International Journal of Scientific Engineering and Science
Volume 4, Issue 1, pp. 58-62, 2020. ISSN (Online): 2456-7361

Optimization Analysis of Heavy Equipment Combination in the Soil Pilot Project, Viewed From the Time and Cost of the Bendo Building Development Project in Ponorogo District, East Java

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Abstract— *Bendo Dam is one of the dams proposed in the Bengawan Solo River Basin Development Project Master Plan in 1974. The construction of the Bendo Dam is one of the efforts to develop the Ponorogo Regency which is related to the development of water resources, to meet various community needs such as irrigation water supply, domestic raw water, and industry as well as flood control and tourism.*

For the analysis of optimizing the combination of heavy equipment in a landfill project, productivity and number of heavy equipment are calculated and making several types of heavy equipment combinations with different types and types. The combination is Combination I, Combination II, Combination III, Combination IV.

Based on the calculation of heavy equipment productivity, the most effective and efficient combination is Combination IV because in this combination the costs incurred are relatively smaller than using other combinations. It can be seen from the productivity and the number of each heavy equipment as follows: Excavator 0.93 m3 (PC-200) 36 units 14 days, 12 m3 Dump Truck 227 units 14 days, Bulldozer 155 Hp (D68) 5 units 13 days, Roller BW-141 72 units 14 days. The most efficient total cost to complete the Bendo Dam embankment project work is: Rp. 21,611,921,049

Keywords— *Heavy Equipment Productivity, Heavy Equipment Combinations, Time and Cost.*

I. INTRODUCTION

Ponorogo is one of the regencies in East Java Province. Most people in rural areas work in agriculture. However, there are problems with the water resources management system. Agricultural fields experience drought in the dry season, and when the rainy season is flooded. Resulting in farmers experiencing losses in terms of income, due to crop failure. In addition to agricultural fields, many people's homes and public facility buildings were affected by the flood. In 2007, Ponorogo Regency was hit by a flood with a large volume of water. Almost all sub-districts in Ponorogo were flooded, including the city area. The disaster was a result of the volume of water that fell during the rainy season, exceeding the capacity of the Keyang River and Ngindeng River. So that water cannot be contained, overflow and soak the area crossed by the two rivers.

Careful management of water resources is needed, in order to obtain maximum results. The Government of the Regency of Ponorogo through the Ministry of Public Works and Public Housing Directorate General of Water Resources, the Great Bengawan Solo River Basin, is working to provide solutions to overcome the problems of flooding and drought through the construction of Bendo Dam, Sawoo, Ponorogo.

Bendo dam is planned to function as a source of irrigation for an area of 3,299 ha and excess water will be channeled to Jati Dam which has an area of 4,500 ha of irrigation through the Keyang River. Bendo Bend will also be used to meet the raw water needs of the city of Ponorogo by 320 liters / second which is projected to meet the needs of raw water until 2025.

Bendo Dam is one of the dams proposed in the Bengawan Solo River Basin Development Project Master Plan, in 1974. In a review of the Bengawan Solo River Basin Development Project Master Plan by the Nippon Koei Consultant Co., LTD., Japan through a Comprehensive Development and Management Plan (CDMP) in 2001, Bendo Bend is still one of the recommended reservoirs for further study.

The construction of the Bendo Dam is one of the efforts to develop the Ponorogo Regency area related to the development of water resources, to meet various community needs, such as the supply of irrigation water, domestic and industrial raw water and flood control and tourism.

The interesting thing about this project so that it can be used as a Thesis material is that the planning consultants do not yet know how much the budget provided by the Government to complete this work project, therefore an optimal time and cost analysis plan is needed to complete the embankment work.

II. LITERATURE REVIEW

The use of heavy equipment in a project affects the change in soil in volume and compactness. Knowledge of the characteristics and behavior of soils is very important because it influences the heavy equipment in determining the type of

Volume 4, Issue 1, pp. 58-62, 2020. ISSN (Online): 2456-7361

equipment to be used and the estimation production, calculation of work volume and the ability to work of heavy equipment under existing material conditions. Thus the suitability of the tool is required with material conditions, otherwise it will cause difficulties in the form of inefficiency of the tool that will automatically cause losses due to the many "lose time". Some of the important physical properties to be considered for earthwork are as follows:

1. Material development
2. Weight and weight of material
3. Material hardness
4. Carrying capacity of the soil

Material development is a change in the form of adding or reducing the volume of soil material disturbed from its original form. From these factors the material form is divided into 3 states, namely:

a. Original Condition (Bank Condition)

