研究紹介，京都大学大学院　工学研究科　社会基盤工学専攻
地盤力学講座　地盤力学分野，木村研

研究テーマ－浸透-変形連成解析法による木津川堤防のパイピング現象の解析

研究背景と目的

パイピング現象とは，堤防やダム等で見られる浸透破壊現象の一種である．たとえば，堤体の基礎地盤が砂礫層など，透水性の高い土質材料で構成されていると（以下，透水層と表記），洪水などにより河川水位が上昇した際に，透水層における水頭差が拡大し，主に川裏法尻部基礎地盤での有効応力が低下し，ゼロに至ることで噴砂や漏水現象が起こる（Figure 1 参照）．平成 29 年 10 月に列島を襲った台風 21 号における出水の影響で，木津川堤内耕作地の至る箇所でパイピング現象による噴砂，漏水が多く発生した．本研究では，以上で述べた実現象を対象に，数値解析を用いて再現することを目的とする．

研究手法

本研究では，有限変形理論に基づく空気-水-土連成動的解析プログラム COMVI2D-DY を用い，浸透-変形連成解析を行うことで，木津川堤内で発生したパイピング現象の再現を試みる．材料の構成式には弾塑性モデル [1]および弾粘塑性モデル [2]を使用し，土骨格の応力変数には不飽和土に適用可能な骨格応力 [3]を使用した．解析対象とした久御山地区（右岸 6.0 k + 150 m）の地質断面を Figure 2 に示す．

研究成果

Figure 3 に，入力した河川水位と，Figure 4 に川裏法尻付近の要素における平均骨格応力の時刻歴を示す．図より，河川水位がピークを迎える時刻において，応力がゼロ付近まで低下していることがわかる．Figure 5 に，河川水位ピーク時の蓄積塑性偏差ひずみ分布を示す．川裏法尻部で局所的に大きな塑性ひずみが卓越しており，実際のパイピング発生地点と重なっていることから，実現象に近い結果を解析的に表現できたといえる．

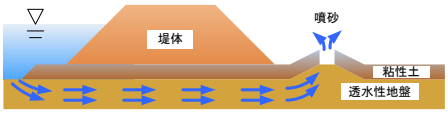


Figure 1 : Piping Failure

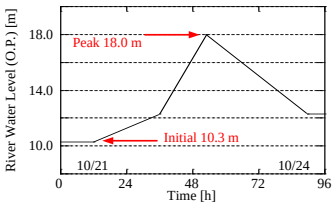


Figure 3 : Water Level input

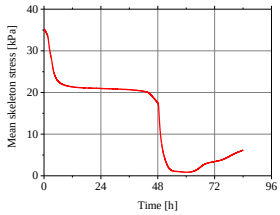


Figure 4 : Transition of skeleton stress

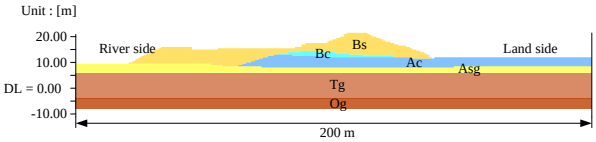


Figure 2 : Geological Profile of Kumiyama District

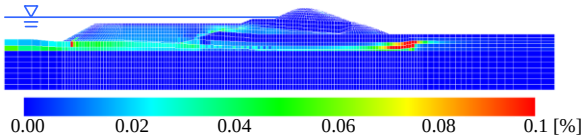


Figure 5 : Distribution of plastic strain

1)Oka, F., Yashima, A., Tateishi, A., Tagichi, Y. and Yamashita, S.: A cyclic elasto-plastic constitutive model for sand considering a plastic strain dependency of the shear modulus, *Géotechnique*, Vol.49, No.5, pp.661-680, 1999.
2)Kimoto, S., Shahbodagh, K.B., Mirjalili, M. and Oka, F.: Cyclic elasto-viscoplastic constitutive model for clay considering the nonlinear kinematic hardening rules and the structural degradation, *International Journal of Geomechanics*, Vol.15, No.5, pp. A4014005-1-A4014005-14, 2015.
3)Jommi, C.: Remarks on the constitutive modeling of unsaturated soils, *Experimental Evidence and Theoretical Approaches in Unsaturated Soils*, Tarantino, A, and Mancuso, C.eds., Balkema, pp.139-153, 2000.

Research theme －Analysis on piping phenomenon at Kizu river levee by seepage-deformation coupled method

Research background and objective

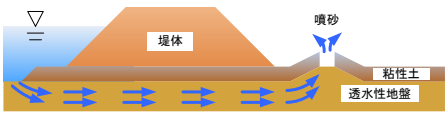
Piping phenomenon is a type of seepage failure phenomena which are seen in the levee or the dam. For example, if the foundation ground of the levee consists of the soil material with high water permeability, for instance the sand and gravel layer, the rise of water level by floods amplifies the water head difference at the permeable layer. When the effective stress mainly at the foundation ground of the bottom of a river back falls to zero, it triggers sand boil and water leakage (Figure 1). By the flood of Typhoon No.21 which hit the Japan Islands on October 2017, many sand boils and water leakage occurred at numerous spots of the cultivated land. This study is aiming to reproduce the aforementioned piping phenomenon by using numerical analysis.

Research method

In this study, the reproduction the piping phenomenon inside of Kizu river levee is attempted by using COMVI2D-DY, a gas-water-soil coupled dynamic analysis program based on finite deformation theory. Elasto-plastic model and elasto-viscoplastic model are used for material composition formula, and skeletal stress which is applicable to unsaturated soil is used for the soil skeleton stress variable. Figure 2 shows the geological profile of the analysis object, Kumiyama area (right bank 6.0 k + 150 m).

Results & Discussion

Figure 3 shows the river water level used for the analysis, and Figure 4 depicts the time history of mean skeletal stress in elements near the bottom of the river back. From the Figure 4, it can be seen that the stress decreases to around zero at the time when the river water level reaches the peak. Figure 5 shows the accumulated plastic deviatoric strain distribution at the peak of river water level. An eminent local plastic strain can be observed at the bottom of a river back and overlapped with the actual piping point. Thus it can be said that the result close to the real phenomenon could be expressed by analytical means.



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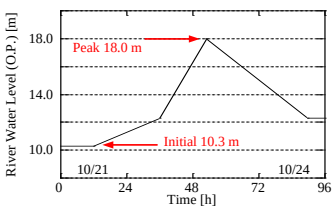
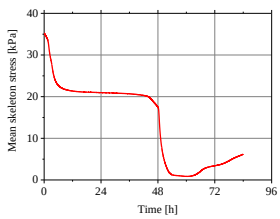


Figure 3 : Water Level input



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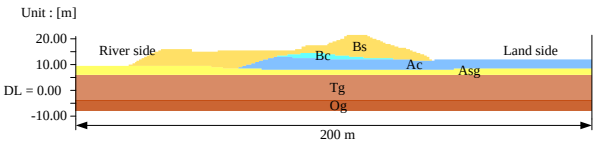

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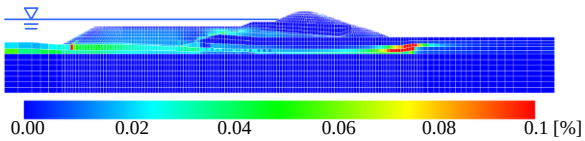

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