The Influence of Water Level Fluctuation Reservoir Stability of the Earth Dam

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The Influence of Water Level Fluctuation Reservoir Stability of the Earth Dam

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Abstract. A large dam construction failure which caused in reservoir by ground water level fluctuations very extreme. Construction of earth dam failures can be avoided if the conditions of the dam slopes are in stable condition. This research discusses the influence of reservoir water level fluctuations on the stability of the earth dam models in the laboratory by analyzing the stress-strain and deformation using PLAXIS program version 8.2. Implementation of the research done in stages which include testing properties of the building blocks of the model earth dam and physical modelling in laboratory experiments with variations in soil types, namely: a mixture of 90% sand-silt 10%, and 80% sand-silt 20% and 100% soil. The slope of the model on the upstream 1:1 and 1:1.5, while in the downstream dam slope was maintained constant 1:1. Instrumentation used includes 6 soil moisture sensors with three accuracy of 2%, 1 deformation pressure sensor with detection range, 3 dial gauges, capacity level 1 meter with accuracy 2%. Furthermore, analysis on the stability of the earth dam modelling in laboratory tests using PLAXIS version 8.2. The results of this analysis are total displacement Plaids, total stress, total strain, pour water pressure and the safe rate (safety factor). Based on the review of the three nodal, at upstream slope of the dam are same, the effective value of the largest stresses occur in the model 10% soil 90% sand with the upstream slope 1:1, that is equal to -16.52 kN/m² lowering phase. Total value of largest stresses occur in the model 20% soil 80% sand with the upstream slope 1:1, that is equal to -12.89kN/m² phase rising 3 phase displacement (vertical displacements, the total displacements, the total incremental displacements and incremental strains), the largest value occurs in the model 100% of the land, the vertical displacements 8.12 x 10⁻⁶ m, the total large displacements 3.92 x 10⁻⁵ m, 1.43 x 10⁻⁵ m total incremental displacements and incremental strains for-1.75 x 10⁻². Lowest safety factor (critical condition) due to raising and lowering of water level in the upstream occurred at a slope 1:1 at 1.4710.

1. Introduction

Dam is a construction that serves water reservoir and retaining water on a large scale. Earth dam serves as a lifting surface of water in reservoir and downstream towards retaining water seepage and water buffer tank. Many of the dam construction failures caused by ground water level fluctuations in the reservoir. Dams land prone to overtopping. This study is continuation of several previous studies that aim to analyse the influence of rising reservoir water level (rising of water level) [1-5] and a decrease in water level (rapid drawdown) to the structural integrity of the earth dams and modelled in 2D modelling [6-7]. In this study, earth dam is physically modelled in laboratory experiments with 3D modelling. The purposes of this study are;
i. Analyzing deformation and land slope stability weir reservoir water level fluctuations due to the physical way modelling in laboratory models and numerical calculations using Plaxis software version 8.2.
ii. Knowing the mechanisms and causes of avalanches on land weir body.
iii. Knowing earth dam deformation patterns visually in the laboratory and compared with the deformation generated using Plaxis program.
iv. Providing solutions precaution against the possibility of instability slope and collapse due to the soil body dam reservoir water level fluctuations.

2. Research Methods

2.1 Location Research
The experiment had been done at the Hydrology Laboratory of the Faculty of Civil Engineering, Gadjah Mada University, and Yogyakarta. Testing value of index properties of soil and sand carried out in the Laboratory of Soil Mechanics Faculty of Civil Engineering, Gadjah Mada University, Yogyakarta.

2.2 Organisations
Materials used for the study are as follows:

- Mix of soil and sand through sieve No. 4 (4.75 mm) and retained at No. 200 (0.075 mm).
- Sand through sieve No. 10 (2.00 mm) sieve and retained on the No. 200 (0.075 mm).
- Water.
- Preview research reports.
- Text books, proceedings, journals, referent, final report and thesis statements.
- Tool which is used in this research is computer, digital camera, handy cam, six soil moisture sensors with an accuracy of 2%, 1 deformation pressure sensor with detection range, 3 dial gauge, capacity level 1 meter with accuracy 2%, moisture sensor, ruler, measure cup, mals and stationery.

Figure 1. Material and Tool
2.3 Stages of research
Research conducted consists of several stages as follows;

i. Study literature.
ii. Preparation of equipment and materials.
iii. Sampling.
iv. Preparation of mixture of soil and sand properties testing.
v. Testing properties for mix soil.
vi. Determination theoretical compaction of water content.
vii. Making a model laboratory test tube.
viii. Value testing of soil density and water content for model.
ix. Simulation (simulation model dam in the laboratory and simulation with finite element models using PLAXIS version 8.2).
x. Analysis the results and discussions.

