viewpoint.

The renovation work of tribune at Penanjakan viewpoint aims to increase the capacity for visitors who can enjoy the sunrise over Mount Bromo. The existing tribune can only accommodate around 200 visitors a day and this renovation is expected to accommodate around 750 visitors a day.

The location of Penanjakan is on the north side of Mount Bromo with altitude of 3,000 above sea level. Access road to this location is tortuous and uphill with an angle of almost 40 degrees over a hill. With the condition of road access, the problem becomes more significant because it causes the price of material at the work location to become more expensive.

Installation of river-stone foundation on the tribune for visitors was done by dismantling the existing foundation on the top only, so that the new foundation can be integrated with the old ones. The layout image of the new foundation on the sides of the tribune can be seen in Figure 1.

Development of the tribune above was divided into 8 sections with maximum number of visitors up to approximately 800 people in a day. The division of entrance and exit becomes clearer, compared to previous condition. River-stone foundation was built with a height of 60 cm with a width of 80 cm in order to facilitate circulation.

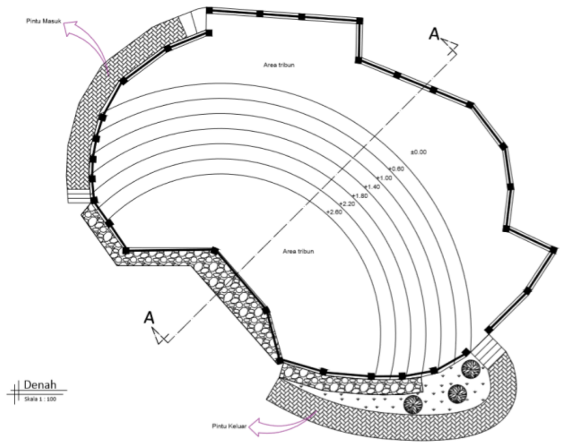


Figure 1: Layout Planning of Viewpoint Tribune Development.

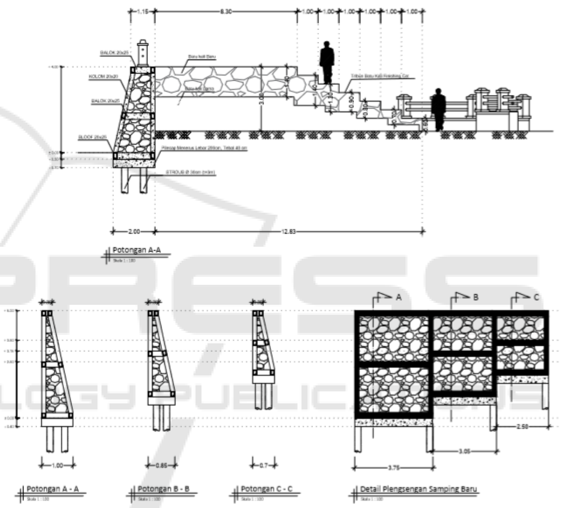


Figure 2: Part of Viewpoint Tribune.

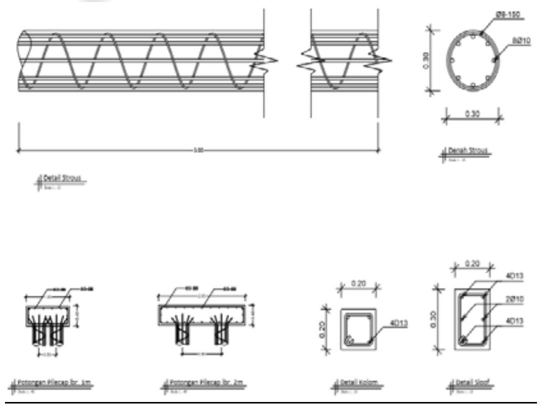


Figure 3: Part of the Foundation.

The work element is described so that measurement variables are obtained based on the work components performed. The construction of river-stone foundation, with a ratio of 1 PC: 3, has the following elements:

1. Dig the ground for the river stone.
2. Make sure that the width and the depth of the ground for the river stone are as planned.
3. Install wooden stakes and threads as benchmark for stone pair levelling.
4. Make a mixture for the river-stone foundation.
5. Lay concreting sand and level it.
6. Dampen the river stones first before installation.
7. Install aanstamping (empty stone) first.
8. Install river stones over the aanstamping using a mixture that evenly fills the cavities between the stones.
9. The river stones are arranged in such a way that the stone foundation will not be easily broken and largely hollow.
10. Check the elevation of the stone construction, whether it is according to plan or not.
11. Non-productive.