The condition of soil material that is still natural and has not experienced technological disruption is called the original state (bank). The grain conditions it contains are still well consolidated, the size of this land is used as a basis for calculating the amount of land removal

b. Loose condition

The condition of the soil material after being carried out (disturbing), such land for example is in front of the dozer, in a bucket on a truck, and so on. Material excavated from its place of origin will experience a change in volume. This is due to the addition of air cavities between the grains of soil. Thus the volume will be greater. Size of loose material is usually expressed in loose measurements (LM)

c. Solid state (Compact)

Solid state is the state of the land after being backfilled with compaction efforts. This situation will be experienced by materials that undergo the process of compaction (compression). Volume changes occur because of the shrinkage of the air cavity between the soil particles. Thus the volume decreases, while the weight remains. The volume of land after the compaction is held, may be greater or perhaps also smaller than the volume in the state of the bank, this depends on the compaction effort undertaken. Size of soil volume in solid condition is usually stated in compact measure.

A. Excavation Work

This work is generally required for the manufacture of clean water channels and gutters, for the formation of excavations or foundation pipes, culverts, sewers or other structures, for the disposal of unused material and topsoil, for slope stabilization work and disposal of landslides, for excavation of construction materials and disposal of the remaining excavated material, for stripping and disposal of asphalt pavement in old pavement, and generally for the formation of profiles and cross sections of the road body. Excavation work can be in the form of:

- Common excavation

The usual excavation covers all excavations that are not classified as quarrying stones, structural excavations, excavation excavation of material sources (borrow excavation) and excavation of road pavement

- Stone scrap

The excavation of chunks of rock in volume 1 or more and all such stones or other materials is impractical to be excavated without the use of compressed air devices or embossing and blasting

- Structural excavation

The excavation on all types of soil within the occupational boundary is called or shown in the figure for the structure. Any excavation defined as ordinary quarry or quarry excavation cannot be included in the excavated structure Limited structure excavation for excavation of bridge foundation floor, concrete retaining wall, and other load-bearing structures. Structural excavation works include: backfilling with approved materials, disposal of unused quarrying materials, all drainage, pumping, landfill, support, construction workplaces and demolition needs

- Paved asphalt pavement.

Excavation on old pavement and pavement pavement material removal with or without Cold Milling Machine

B. Dumping Work

Heaps are divided into three types, namely ordinary heaps, heaps of choice and heaps of choice on swamps. The optional pile will be used as a capping layer to increase the carrying capacity of the subgrade, as well as in water drainage areas and similar locations where plastic material is difficult to compact properly. Optional dumps can also be used for slope stabilization or embankment widening work if steeper slopes are needed due to space constraints, and for other embankment work where embankment strength is a critical factor. Selected piles on swamp land will be used to cross low-lying areas and are always inundated by water.

The weighing materials used consist of:

- Material of soil deposits from excavated with good quality
- Soil deposited material will meet the height of the embankment / cliff which is landslide, impermeable to water, and the quantity of material does not contain organic substances (easily dissolved) and the material used must be durable.
  - Groundwork method
    1. Excavators
       The soil is dug using heavy equipment Excavators in accordance with the predetermined planning, the excavated soil is put into a dump truck
    2. Dump Truck
       After the excavation of soil is put into a dump truck dumped into the disposal area of the remaining land that is still within the project site
    3. Bulldozers
       After the soil is dumped into the remaining landfill area, then the soil is flattened using a bulldozer
    4. Roller
       After leveling using a dozer then the ground is compacted using a roller

Types of Heavy Equipment

Heavy equipment in civil engineering is used to assist humans in carrying out structural construction work, especially large-scale projects that aim to facilitate humans in the process so that the expected results can be achieved easily

in a relatively shorter time. In a project to be started the contractor will choose the tools to be used by the project, the selection of tools to be used is one of the important factors in the success of a project in the selection of heavy equipment, there are several factors that must be considered so mistakes in the selection of tools can be avoided. These factors include the following

1. Functions that must be carried out. Heavy equipment is grouped according to function, such as for digging, transporting leveling surfaces and others.
2. Equipment capacity. The choice of heavy equipment is based on the total volume or weight of the material based on the total volume or weight of material that must be transported or worked on. The capacity of the chosen tool must be suitable so that the work can be completed at the specified time.
3. How to operate. The machine is chosen based on direction (horizontal and vertical) and distance of movement, frequency of movement, etc.
4. Economy. In addition to investment costs or equipment rental costs, operating and maintenance costs are important factors in the selection of heavy equipment.
5. Type of project. There are several types of projects that generally use heavy equipment. These projects include building projects, ports, roads, bridges, irrigation, forest clearing, and so on.
6. Project location. The location of the project is another thing that needs to be considered: in the selection of heavy equipment, for example high-altitude project sites require heavy equipment that is different from the low-lying project location.
7. The type of material to be worked on can affect the heavy equipment to be used. Soil can be solid, loose, hard or soft.
8. Field conditions. Conditions with difficult terrain and good terrain are other factors that influence machine selection.

