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PROPOSAL OF A COUNTERMEASURE FOR EARTHQUAKE RESISTANT DESIGN OF DAM

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SUMMARY

It is well known that a top part (1/3 Height) of dam extreamly vibrates more than other part, and almost damages occurred in that part. So the author proposed a reasonable shape on top of dam. A proposed shape is guided by the results of earthquake observation records, vibration model studies and numerical analysis. It is under calculation of more details for an embankment dam with proposal shape of top part. This proposal aims to embankment dam at this stage, the author intended to expand this idea to other types of dams.

1. INTRODUCTION

Almost damages by strong motion earthquakes occurred at the top part of embankment type dams. According to the results of earthquake observation on dam, the response of dams are extreamly larger in that part than others. It is well understood the multiplications of accelerations are 2-4 times of its foundation's. These multiplications apear in the vibration with both directions (rever flow and dam axis).

Damages those are cracks along slopes or cracks along dam axis, and slip down of embanked materials both shoulders, disapear almost said top part of dam. By means of some vibration model studies indicated same trends of collapses at the top part by large acceleration. Stability analysis of embankment dam using finite element methods shows also high strain zones concentrated upper and suface of slopes.

Author proposed a curvature for top part of embankment dam as a countermeasure for earthquake resistant.

2. A RESULT OF VIBRATION MODEL TEST

A vibration model test conducted by scale model of typical embankment dam. The model dam is zone type with impervious core in center and inpouring water as a part of reservoir. The kinds of measurements are accelerations, hydrodynamic pressure and pore pressure.

This model made of crushed stone of the 10-20 mm grain size for shell parts and clay for impervious core with physical property shown in Fig.2. The test were conducted with constant frequency set at 15 Hz and with the acceleration being increased gradually so that it may clarify how the slope develops a failure to let water overtopped the dam. The failure process began with the collapse of the top of the downstream side of the steeper slope, followde by the stone slipping down from the top of the core began toshow a sudden decrease in acceleration due probably to the crack developed on the top of the core. With the dam crest showing further decrease in acceleration to fall below the acceleration of the shaking table, the top of the core began to collapse in the downtream direction leading to the water leaking therefrom. The process of failure test, a result of hydrodynamic pressures and pore pressures are shown in Fig.1 and the profile of model dam after failure is shown in Fig.2

3. A RESULT OF DYNAMIC NUMERICAL ANALYSIS

A dynamic numerical analytical method for embankment dam has been developed by the author et al, and a results are shown in Fig.3 and Fig.4. In this analytical method, it showed to be discussed first step as a initial condetion, and physical properties of embanked materials in static and dynamic conditions. The second step is numerical caluculation by finite element method. In final step, the results from calculation are evaluated against a stabilities of embankment in a distribution of principal strains. The evaluation suggests Mobilized Plane in the dam. It can be seen the mobilized plain in the top part of dam in Fig.4. It is needless to say the concept of this mobilized plain is quite differ from the concept of slip circle by conventinal method, and the concept for safety factor.

4. PROPOSED CREST SHAPE OF DAM

On the basis of the results so far obtained, a crest shape of dam is proposed as shown in Fig.5. The author indicated a formula for the crest curvature as follows;

$$Y = -\frac{2}{H \cdot M^{1.6}} \cdot X^2 + \left(H - \frac{H}{16} \right)$$

where

H: Height of Dam

M: Grade of Up and Down Stream Face

In this formula, if grade of dam is different in up and down stream face, the two curvatures are connected at center ofcrest. In Fig.5 three curvature in grades of 1:2.5, 1:2.0 and 1:1.5 respectively, and width of flat part of crest in 10 m. The curvature for grade 1:2.5 is fairly good corresponded to the mobilized plain in Fig.4.

According to a results of numerical analysis for dam with proposed crest shape and gradient of 1:2.5 and 1:2.0 up and down stream faces respectively, any mobilized plain can't be seen up to 600 gals of input earthquake motion with predominant period 0.125 sec.

It is under stadying more details for stability analysis of embankment dams with proposed crest shape.

5.CONCLUSION

The dynamic behaviors of dams are obtained so accurate as observation by seismographs and stadies by vibration models. In pallarell the dynamic analyses are so developed by many researchers as highly evaluated level. However there are many lacks of rational input data for computational analysis.

The manner of design for dams seems to be fixed with conventional concept. Sone countermeasures for earthquake resistant design of dams should be discussed and more reasonable design of dams shall be obtained.

