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Closure to “Roles of Particle Breakage and Drainage in the Isotropic Compression of Sand to High Pressures” by Woongju Mun and John S. McCartney

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If there is anything else you wish to communicate to the editor of the journal, please do so in this box.	Here are some minor editorial comments on the discussion of our paper: Line 25: in a limited zone Line 40: Change particles to particle

	Line 41: that the dependence Line 41: is due to the change Line 50: change emphasis to emphasize Line 53: we can be sure Line 55: widen the applicability Figure 1: use lower case p’ Figure 3: change Mpa to MPa

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The authors are grateful for the discussion of our paper by Dr. Dallo, who provided valuable comments regarding the role of initial relative density on the isotropic compression curves and breakage factors of sands under high pressures. Although we measured different breakage factors for sand specimens having an initial relative density of $D_{R,0}$ = 0.75 compressed to several mean effective stresses, we only evaluated breakage factors for sand specimens prepared at other initial relative densities of 0.60 and 0.96 after compression to a mean effective stress of 160 MPa. The isotropic compression curves for these sand specimens converged at mean effective stresses greater than 30 MPa, but the measured breakage factors increased with increasing relative density, consistent with studies like Nakata et al. (2001). However, we were not able to quantify the trends in breakage factors with mean effective stress for these initial conditions when parameterizing our model. Nonetheless, we agree with the discusser that alternative parameterizations may be used in the empirical equations developed in our study to link the relationship between the relative breakage index and mean effective stress with the shape of the compression curve of sands to better consider the effects of the initial relative density. The empirical equation for the drained virgin compression curve of sands from the paper under discussion is given as follows:

$$e = e_0 \times e^{-\alpha(100\times B_r)^{\delta}} - \beta p' \quad (1)$$

where e is the void ratio at a given mean effective stress p', e_0 is the initial void ratio, α, β, and δ are empirical parameters, and B_r is Hardin's relative breakage factor which was defined in the paper under discussion as a function of mean effective stress, as follows:

$$B_r = \Lambda_r p'^{\Gamma_r} \quad (2)$$

where Λ_r and Γ_r are empirical parameters.

Following the recommendation of the discusser, if the empirical parameters α, β, and δ in the model are assumed to be unique for a given sand, then the effects of initial relative density can be incorporated into the definition of the relative breakage index B_r. This alternative parameterization would simplify the model, better represent trends in breakage factors for sands with initial relative density, and potentially extend is applicability as noted by the discusser. We performed such an analysis using the same empirical factors of $\alpha = 0.3$, $\beta = 1.7\times10^{-7}$, and $\delta = 0.7$ obtained for the tests on specimens with $D_{r,0} = 0.75$ and also assuming that the value of Γ_r in Equation (2) is constant and equal to 0.99 and that the value of Λ_r varies with mean effective stress in order to fit the compression curves for dry sand specimens with initial relative densities $D_{r,0}$ of 0.60, 0.75, and 0.96 shown in Figure 10(b) of the paper under discussion. When revisiting Figure 10(b) of the paper under discussion, we noticed that the labels for $D_{r,0} = 0.75$ and 0.96 were accidentally switched. A comparison between the new parameterizations of Equations (1) and (2) and the experimental isotropic compression curves for dry Mason sand having different initial relative densities is shown in Figure 1(a). Not only were reasonable matches observed between the fitted and experimental compression curves, but the predicted values of B_r from Equation (2) for specimens with different initial relative densities are consistent with those shown in Figure 9(c) of the paper under discussion. The variation in Λ_r with mean effective stress resulting in the best fit of the compression curves is shown in Figure 1(b). A slight increasing trend in Λ_r with increasing

initial relative density was observed, which implies more particle breakage occurring in initially denser soils. This trend is consistent with the trends in breakage factors during compression observed in previous studies like Sun et al. (2015). Regardless, further research is needed to quantify the evolution of relative breakage index of sands during isotropic compression to fully confirm this approach. Most other studies involving isotropic compression of sands to high stresses only measured breakage factors at the highest stresses applied and did not measure trends breakage factors with mean effective stress (e.g., Nakata 2001). Based on the success of the alternative parameterization in Figure 1(a), we concur with the discusser that it is preferred to incorporate the effects of the initial relative density into the definition of the relative breakage index when defining the compression curves of sands over the full range of mean effective stress.