In accordance with the limitations of the problem in the preparation of this thesis, the heavy equipment used by the Bendo Dam project in earthworks includes pile excavation work. The heavy equipment used are:

- Excavators
- Dump Truck
- Dozer
- Roller

III. Research Methods

3.1 Research Location

The locations in this study are:

a. The location of the landfill is located in Sokoo District
b. The location of the landfill is located 15 km from the project site
c. The backfill location is located in Bendo Hamlet, Nginden Village, Sawo District, Ponorogo Regency.

3.2 Primary Data

a. Data on the size of the area carried out backfill
b. Distance data between capture location and backfill location
c. Excavator cycle time data
d. Dump Truck travel time data
e. Bulldozer cycle time data
f. Roller cycle time data

3.3 Secondary Data

Secondary data is data obtained indirectly, in the form of data obtained from certain references or literature relating to heavy equipment in the Bendo Dam landfill construction project, including:

a. Project technical specifications
b. Design engineering details
c. Project implementation method
d. Heavy equipment manual

3.4 Combinations of Heavy Equipment Under Study

TABLE 3.1: Machine Combinations

No	Tool Combination Diagram	Description	Note
1.	Combination 1: 1, 3, 5, 6	1. Excavator Komatsu (PC-708) 3. Dump Truck (5m^3) 5. Bulldozer Komatsu (D68) 6. Roller Bomag (BW-141)	1. Excavator Komatsu (PC-70) 2. Excavator Komatsu (PC-200)
2.	Combination 2: 1, 4, 5, 6	1. Excavator Komatsu (PC-70) 4. Dump Truck (12m^3) 5. Bulldozer Komatsu (D68) 6. Roller Bomag (BW-141)	3. Dump Truck (5m^3) 4. Dump Truck (12m^3)
3.	Combination 3: 2, 3, 5, 6	2. Excavator Komatsu (PC-200) 3. Dump Truck (5m3) 5. Bulldozer Komatsu (D68) 6. Roller Bomag (BW-141)	5. Bulldozer Komatsu (D68) 6. Roller Bomag (BW-141)
4.	Combination 4: 2, 4, 5, 6	2. Excavator Komatsu (PC-200) 4. Dump Truck (12m^3) 5. Bulldozer Komatsu (D68) 6. Roller Bomag (BW-141)	

Source: Ordered according to Chapter II

3.5 Research Stages

The stages of the research are systematic steps to complete the study of landfill in the Bendo Bendo Dam Ponorogo construction project. The stages in question are as follows:

a. Literature study from various literary books
b. Summarize the theories that are interconnected
c. Collecting and managing data
d. Determine the pile volume

e. Determine the alternative combination of heavy equipment used (excavators, dump trucks, bulldozers, rollers).
f. Calculate the optimum time and cost ratio for each alternative

IV. Discussion Analysis

TABLE 4.1: Alternative Combination of Heavy Equipment

Combination	Excavator	Dump Truck	Dozer	Roller
I	(PC 70) Bucket = 0.37 m3	5 m3	D68 2.60 m3	BW-141 1.5 mm
II	(PC 70) Bucket = 0.37 m3	12 m3	D68 2.60m3	BW-141 1.5 mm
III	(PC 200) Bucket = 0.93 m3	5 m3	D68 2.60 m3	BW-141 1.5 mm
IV	(PC 200) Bucket = 0.93 m3	12 m3	D68 2.60 m3	BW-141 1.5 mm

Source: Analysis Data

Before analyzing the production capacity of heavy equipment from each combination, the Job Factors (Factors that affect equipment productivity) are determined first from each machine.