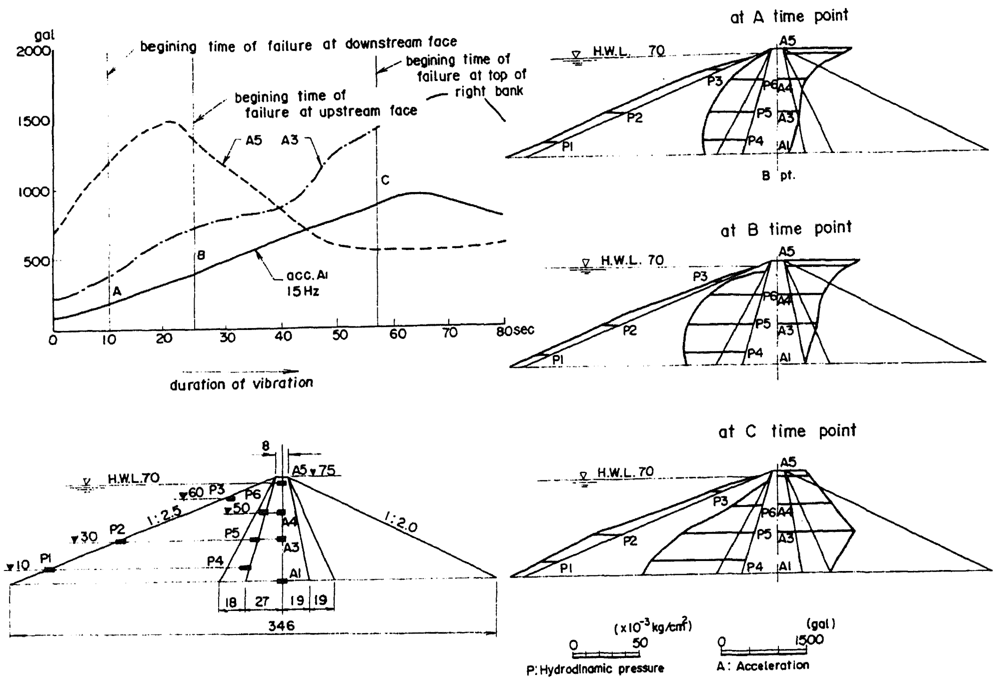
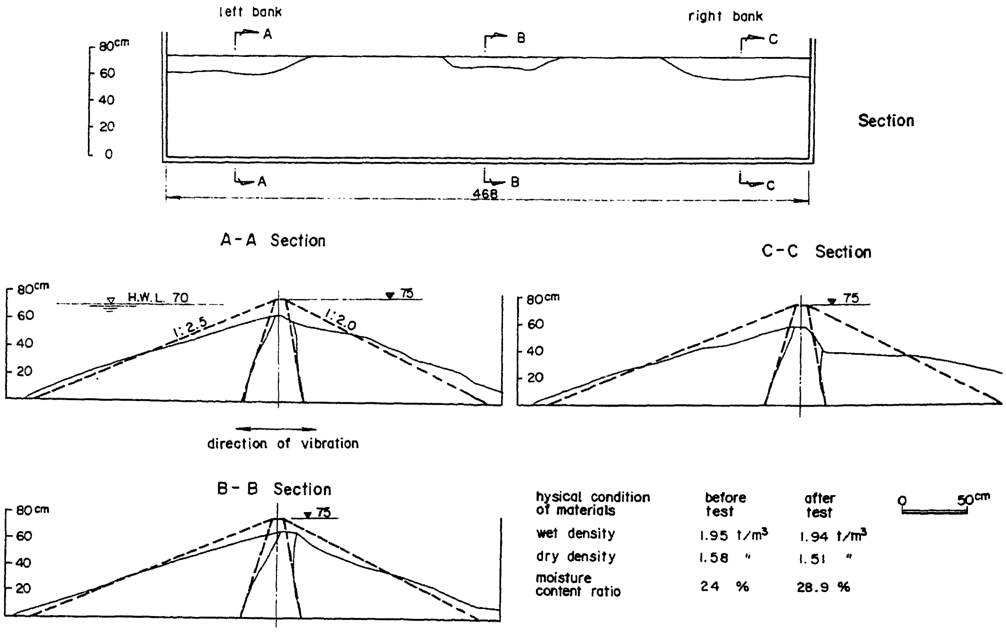


Fig.1 Failure Test of Rockfill Dam Model



hysical condition of materials	before test	after test
wet density	1.95 t/m³	1.94 t/m³
dry density	1.58 "	1.51 "
moisture content ratio	24 %	28.9 %

Fig.2 Profile of Model After Failure

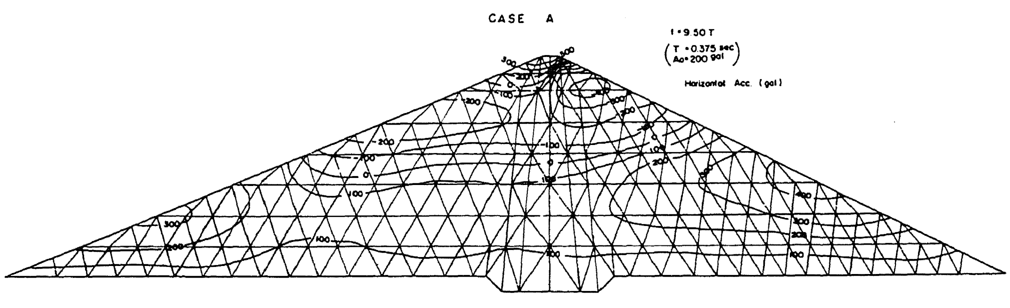


Fig.3 Distribution of Horizontal Acceleration (CASE A, t = 9.50 T)