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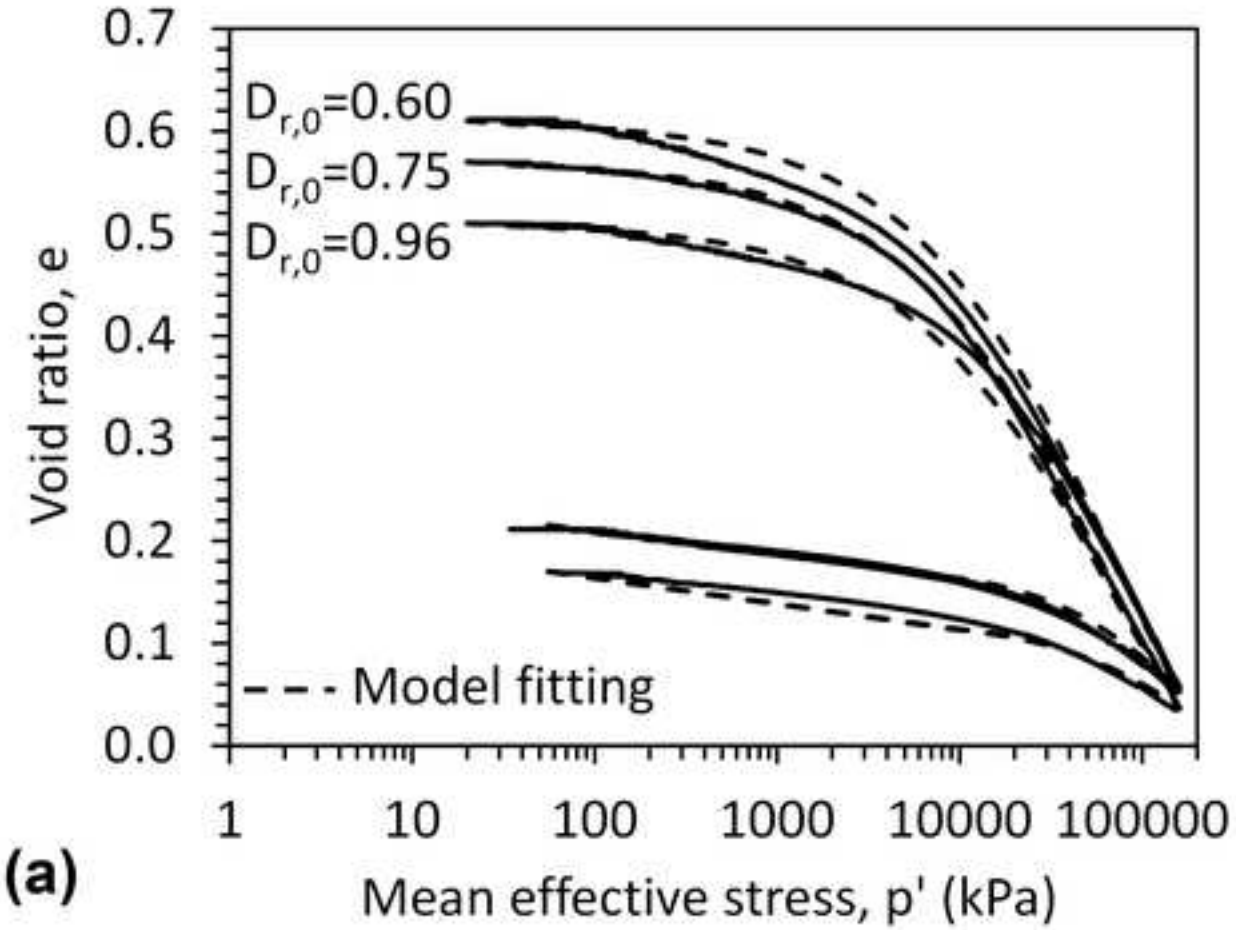
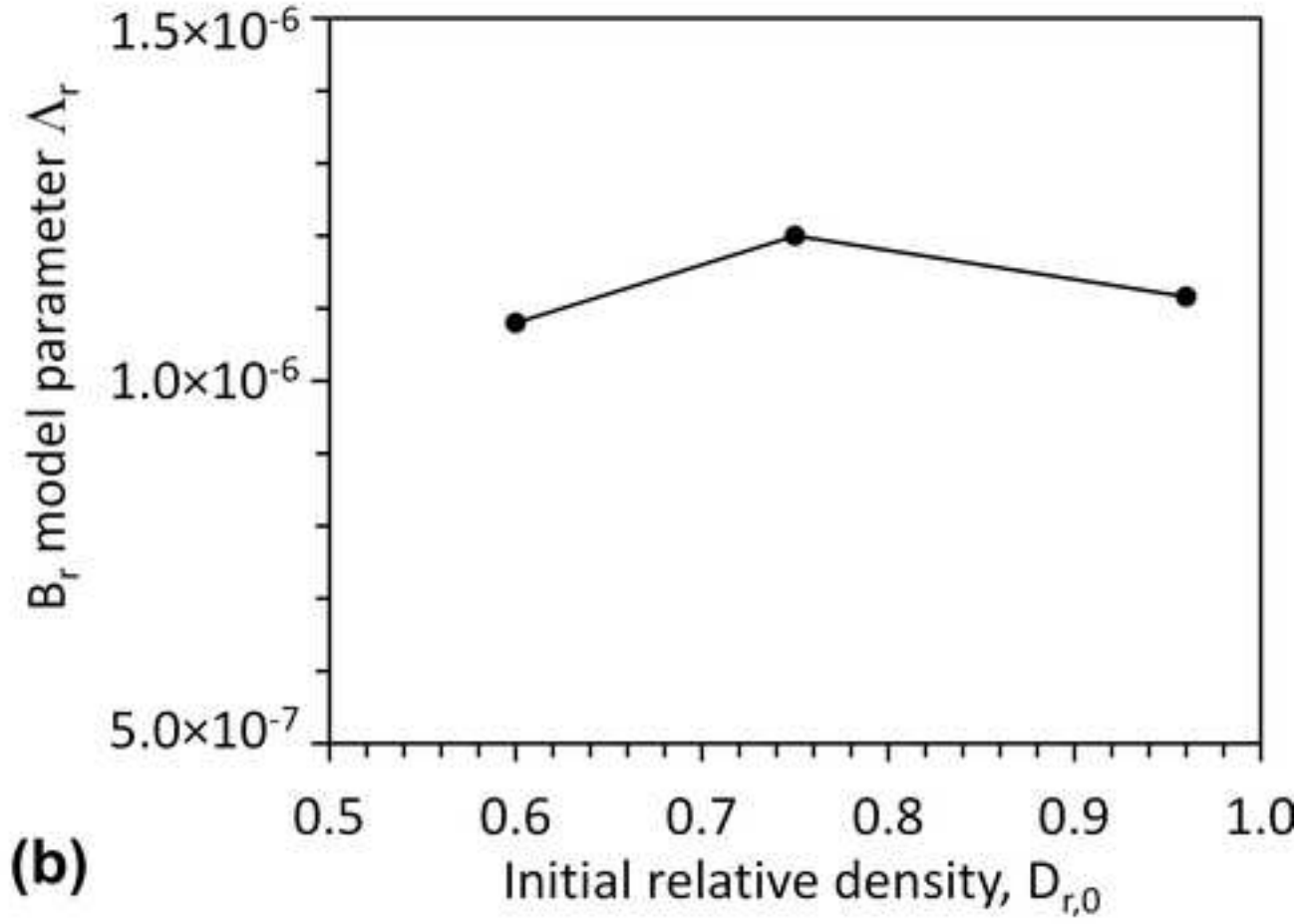
FIGURE CAPTIONS

Figure 1: (a) Comparison of fitted and experimental isotropic compression curves for dry sand specimens having different initial relative densities; (b) Variations in the relative breakage index parameter Λ_r with mean effective stress



(a)



(b)

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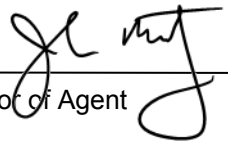

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