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Dynamic Analysis of Concrete Gravity Dams Including Dam-Foundation Rock Interaction

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ABSTRACT

Past studies have shown that dam-foundation rock interaction has significant effects on dynamic response of concrete dams. Moreover, several methods have been presented to investigate this subject such as, boundary element approach or the combination of boundary element and finite element procedures. Most of these methods are relatively complicated. Therefore, in the present study, a new computer program has been developed with a simplified approach. In this program, the dam body and foundation rock are modeled by three-dimensional finite element method. The results obtained by the present method (i.e., FE-FE approach) are very similar to the results published by previous complicated methods. Furthermore, this program is able to also utilize damping solvent extraction method. Therefore, the effects of damping solvent extracting on increasing convergence rate for dynamic response of concrete gravity dams has also been studied.

KEYWORDS

Dynamic Interaction Dam and Foundation Rock, Concrete Gravity Dams, Finite Element Method, Damping Solvent Extraction.

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1- INTRODUCTION

Considering the dam-foundation rock interaction is one of the complications in dynamic analysis of concrete gravity dams. Dynamic interaction of dam and foundation rock is a study about dams over flexible foundation rock which is exposed to dynamic motions. In this study, a computer program [1] has been developed to solve interaction of concrete gravity dams and foundation rock around it.

Considering previous studies related to the discussable issue, it should be mentioned that Chopra & Chakrabarti published a paper in 1980 [2]. They considered dam-water-foundation rock interaction. Also, Lotfi & Sharghi used the FE-BE procedure in 2001[3]. In this study, dam and foundation rock were modeled by finite element and boundary element respectively.

2- EQUATIONS OF DAMS OVER FLEXIBLE FOUNDATION ROCK

In this section, dynamic equivalence equations of dam and foundation rock will be presented. Using direct stiffness method in structure analysis, equivalence equations of dam- foundation rock system would be in (1):

$$\mathbf{M}\ddot{\mathbf{r}}+\mathbf{C}\dot{\mathbf{r}}+\mathbf{K}\mathbf{r}=-\mathbf{M}\ddot{\mathbf{u}}-\mathbf{C}\dot{\mathbf{u}}-\mathbf{K}\mathbf{u} \qquad (1)$$

In above equation **M**, **C**, **K** are mass, damping and stiffness matrix of dam-foundation rock system respectively.

By simplifying the right section of equation (1), this equation could be mentioned like equation (2):

$$\mathbf{M}\ddot{\mathbf{r}}+\mathbf{C}\dot{\mathbf{r}}+\mathbf{K}\mathbf{r}=-\begin{bmatrix}\mathbf{M}_{uu} & \mathbf{M}_{ub} & 0\\ \mathbf{M}_{bu} & \mathbf{M}^{u}_{bb} & 0\\ 0 & 0 & 0\end{bmatrix}\begin{bmatrix}\ddot{\mathbf{u}}_u\\ \ddot{\mathbf{u}}_b\\ \ddot{\mathbf{u}}_f\end{bmatrix}-\begin{bmatrix}\mathbf{C}_{uu} & \mathbf{C}_{ub} & 0\\ \mathbf{C}_{bu} & \mathbf{C}^{u}_{bb} & 0\\ 0 & 0 & 0\end{bmatrix}\begin{bmatrix}\dot{\mathbf{u}}_u\\ \dot{\mathbf{u}}_b\\ \dot{\mathbf{u}}_f\end{bmatrix} \qquad (2)$$

In order to transfer from time domain to frequency domain, it is only needed to change time function to frequency function. Considering harmonic motion and hysteric damping, equation (2) would be like (3):

$$\left[-\omega^2\mathbf{M}+(1+2\beta i)\mathbf{K}\right]\mathbf{r}(\omega)=-\begin{bmatrix}\mathbf{M}_{uu} & \mathbf{M}_{ub} & 0\\ \mathbf{M}_{bu} & \mathbf{M}^{u}_{bb} & 0\\ 0 & 0 & 0\end{bmatrix}\ddot{\mathbf{u}}(\omega) \qquad (3)$$

3- CONCLUSION

In this study, equations of dynamic analysis of dam and foundation rock have been explained in frequency domain. A computer program has been developed according to these equations and dynamic response of concrete gravity dam and foundation rock has been considered. Results showed that responses of FE-FE method with using damper are rather equal to responses of previous complicated methods. It observed that TM4 model (L/B=4) is appropriate for three cases (foundation flexibility only, Massless foundation and Foundation with mass and dashpot), so there is no need to increase modeled limitation of foundation rock.

Furthermore, results indicated that in foundation flexibility only case, when the ratio of elasticity modulus of foundation rock to dam reduces, the first frequency decreases and absolute value of acceleration of crest increases. In two other case, by reducing elasticity modulus of foundation rock to dam, the first frequency and absolute value of acceleration of crest in first frequency decreases. It should be mentioned that there are some differences between massless foundation case and foundation with and dashpot case, so massless foundation case is not acceptable case for dynamic analysis of concrete gravity dams. Regarding damping solvent extraction method, it observed that this method causes a more rapid convergence in response.

4- REFERENCES

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