## Study on the Effect of Seepage in Jointed Rocks at Arch Dams Abutments

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## ABSTRACT

Abutments and foundation are among the most vulnerable parts of arch dams therefore, understanding their defects are of high priority. As far as seepage forces have a great effect on abutment stability, understanding the seepage in rock masses has a great importance. Joints hydromechanical interaction is a phenomenon that is not studied sufficiently. In this research, an effective algorithm is devised so that the mechanical behavior of jointed rock mass has been described and modeled by an equivalent continuum rock model with multilaminate concept and the hydraulic behavior assuming laminar flow with cubic law for joint systems. The hydromechanical interaction is thus modeled for a hypothetical arch dam and the effect of the phenomenon is studied on the stresses, their redistribution and in the rock mass abutments. It is concluded that disregarding the seepage effect or the H-M interaction may introduce significant errors in displacements and shear stresses of dam abutments.

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## Keywords

Arch dam, hydromechanical interaction, jointed rock mass, finite element

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$$\begin{aligned} \varepsilon^{rm} &= \varepsilon^{Ir} + \varepsilon^{j} = C^{ir} \sigma + C^{*} \sigma = (C^{Ir} + C^{*}) \sigma \\ \Rightarrow \sigma &= (C^{I} + C^{*})^{-1} \varepsilon^{rm} = D^{rm} \varepsilon^{rm} \end{aligned}$$
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$$\boldsymbol{D} = \begin{bmatrix} 0 & D_s & 0 \\ 0 & 0 & D_s^J \end{bmatrix}$$

$$\boldsymbol{\cdot} \qquad \boldsymbol{\cdot} \qquad \boldsymbol$$

$$\delta = C^{J} \sigma \qquad ()$$

$$C^{J} = [D^{J}]^{-1} \qquad ()$$

$$m \qquad :$$

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$$\sigma \cdot \sigma'$$

$$\vdots \quad C_m^{JS} = f_m C_m^{J}$$

$$\sigma = \sigma' - mp \quad () \quad f_m \quad m \quad C_m^{JS}$$

$$\sigma_{yy} = \sigma_{yy}' - \gamma_{w}(\varphi - z), \quad \tau_{xz} = \tau_{xz}' \quad () \qquad : \qquad (\beta) \qquad (\alpha)$$

$$\sigma_{zz} = \sigma_{zz}' - \gamma_{w}(\varphi - z), \quad \tau_{yz} = \tau_{yz}' \quad () \qquad : \qquad (\beta) \qquad (\alpha)$$

$$\sigma_{zz} = \sigma_{zz}' - \gamma_{w}(\varphi - z), \quad \tau_{yz} = \tau_{yz}' \quad () \qquad : \qquad (\beta) \qquad (\alpha)$$

$$T_{m}^{T} = \begin{bmatrix} \sin^{2}\beta\cos^{2}\alpha & -\frac{1}{2}\sin2\alpha\sin\beta & -\frac{1}{2}\cos^{2}\alpha\sin2\beta \\ \sin^{2}\beta\sin^{2}\alpha & \frac{1}{2}\sin2\alpha\sin\beta & -\frac{1}{2}\sin^{2}\alpha\sin2\beta \\ \cos^{2}\beta & 0 & \frac{1}{2}\sin2\beta \\ -\sin^{2}\beta\sin2\alpha & -\sin\beta\cos2\alpha & \frac{1}{2}\sin2\alpha\sin2\beta \\ -\sin^{2}\beta\sin2\alpha & -\sin\beta\cos2\alpha & \frac{1}{2}\sin2\alpha\sin2\beta \\ -\sin^{2}\beta\sin2\alpha & -\sin\beta\cos2\alpha & \frac{1}{2}\sin2\alpha\sin2\beta \\ -\sin\alpha\sin2\beta & -\cos\alpha\cos\beta & \sin\alpha\cos2\beta \\ \cos\alpha\sin2\beta & -\sin\alpha\cos\beta & -\cos\alpha\cos2\beta \end{bmatrix}$$

$$A(u) = \begin{cases} \frac{\partial\sigma_{xx}'}{\partial x} - \gamma_{w}\frac{\partial\varphi}{\partial x} + \frac{\partial\tau_{yx}}{\partial x} + \frac{\partial\tau_{yz}}{\partial z} \\ \frac{\partial\sigma_{yy}}{\partial y} - \gamma_{w}\frac{\partial\varphi}{\partial z} + \gamma_{w} + \frac{\partial\tau_{xz}}{\partial x} + \frac{\partial\tau_{yz}}{\partial y} \end{cases} + \begin{cases} b_{x} \\ b_{y} \\ b_{z} \end{cases} = 0 \quad () \end{cases}$$

$$\boldsymbol{b} = \begin{bmatrix} \boldsymbol{b}_x & \boldsymbol{b}_y & \boldsymbol{b}_z \end{bmatrix}^T \qquad \boldsymbol{C}^* = \sum_{m=1}^n \boldsymbol{C}_m^{JSC} \qquad ()$$

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 $\epsilon^{j'}$ 

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FEAP-HM . k m. ( )

K

m= . n. *K* 

FEAPpv

FEAP-HM

(Morrow Point)

 $\Delta l = \frac{\sigma_n'}{E_{Ir}} (L - e_{new}) + \frac{L}{d} \cdot \frac{\sigma_n'}{D_{tension}}$ 



$$\varepsilon^{j'} = \frac{\varepsilon^{rm'}}{1+\theta} \Longrightarrow \frac{e_{new}}{d} = \frac{\varepsilon^{rm'}}{1+\theta} \tag{()}$$

 $\{\varepsilon'\} = [D']^{-1} \{\sigma'\} = [D']^{-1} [\overline{T}] \{\sigma\} \qquad ()$ 

[ ] FEAPpv [ ] FEAP-HM

 $\omega = z + \frac{p}{2}$ 

$$\varphi = z + \frac{p}{\gamma} \tag{()}$$









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