The observation time was determined randomly, under the condition that the time was between 7:30 a.m., which is the time when the workers started working, and 11:30, and between 12:30 and 16:30. Between 11:30 and 12:30 is a break for the workers. Working hours were 8 hours in a day.

4.2 Data Processing of Field Observation Results

Data were collected 42 times for each working day and for each worker. There were 5 workers within 5 days. Thus, the data obtained in 5 working days were 5x42 = 210 data, so here, N is 210 (for each worker). Data processing and % productive control of the observation results on builders and workers are presented in the form of tables and graphs as follows:

Table 1. Work Sampling Data of Construction Work.

Activity	Worker	Observation Frequency (Day)					Total
		1	2	3	4	5	
Produktive	Builder I	37	39	38	37	39	190
	Builder II	36	38	36	37	39	186
	Worker I	38	36	34	37	37	182
	Worker II	35	35	38	38	36	182
	Worker III	37	38	37	39	36	187
Non Produktive	Builder I	3	1	2	3	1	10
	Builder II	4	2	4	3	1	14
	Worker I	2	4	6	3	3	18
	Worker II	5	5	2	2	4	18
	Worker III	3	2	3	1	4	13
Total % Produktive	Builder I	40	40	40	40	40	200
	Builder II	40	40	40	40	40	200
	Worker I	40	40	40	40	40	200
	Worker II	40	40	40	40	40	200
	Worker III	40	40	40	40	40	200
Total % Produktive	Builder I	92,5	97,5	95	92,5	97,5	475
	Builder II	90	95	90	92,5	97,5	465
	Worker I	95	90	85	92,5	92,5	455
	Worker II	87,5	87,5	95	95	90	455
	Worker III	92,5	95	92,5	97,5	90	467,5

Uniformity Test for Data of River-Stone Foundation Construction Job

Uniformity test results can be seen in Table 2 below:

Table 2: Data Uniformity Test.

Worker	$p = \frac{\Sigma pi}{k}$	$n = \frac{\Sigma ni}{k}$
Worker I	0.95	40
Worker II	0.93	40
Builder I	0.91	40
Builder II	0.91	40
Builder III	0.935	40

BKA $= p + 3\sqrt{\frac{p(1-p)}{n}}$	BKB $= p - 3\sqrt{\frac{p(1-p)}{n}}$
1.04	0.823
1.05	0.872
1.03	0.782
1.05	0.875
1.04	0.839

where:

p = productivity percentage on day i
k = number of observations (5 days)
n = number of observations on day i

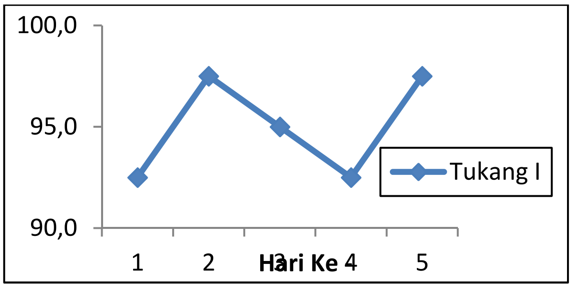


Figure 4: Control Chart of Productive Percentage of Builder I.

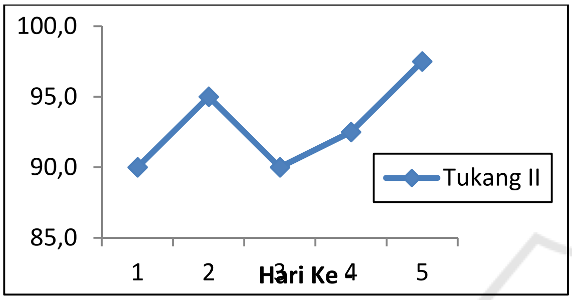


Figure 5: Control Chart of Productive Percentage of Builder II.

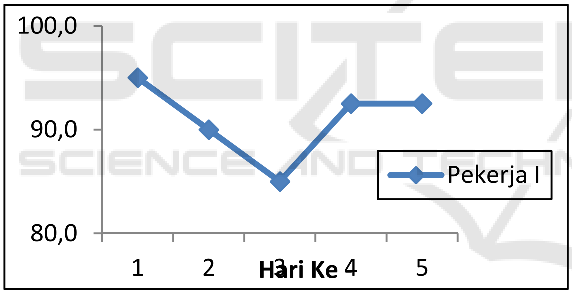


Figure 6: Control Chart of Productive Percentage of Builder III.