TABLE 4.2: Job Value Factors

No	Factor	Condition	Koef	Excavator	Truck	Dozer	Roller
1	weather	Hot Dusty	E_{00}	0.691	0.691	0.691	0.691
	Operator	Medium					
2	Tool Condition	Medium	E_{am}	0.715	0.715	0.715	0.715
	field	Medium					
3	Material	Medium	E_m	1.1	0.9	0.9	0.81
4	Management	Enough	E_M	0.85	0.85	0.85	0.85

Source: Analysis Results

TABLE 4.3: Number of Heavy Equipment Needs

No	Combination	Excavator		Dump Truck		Dozer	Roller
		0.37 m^3	9.93 m^3	5 m^3	12 m^3	155 Hp	6.9 ton
1	I	89		474		5	72
2	II	89			260	5	72
3	III		36	478		5	72
4	IV		36		227	5	72

Source: Analysis Results

Implementation Time Analysis

After getting the number of heavy equipment needs in each combination, then an analysis of the time of work carried out for each combination.

From the analysis results we will get heavy equipment rental costs and implementation time for each heavy equipment from each combination. The following analyzes the timing of various combinations.

TABLE 4.4: Timing of Each Combination

No	Combination	Excavator		Dump Truck		Dozer	Roller
		0.37 m^3	9.93 m^3	5 m^3	12 m^3	155 Hp	6.9 ton
1	I	14		14		13	14
2	II	14			14	13	14
3	III		14	14		13	14
4	IV		14		14	13	14

Source: Analysis Results

Cost Analysis

The data needed to analyze the cost of heavy equipment is Heavy Equipment Rental Price Data, this data is used as a reference to determine the rental price of each heavy equipment. Information on heavy equipment rental prices is obtained from PT Kayana BSE.

TABLE 4.5: Heavy Equipment Rental Prices

No	Type of Equipment	Code	HP	Capacity (M3)	Price Tool (Rp)	Cost of Tool / Hour (RP)	Cost of Rental Tools Rp / Day (7 HOURS)	Mobilization & Demobilization Fee For Heavy Equipment (Rp)
1	EXCAVATOR K0MATSU PC-70	E01	48.5	0.37	1.134925.275	401.880	2.813.159	12.000.000
2	EXCAVATOR KOMATSU PC-200	E02	138	0.93	1.709.954.081	747.597	5.233.181	12.000.000
3	DUMP TRUCK MITSUBISHI 5 M3	E03	100	5	380.000.000	355.464	2.488.251	500.000
4	DUMP TRUCK MITSUBISHI 12 M3	E04	190	12	390.000.000	574.714	4.022.998	500.000
5	BULLDOZER KOMATSU D68	E05	155	2.60	2.693.555.986	1.010.838	7.075.865	12.000.000
6	ROLLERS BOMAG BW141AD	E06	75.3	7.05	1.225.719.297	626.937	4.388.557	12.000.000

Source: PT. Kayana BSE

Analysis of Total Rental Costs for Each Combination

After knowing the total needs of each machine, then the time (working days) of each machine for each combination, and also knowing the cost of equipment rental per day from each machine, then the Total Equipment Rental Cost can be calculated Combination.

From table 4.6, we can see the most efficient combination in terms of completion time and total cost of renting heavy equipment is Combination IV.

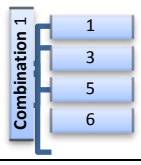
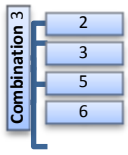
This explains that the work of the Bendo Bendo Dam project in Ponorogo Regency will be more optimal and efficient if it is carried out with the following references:

1. Heavy equipment used is:
   a. Excavator 0.93 m3 (PC-200) = 36 units
   b. 12 m3 dump truck = 227 units ^
   c. Bulldozer 155 Hp (D68) = 5 units
   d. Roller BW-141 = 72 units
2. Duration of Implementation = 14 working calendar days
3. Total Cost of Heavy Equipment Rental = Rp. 21,611,921,049

So, the total cost needed to complete the landfill work is Rp. 21,611,921,049.

