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8 **Reset of Secondary Compression Clock for Peat by** 9 **Cyclic Straining**

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13 Peat soils are widely recognized as being highly compressible. The virgin compression index, C_c ,
14 is often 5 to 20 times larger than for soft clay, and the secondary compression index, C_{α} , is in the
15 range of $(0.05 \text{ to } 0.07)C_c$, which is also higher than for typical clays (Mesri and Ajlouni, 2007).
16 Secondary compression is often the dominant source of volume change in peat over time. The
17 compressibility of peat has typically been investigated due to total stress increase imposed by
18 static loads. This manuscript discusses time-dependent volumetric strains due to cyclic shear
19 straining.

20 A multi-stage cyclic simple shear laboratory testing program using the UCLA digitally
21 controlled direct simple shear device (Duku et al. 2007), modified for constant height testing,

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was used to investigate post-cyclic volume change of relatively undisturbed specimens of fibrous peat from Sherman Island in the Sacramento / San Joaquin Delta. During each stage, 15 strain-controlled cycles (1 Hz) were imposed on peat specimens while maintaining constant height by varying the vertical stress, after which specimens were reconsolidated to the initial vertical stress (σ_{vc}'). Post-cyclic reconsolidation was monitored for approximately 20 min. following each loading stage. Oedometer tests indicate primary consolidation was complete after 1 min, leaving the remaining time to record the rate of secondary compression.

Test results for a peat specimen with 55% organic content, $\sigma_{vc}' = 12$ kPa, OCR = 4.9, $C_c = 2.21$, and $C_r = 0.14$ are shown in Fig. 1. Part (a) shows that excess pore pressure ratios (r_u) are non-zero when $\epsilon_{cyc} > 3\%$, with a residual $r_u = 0.2$ for $\epsilon_{cyc} = 10\%$. As shown in part (b), although these r_u values are modest, post-cyclic volumetric strains are significant when $\epsilon_{cyc} > 1\%$ because of the peat's high compressibility. Part (c) shows that the secondary compression rate, which is related to the difference between ϵ_v at 1 and 20 min, increases with ϵ_{cyc} . This suggests that cyclic straining can increase the secondary compression rate, which has not been previously recognized. Similar increases in secondary compression rate are routinely observed when total stress is increased in laboratory oedometer tests, which can be viewed as re-setting the "clock" to zero at the time the load is applied. The data in Fig. 1 indicates that cyclic straining can at least partially reset the secondary compression clock, without total stress increase.

Implications

Seismic risk is a significant issue for the Sacramento / San Joaquin Delta because levees are composed of saturated, often liquefiable soils that rest atop soft compressible peats and organic soils. If seismic ground failure were to occur in or beneath a levee, the interior islands could flood. If repeated over a sufficient number of islands, this process would likely draw saline water

45into the Delta from the San Francisco Bay, compromising fresh water delivery via several of
46California's major aqueduct systems.

47 Liquefaction of saturated loose cohesionless levee fill and foundation soil is recognized as a
48significant driver of ground failure risk in the Delta. This work identifies a new mechanism by
49which levees that do not fail during shaking may experience increased settlement rates due to
50secondary compression following an earthquake, possibly causing overtopping. Further study is
51required to better characterize this potential hazard. Although ϵ_{cyc} as high as 10% is considered
52very large for typical inorganic soils, the Delta peats are unusually soft and such large shear
53strains are feasible during design-level shaking.

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56contract number 4600010406, and the US Geological Survey under contract number
57G11AP20169.

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64 **Fig. 1.** Cyclic direct simple shear test results of Sherman Island peat (a) pore pressure ratio (r_u) versus number of cycles (N), (b)

volumetric strain (ε_v) versus time (t), and (c) ε_v versus cyclic shear strain amplitude (γ_{cyc}).