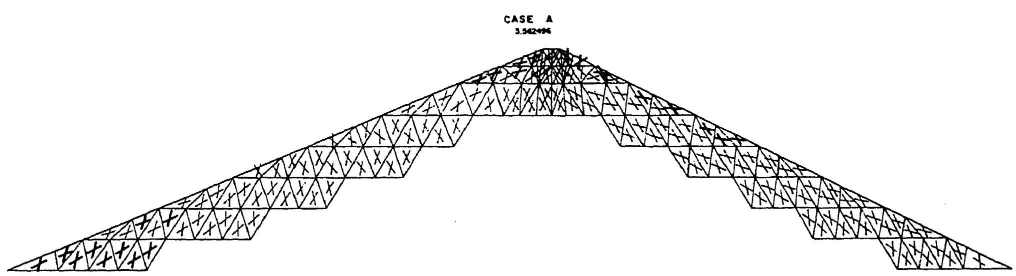
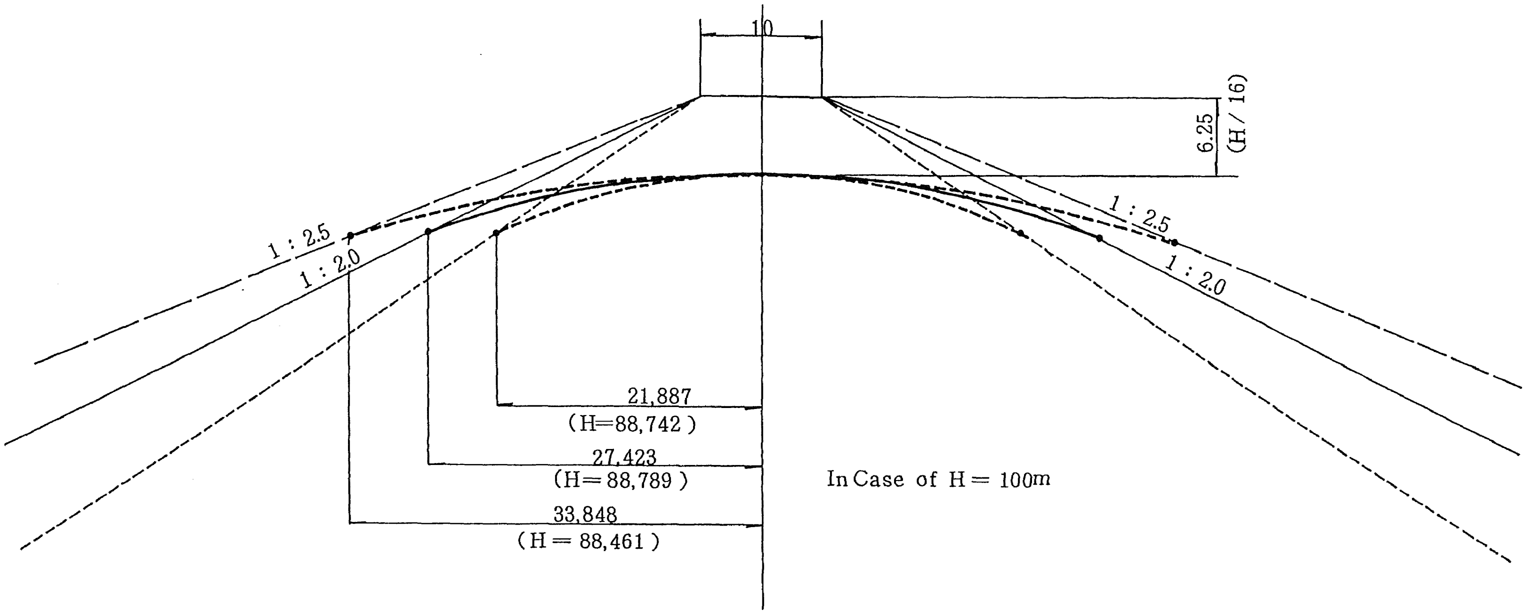


Fig.4 Distribution of Direct of Mobilized Plane (CASE A, t = 9.50 T) Bold Arrows are Less Than 1.0 of Partial Safety Factor



$$Y = \frac{2}{H \times M^{1.6}} X^2 + \left(H - \frac{H}{16} \right)$$

H : Height of Dam

M : Grade of Up and Down Stream Face

(K.BABA)

Fig.5 Proposed crest shape of embankment dam

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