International Journal of Scientific Engineering and Science
Volume 4, Issue 1, pp. 58-62, 2020. ISSN (Online): 2456-7361

TABLE 4.6: Results of Calculation of Time and Costs

No	Tool Combination Diagram	Description	Note
1.		1. Excavator Komatsu (PC70) 3. Dump Truck (5m^3) 5. Bulldozer Komatsu (D68) 6. Roller Bomag (BW-141)	1. Time:14 day 2. Cost: **Rp 27.079.426.431,-**
2.		1. Excavator Komatsu (PC-70) 4. Dump Truck (12m^3) 5. Bulldozer Komatsu (D68) 6. Roller Bomag (BW-141)	l. Time:14 Day 2. Cost: **Rp 25.104.105.515,-**
3.		2. Excavator Komatsu (PC-200) 3. Dump Truck (5m3) 5. Bulldozer Komatsu (D68) 6. Roller Bomag (BW-141)	l. Time:13 Day 2. Cost: **Rp 25.717.095.597,-**
4.		2. Excavator Komatsu (PC-200) 4. Dump Truck (12m^3) 5. Bulldozer Komatsu (D68) 6. Roller Bomag (BW-141)	l. Time: 14 Day 2. Cost: **Rp 21.611.921.049,-**

Source: Analysis Results

TABLE 4.7: Consultant Calculation Results

No	Machine Name	Time	Cost
1	1. Excavator 2. Dump truck 3. Bulldozer 4. Roller	14 Day	Rp 25.524.865.547,-

Source: Consultant Planner

From table 4.8, we can see the results of the calculation of the consultant planner without knowing how many alternative combinations are taken into account, where information on the results of this calculation can be via mobile, but we can observe that the time and cost is greater when compared to the existing Combination IV calculation in table 4.7, it can be concluded that the calculation of alternative heavy equipment combinations in this thesis is far more efficient compared to the calculations of the planning consultant.

V. Conclusions And Suggestions

5.1 Conclusions

From the results of the analysis that has been done, it can be concluded as follows:

1. From all the results of alternative combinations, the most effective and efficient combination is COMBINATION IV because the cost incurred is relatively lower than using other combinations. It can be seen from the productivity and the amount of each machine as follows:
   a. Excavator 0.93 m3 (PC-200) = 36 units
   b. Dump Truck 12 m3 = 227 units
   c. Bulldozer 155 Hp (D68) = 5 units
   d. Roller BW-141 = 72 units
2. The length of time for the most effective implementation to complete the Bendo Dam embankment project is as follows:
   a. Excavator 0.93 m3 (PC-200), (36 units) = 14 days
   b. Dump Truck 12 m3, (227 units) = 14 days
   c. Bulldozer 155 Hp (D68), (5 units) = 13 days
   d. Roller BW-141, (72 units) = 14 days
3. The most efficient total cost to complete the Bendo Dam embankment project work is: IDR 21,611,921,049

5.2 Suggestions

Based on the analysis that has been done, we give the following advice:

1. For further research it is recommended to make combinations with other types of heavy equipment, so that more effective combinations can be obtained, both in terms of time and cost.
2. For further researchers, it is better to observe or find as much information about the selection of heavy equipment, starting from the type, type, rental price, in order to obtain optimal and efficient results both in terms of time and cost.

References

[1] Rochmanhadi. 1985. *Calculation of Cost of Performing Work Using Heavy Equipment*. Jakarta: Ministry of Public Works, Public Works Publishing Agency.
[2] Rochmanhadi. 1992. *Heavy Equipment and Its Use*. Jakarta: Ministry of Public Works, Public Works Publishing Agency.
[3] Rochmanhadi. 2000. *Capacity and Production of Heavy Equipment.* Jakarta: Ministry of Public Works, Public Works Publishing Agency.
[4] Deitiana, Titi. 2011. *Operational Strategy Management and Analysis.* Jakarta: Publisher Media Discourse Partner.
[5] Kholil, Ahmad. 2012. *Heavy Equipment*. Bandung: Teen Rosdakarya.
[6] Adhi Karya. 2002. *General Survey Procedures and Work Instructions and Equipment*. Jakarta: Adhi Karya (Persero) Directorate I of Construction Services.
[7] Rostianti, F. S. 2002. *Heavy Equipment for Construction Projects.* Jakarta: Rineka Cipta.
[8] Asiyanto. 2011. *Road Construction Methods.* Jakarta: University of Indonesia
[9] Sastraadmaja. A. S. 1994. *Analysis (Modern Way) of Implementation Budget.* Bandung: Nova.
[10] Bhukti, A. R. 2012. *Analysis of Productivity and Cost of Using Heavy Equipment in The Singhasari Resort and Convention Hotel Development Project*. Malang: National Institute of Technology
[11] Wilopo, Djoko. 2009. *Construction Methods and Heavy Equipment.* Jakarta: University of Indonesia.
[12] Hartono, W. 2008. *Mechanical Soil Removal (Heavy Equipment).* Surakarta: LPP UNS AND UNS PRESS.