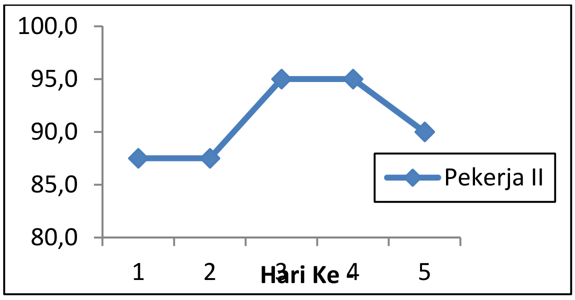


Figure 7: Control Chart of Productive Percentage of Builder IV.

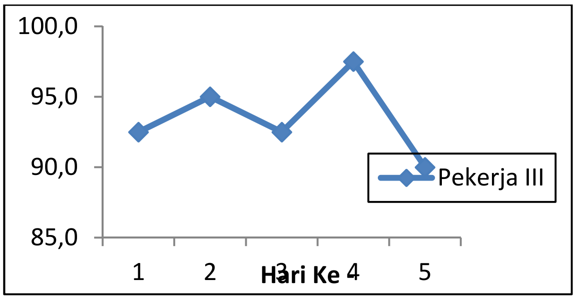


Figure 8: Control Chart of Productive Percentage of Builder V.

Accuracy level was calculated as a reference to minimize errors made by researchers in retrieving data during the construction work.

Table 8: Number of Observations on River-Stone Foundation Construction Job.

Human Resource	N	N'	Ket
Builder I	200	172.96	N' < N
Builder II	200	177.76	N' < N
Worker I	200	168.45	N' < N
Worker II	200	182.85	N' < N
Worker III	200	172.96	N' < N

Based on the data obtained, it was found that N '<N both from workers and from builders. This finding means that the observational data obtained was sufficient.

Table 9: Allocation of Time Utilization on Work Elements by Workers.

$p-3\sqrt{\frac{p(1-p)}{n}}$	pi	$P+3\sqrt{\frac{p(1-p)}{n}}$
0.00672	0.020	0.03348
0.00740	0.023	0.03470
0.02932	0.048	0.07067
0.00808	0.027	0.03492
0.06853	0.091	0.12468
0.04495	0.062	0.09314
0.06892	0.104	0.12472
0.10889	0.142	0.17512
0.04328	0.333	0.36782
0.28636	0.072	0.08971
0.05854	0.080	0.11237

4.3 Calculation of the Standard Time Needed in the Installation of River-Stone Foundation Using the Composition of 1 PC: 4 PS

From the data above, the standard time of construction of river-stone foundation can be calculated using the following steps:

a) The number of data from 5-day observation on 5 workers with each worker becoming the source 40 data can be calculated as following:

5 (days) x 5 (workers) x 40 (data) = 1000 observational data

b) Total time (in minute) spent for 5-day observation = 8 (hours) x 60 (minutes) x 5 (days) = 2400 minutes

c) The number of observed productive activity data from the table can be calculated as follows:
Number of productive data of builders = 376 data
Number of productive data of workers = 551 data
Total Number = 927 data

d) Productive percentage:
Total number of productive data = 927 data
Number of observation data = 1000 data
Productive percentage = (927/1000) x 100% = 92.7%

e) Productive time (in minute):
Productive percentage x amount of time (in minute) of observation = 92.7% x 2400 minutes = 2224.8 minutes

f) Number of products produced: (2.5+2.4+2.6+2+2.5) m3 = 12 m

g) Cycle time (Ws) required:
Amount of productive time (in minute)/number of products: = 2224.8 minutes/12 m3 = 185.4 minutes/m3

h) Time allowance (I) used is as follows:
Personal needs = 5%
Relieving fatigue = 4%
Inevitable obstacles = 5%
Total = 14%

i) Adjustment factor (p), using Westinghouse method:
Skills: Good (B2) = +0.08
Effort: Excellent (B1) = +0.10
Working condition: Good (C) = +0.02
Consistency: Good (C) = +0.01
Total = +0.21

j) Standard time (Wb) = Wn + (I x Wn)
= 185.4 + (0.09 x 185.4)
= 202.086 minutes/m3
= 3.3681 hours/m3

In other words, it took 202.086 minutes or 3.3681 hours to complete the construction of river-stone foundation for every m3.

k) The analysis of the unit price of river-stone foundation installation in the contract was as follows:

Worker = 1.5 person/day
= 1.5 x Rp 100,000.-
= Rp 250,000.-
Bricklayer = 0.75 x Rp 125,000.-
= Rp. 93,750.-
Chief Bricklayer = 0.0750 x Rp 135,000.-
= Rp 10,125.-
Supervisor = 0.0750 x Rp 150,000.-
= Rp 11,250.-
Total Wages for Installing River-Stone Foundation/m3 = Rp 365,125. -

l) Based on observation in the field, the installed prices were as follows:

