Seismic response of embankment dams with different upstream conditions(Abstract_要旨)

AUTHOR(S):

Adapa, Gautham

京都大学	博士（工学）	氏名	Adapa Gautham
論文題目	Seismic response of embankment dams with different upstream conditions （ため池堤体の異なる貯水状態を考慮した地震時応答）		

（論文内容の要旨）

This study sets out with the aims of evaluating the effect of seepage and different upstream conditions of embankment on its response to earthquake and deformation when subjected to earthquake. Centrifuge model tests and numerical simulations were performed. There are six chapters in total in the thesis.

Chapter 1 presents the introduction of this study. In this chapter, different methods and analysis which are present at the moment to analyze the response of embankment to seepage and shaking have been presented. Different types of failure modes of the earthen embankment dam are also explained briefly. This chapter gives a brief view of introduction to the readers before going into details.

Chapter 2 presents the review of current literature related to the response of embankments to shaking and seepage. A few cases of dam incidents and failures were presented along with studies related to seepage analysis and seismic analysis of embankments individually. There was an intense research studies by different researches in the field of response of embankment to seepage in the body of embankment. There were different methods proposed by different experts to formulate and design the embankment structure. For these methods, seepage, different parts in the embankment structure and earthquake were considered. However, the influence of different upstream slope seepage conditions is needed to study under seismic loading. Therefore, the objective of this study is to understand the effect of different upstream seepage conditions and densities of the soil on the response of embankment to earthquake.

Chapter 3 presents the basic parameters of the soil used in this work. It presents the various laboratory experiments conducted in this work along with the data obtained from these experiments. Different laboratory tests performed in this test are grain size distribution, proctor compaction test, hydraulic permeability test, monotonic tri-axial tests and cyclic tri-axial test were conducted on two different densities of the soil and presented in this chapter. For analyzing the unsaturated condition of the soil, an experiment to obtain the suction pressures with different volumetric contents (SWCC tests) were also performed on two different densities of the soil.

Chapter 4 presents the centrifuge experiments on the embankment model. It describes the various cases conducted with different densities and upstream water levels. Embankment model tests performed in geotechnical centrifuge with different upstream conditions were presented. A custom made centrifugal box was used to create realistic conditions while performing centrifugal tests. Centrifuge experiments on embankment by inducing seepage and

shaking were repeated and the results between each of these tests were in good agreement with each other. In the case of an embankment with a higher dry unit weight, neither piping nor erosion is observed in the embankment irrespective of the level of water on the upstream side. Whereas the embankment with lower dry unit weight, failed at toe of downstream side in seepage, only in the cases with water level of 95% of the height of embankment on the upstream side. Due to the variability of stiffness of embankment between the embankments of different densities, the embankment with lower dry unit weight has deformed while the embankment with higher dry unit weight did not deform due to shaking. The height of water level on the upstream side of the embankment affects the deformation of embankment due to shaking because of the difference in external water pressure on the embankment. In the cases of higher dry unit weight, embankment had a local failure only due to the increase in PWP value at the location of failure. This suggests that the embankment of higher dry unit weight is highly vulnerable to shaking after it is subjected to rapid drawdown.

Chapter 5 presents the numerical study done in this study. The finite elements modeling was done with three different materials. Different stages were used to simulate the embankment model. For each stage different boundary conditions need to be given to simulate the embankment model. Simulation of embankment model subjected to centrifugal acceleration, rise in water level and drawdown on the upstream slope and horizontal acceleration. From the numerical simulations of the embankment model subjecting it to seepage and shaking. Aerial elements are important for achieving convergent form of solution of the FEM in the stage of seepage in an embankment model. Simulation of embankment model using FEM was successful in all the cases by varying the upstream conditions of the embankment. The settlement value of the top of embankment is a little higher than the experiments when the water level is higher on the upstream side of embankment. Except degree of saturation, all other parameters are similar to each other in the analysis varying the SWCC parameters as wetting and drying curves. The response of embankment to shaking is sensitive to SWCC parameters in the elements near to the water level on upstream slope and at the downstream toe. The analysis using drying curve of SWCC overestimates the response of embankment to the shaking irrespective of the water level on the upstream slope.

Chapter 6 summarizes and concludes the present study and suggests scope for future works.

氏　名	Adapa Gautham

（論文審査の結果の要旨）

本論文は、ため池の異なる貯水状態に対する堤体の地震時応答を評価することを目的としたものである。ため池堤体の地震時応答の従来の検討では、一定の水位に着目したものが多いが、本研究ではため池の水位やその変動に着目した点に新規性がある。本研究では遠心模型実験や数値解析を用いて、ため池の異なる貯水状態に対する堤体の地震時応答を評価した。得られた主な成果は次の通りである。

１．遠心模型実験では、貯水状態と堤体密度を変えて浸透・加振実験を行った。浸透時において、堤体の乾燥密度が大きい場合、上流側の水位に関係なく浸透時の堤体変状はみられない。一方、堤体の乾燥密度が小さい場合、下流側の堤体つま先で浸透破壊が発生した。浸透後の加振時には、堤体の乾燥密度が大きい場合、上流側の水位の急激な低下を再現したケースのみ上流側の堤体のり面に局所的な変状が見られた。堤体密度が大きい場合でも、水位の急激な低下後に地震が作用した場合は堤体の安定性を損なう恐れがある。堤体の乾燥密度が小さい場合、加振時の堤体の変形量は比較的大きくなり、加振前の水位高さは堤体の変形モードに影響することが明らかとなった。貯水がない場合、堤体は左右対称的に変形するが、貯水がある場合は堤体全体が下流側に移動するモードがみられた。

２．数値解析では、土・水・空気連成の多孔質体理論と弾塑性モデルを用いた有限要素解析を実施した。遠心模型実験過程を再現するために、遠心載荷、浸透および加振の三段階で解析を実施した。大気要素の利用によって容易に境界条件を再現することができ、数値計算の収束性を確保することができた。解析は浸透時の堤体内の間隙水圧応答や加振時の堤体の変形を概ね再現した。堤体の天端沈下量については、水位が高い場合ほど解析が実験値を過大評価した。解析では不飽和土の水分特性曲線の影響を検討するために、脱水時および浸潤時の二つの水分特性曲線を用いた。水分特性曲線の違いが浸透解析結果に与える影響は大きくないが、加振時の変形には大きく影響し、脱水時の水分特性曲線を用いた場合、加振時の変形量を過大評価することが明らかとなった。

以上のように、ため池の異なる貯水状態に対する堤体の地震時応答を実験的・解析的に評価したものであり、今後のため池堤体の耐震対策を検討するうえで有益な知見を与えるものと評価でき、学術上、実際上寄与するところが少なくない。よって、本論文は博士（工学）の学位論文として価値あるものと認める。また、令和３年８月１０日、論文内容とそれに関連した事項について試問を行って、申請者が博士後期課程学位取得基準を満たしていることを確認し、合格と認めた。

なお、本論文は、京都大学学位規程第１４条第２項に該当するものと判断し、公表に際しては、当該論文の全文に代えてその内容を要約したものとすることを認める。