3. Results and Discussions

3.1 Result and analysis
The results of laboratory experiment is seepage discharge data (q), coefficient of permeability (k), amount of deformation and landslide visual on earth dam model. The results can be seen in the table as follows:

The finding in table 1 shows the results of material properties of the models.

Table 1: Results of material properties of the model.

| Soil Type                     | Specific Gravity | Direct Shear Test | k (cm/s) |
|-------------------------------|------------------|-------------------|---------|
|                               |                  |                   |         |
| Sand 100%                     | 2.80             | 0.01              | 42.44   | 0.560579 |
| Soil : Sand (10%: 90%)        | 2.81             | 0.01              | 39.91   | 0.011496 |
| Soil : Sand (20%:80%)         | 2.75             | 0.12              | 43.71   | 0.009561 |
| Soil 100%                     | 2.62             | 0.54              | 38.86   | 0.000235 |

Next is the laboratory experiments result that can tabulate as table 2 below;

Table 2: Results of laboratory experiments.

| No  | Data                          | Electronic | Manual |
|-----|-------------------------------|------------|--------|
| 1   | Water raising and rapid drawdown | ✔️         | ✔️     |
| 2   | Soil Moisture                 | ✔️         | ✗      |
| 3   | Soil Stress                   | ✔️         | ✗      |
| 4   | Deformation                   | ✗          | ✔️     |
| 5   | Seepage                       | ✗          | ✔️     |

Other than that, there are figures that can be explained in details for this paper. The details are as figures shown. The figure 2 shows the example of plot vertical displacement due to gravity load. Next, figure 3
is the example of plot total displacement on the rising 1 phase. Meanwhile, the figure 4 visualized the incremental strains on rising 2 phase while figure 5 show the effective stresses on rising 2 phase. After that, for figure 6 is the example of plot total incremental displacements on rising 3 phase. Hence, all this figures can presents as follow:

**Figure 2:** Example of plot vertical displacement due gravity load

- a) 10%:90% upstream 1:1
- b) 10%:90%, upstream 1:1.5

**Figure 3:** Example of plot total displacement on Rising 1 phase

- a) 10%:90% upstream 1:1
- b) 10%:90%, upstream 1:1.5
Figure 4: Incremental strains on Rising 2 phase

Figure 5: Effective stresses on Rising 2 phase

Figure 6: Example of plot total incremental displacements on Rising 3 phase
3.2 Analysis of safety factor control
The safety factor control result can be tabulate as table 3 below;

| Calculation Phase | Soil: Sand |
|-------------------|------------|
|                   | Sand       | Soil       |
|                   | 100% | 10%-90% | 100% | 20%-80% |
| Rising            | 1:1  | 1:1.5   | 5,5353 | 5,5684 | > 10 | > 10 | 9,1915 | 9,2225 |
| Lowering          | 2,1967 | 2,1935 | 6,0641 | 6,1921 | > 10 | > 10 | 9,4379 | 9,7137 |

4. Comparison between observation and result analysis laboratory plaid
In this study, a comparison between the observations in laboratory with PLAXIS analysis results can be
only qualitative. This is because of;

i. Value land properties in laboratory models and models PLAXIS not same.
ii. Raising treatment and a decrease in water level in the laboratory and in Plaids are not same.
iii. Less accurate measuring devices (dialgauge) used in the measurements in the laboratory, especially in terms of installation.

Based on observations in the laboratory and the results analysis of the analysis in PLAXIS, obtained qualitatively similar results. In test on laboratory models, models with more soil composition having a larger displacement due to the fewer sand composition, the smaller the value of the modulus of electricity.

From visual observation during the experiment and analysis results with PLAXIS Version 8.2 indicates that the model dam sandy soil mixed with material that more silt FK has a higher value compared with that mixture with silt is less. Safety factor (SF) increased in all models earth dam which increased the water level quickly in the upstream.

5. Conclusion
Based on the results model experiments in laboratory soil earth dam and the results of numerical simulations using PLAXIS Software Version 8.2 can be concluded:

i. Displacement (vertical displacements, the total displacements, the total incremental displacements and incremental strains), the largest value occurs in the model 100% of the land, while in the vertical displacements of 8.12 x 10^{-6} m, the total displacements amounting 3.92 x 10^{-5} m, the total incremental higher 1.43 x 10^{-5} m displacements and the incremental strains at-1.75 x 10^{-2}%. 
ii. For models with the same composition of the constituent materials, the model with a gentler upstream slope has a smaller displacement value.
iii. For models with the same upstream slope, the model with less sand content a great value displacement which is inversely proportional to the value of E (modulus of elasticity). This is consistent with the simulation results in the laboratory. The model having the greatest displacement is 100% ground models.
iv. The main factor to determine the degree of deformation that occurs in the model has a height water level in the earth dam. Higher water level, greater deformation. Deformation values stated direction and magnitude caused the movement.
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