Abstract

Hydraulic fracturing defines as cracks in the upstream face of clay core a rockfill dam in case the vertical effective stress in the core is reduced to levels that are small enough to allow tension fracture to occur. This situation may lead to the internal scouring due to piping progress in the core, and further may resulting failure of the dam. Statistic of dam incidents and failures indicated that internal erosion was the main cause of the incident and failure on the rockfill dams, while hydraulic fracturing may initiate the piping process in the rockfill dams. The research in hydraulic fracturing will give better understanding of the caused, core embankment materials, construction methods, as well as the configuration of the core. In this research, the hydraulic fracturing tests in the laboratory and numerical analyses using finite element method were carried out on the same materials. The aims of this research are: in the embankment materials to indicate the better materials against hydraulic fracturing in terms of fine and clay minerals contents of the core, in the construction method which better the construction moisture contents against hydraulic fracturing, in the design stage which configuration of clay core resulting hydraulic fracturing and assessing the maximum height of the dam may resist against hydraulic fracturing using nomogram.

In order to perform hydraulic fracturing test in the laboratory, a special test apparatus which developed and modified from the previous researcher. This research also analyzes the hydraulic fracturing of rockfill dams using finite element by couple analysis. The soil specimens were the clay core from Batubulan, Batutegi, Kedungombo, Pelaparado, Sermo and Wonorejo dams which modeled have 30%, 40%, 50%, 60%, 70% and 80% fine contents. The soil specimens also compacted in dry side, proctor maximum and wet side in order to obtain the variety moisture contents, and the 3 (three) initial stress states were applied to the specimens. These variations will produce 324 different soil specimens. The preliminary tests on various soil specimens indicated that the tension failure is only found on the specimen if the initial stress state falls in the envelope of $\frac{1}{2}(\sigma_1 - \sigma_3) < c$. In the analyses hydraulic fracturing using finite element methods, first attempt is to validate the program by running on the model of Hyytejuvet dam which experiencing hydraulic fracturing using embankment materials from Batubulan dam. The soil model adopted for clay and filter materials was non-linear elastic hyperbolic, while linear elastic model is used for rockfill. The high order triangular and quadrilateral elements with 6 and 8 nodal points respectively were used in the analyses. Analysis results shows that the program can indicate the locus of hydraulic fracturing similar to the actual location. The hydraulic fracturing analysis then made on the model of Hyttejuvet dam using embankment materials from Batubulan, Batutegi, Kedungombo, Pelaparado, Sermo and Wonorejo dams in various fine contents and compaction conditions, in order to obtain the most suitable clay core materials from the range of fine contents, compactions as well as clay mineral contents. The hydraulic fracturing analyses were also made to the Batubulan, Batutegi, Kedungombo, Pelaparado, Sermo and Wonorejo at their original configuration. The slenderness of the clay core then analysis on the 125 meter of rockfill dam model, where the configuration was similar to the original in order to investigate the clay configurations against hydraulic fracturing. In order to give guidance in the design stage, a nomogram which may indicate the maximum height of the dam which may resist against hydraulic fracturing in various clay core configurations and fine contents of the materials will be made.

The hydraulic fracturing test results indicated that for all clay core embankment materials at their variation of fine contents and compaction indicated that stress at failure (σ_f) increase when the fine contents were increased. The montmorillonite clay mineral affected to the clay core, where the hydraulic fracturing pressure (u_f) decreased when the fine contents we increased. The core materials which have greater fine contents and compacted on wet side may have better resistant against hydraulic fracturing. The clay core which have better resistant against hydraulic fracturing may be placed on $^1/_3$ the height of the dam from the top where the greatest arching takes place. The hydraulic fracturing analyses results indicated that the height and clay configuration were the most factor influencing the hydraulic fracturing, while the initial stress state on the upstream face of the core which fall in the envelope of $\frac{1}{2}(\sigma_1 - \sigma_3) < c$ may resulting hydraulic fracturing. The nomograms to access the maximum height of the rockfill dam which resists to the hydraulic fracturing if the core configuration and fine contents of the clay materials known are provided as the results of this research

Keywords: hydraulic fracturing, embakment dam, finite element method.