Builder = 2 x Rp 125,000.-
= Rp 250,000.-
Worker = 3 x 100,000.-
= Rp 300,000.-
Chief Builder = 1 x 135,000.-
= Rp 135,000.-
Supervisor = 1 x 150,000.-
= Rp 150,000.-
Material transport cost = 1 Ls = Rp. 175,000.-
Wages for installing foundation in 1 day (8 Hours) = Rp. 1,010,000. -
Every 1 m3 took 3.3681 hours, so for every 1 m3, real direct cost was (Rp. 1,010,000 / 8 hours) x 3.3681 = **Rp 425,222. -.**

m) There was a difference in wages as many as Rp 60,097. - for every m3 of river-stone foundation.

4.4 Installed Cost Analysis of Supplier of River Stone, Cement, and Sand in One Cubic Meter at the Renovation Work Site of Penanjakan Tribune

Material transport cost at locations that have special terrain was calculated by referring to the Ministry of Public Works and Public Housing Regulation No.28/PRT/M/2016 on Unit Price Analysis (this analysis only applies to higher or steeper slope of 1v: 10h). The calculation is as follows:

Menaikkan 1 m^3 material sejauh 100 m					**Rp 785.910,00**
(Pasal T.15.c.10) + (Pasal T.15.c.11) halaman 129-130)					
Tenaga					
No	Uraian	Satuan	Koef	Harga	Jumlah Harga
1	Pekerja	Org	6,294	Rp100.000,00	Rp629.400,00
2	Mandor	Org	0,36	Rp150.000,00	Rp54.000,00
				Jumlah Tenaga	Rp683.400,00
				Overhead + Profit 15%	Rp102.510,00
				Harga Satuan Pekerjaan per - m^3	Rp785.910,00

Figure 9: Analysis of Foundation Construction.

From work unit basic price, the material was transported as far as 100 m above, then material transport cost to the work location can be calculated as follows:

- 1 m3 of split stones
  Unit basic price of transport of 1m3 stones

  =1.1 x 1.26/1.1 x unit basic price

  =1.1 x 1.26/1.1 x Rp 785,910.00
  = Rp 990,246.60
- 1 m3 of coral/gravel
  Unit basic price of transport of 1 m3 of coarse/coral aggregate
  = 1.0 x 1.26 / 1.1 x unit basic price
  = 1.26 / 1.1 x Rp 785,910.00
  = Rp. 900,224.18
- 1 bag of cement
  Unit basic price of transport of 1 bag of cement
  = 1.0 x 0.05 / 1.1 x unit basic price
  = 0.05 / 1.1 x Rp 785,910.00
  = Rp 35,723.18

5 CONCLUSIONS

From observation results, data processing, and data analysis using work sampling method on construction of river-stone foundation in the renovation project of Penanjakan tribune viewpoint, the conclusions are as follows:

1. From the primary observational data, it is obtained standard completion time for each m3 of river-stone foundation, which is 202.086 minutes/m3 or 3.3681 hours/m3. This finding means that the productivity of 2 workers and 3 workers in one day is 2.375 m3.

- Based on the analysis of unit price of river-stone foundation installation in the contract, it is obtained total wages for installing river-stone foundation/m3 = Rp 365,125. -.
  According to field observation, wages for installing foundation in 1 day (8 Hours) was Rp. 1,010,000. -.
  Every 1 m3 took 3.3681 hours, so for every 1 m3, real direct cost was (Rp. 1,010,000 / 8 hours) x 3.3681 = Rp 425,222. -.
- There was a difference in wages as many as Rp 60,097.- for every m3 of river-stone foundation. It can be interpreted that installed price in the field is more expensive than the price according to unit price analysis using Indonesian National Standard (SNI). This difference was caused by several factors, such as weather, workplace altitude, unobserved behavior of the workers.

2. On-site price of material, based on calculations, is as follows:

1 m3 of split stone = Rp 990,246.60
1 m3 of coral/gravel = Rp 900,224.18
1 bag of cement = Rp 35,723.18

From overall result of this research, the following recommendations were proposed:
1. Research variables, such as weather, worker behavior, oxygen level in the body, are recommended to be added in future research because this research was conducted in mountainous area, in which the higher altitude gets, the lower the oxygen level becomes.
2. It will be better if the period of observation can be longer so that more precise standard time can be obtained.
3. Other types of work, such as concrete work, plastering, etc., should be studied in order to develop job analysis coefficients for projects taken place in highland areas.

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