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1 Closure to "Kinematic Framework for Evaluating Seismic Earth Pressures on Retaining Walls"

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4 by Scott J. Brandenberg, M. ASCE[1], George Mylonakis, M. ASCE[2], and Jonathan P. Stewart, F. ASCE[3]

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6 The Authors thank the Discusser for his insightful extensions to the kinematic framework for evaluating

7 seismic earth pressures, and for supporting the overriding principle that seismic earth pressures form as

8 a result of relative displacements between the wall and free-field soil profile. This displacement-based

9 approach is fundamentally different from assigning an acceleration-proportional pseudo-static seismic

10 coefficient to an active wedge, regardless of wall kinematics and wave propagation in soil, which has

11 been common practice since the work of Okabe (1926) and Mononobe and Matsuo (1929) nearly a

12 century ago.

13 The Discusser's solutions for the case of a rigid base (i.e., $K_y = K_{xx} \rightarrow \infty$) are a useful application of the

14 original equations for cases where the base slab is large and/or founded on soil or rock that is

15 significantly stiffer than the retained soil. Furthermore, the introduction of damping within the backfill

16 for the case of rigid media below the wall foundation provides interesting insights, as it prevents

17 development of zero seismic thrusts that otherwise occur at certain frequencies. This can be interpreted

[1] Associate Professor and Vice Chair, Dept. of Civil and Environmental Engineering, 5731 Boelter Hall, Univ. of California, Los Angeles, CA 90095-1593 (corresponding author). Email: sjbrandenberg@ucla.edu.
[2] Professor and Chair in Geotechnics and Soil-Structure Interaction, Dept. of Civil Engineering, Unviersity Wal, Clifton BS8, Univ. of Bristol, U.K.; Professor, Univ. of Patras, Greece; Adjunct Professor, Dept. of Civil and Environmental Engineering, 5731 Boelter Hall, Univ. of California, Los Angeles, CA 90095-1593. E-mail: g.mylonakis@bristol.ac.uk
[3] Professor and Chair, Dept. of Civil and Environmental Engineering, 5731 Boelter Hall, Univ. of California, Los Angeles, CA 90095-1593. E-mail: jstewart@seas.ucla.edu

18   as imperfect destructive interference of the impinging seismic waves on the wall, due to phase

19   differences in pressures at different elevations caused by damping.

20   The Discusser's solutions for vertically inhomogeneous soil stiffness are important since many soil

21   profiles exhibit an increase in stiffness with depth. The constant stiffness assumption in our original

22   paper was acknowledged as a limitation, and the Discusser's solutions help address this limitation for

23   the rigid base condition.

24   The Discusser accurately points out that for a given ground surface displacement amplitude, the

25   kinematic framework predicts that seismic thrust approaches zero as frequency approaches zero. He

26   then presents pseudo-static solutions involving constant horizontal body forces in the soil for which the

27   seismic thrust is non-zero. Although these solutions are interesting and mathematically consistent,

28   Fourier amplitudes of earthquake ground accelerations decay logarithmically as frequency decreases. As

29   a practical matter, there is no acceleration at zero frequency, hence this pseudo-static solution may not

30   reproduce the interaction that occurs during an earthquake. The Authors maintain that consideration of

31   the frequency content of the ground motion is essential for obtaining accurate kinematic earth pressure

32   solutions, which pseudo-static solutions cannot provide.

33   The Authors acknowledge that simplifying assumptions were made in the paper to facilitate the

34   presentation of relatively simple closed-form solutions. We are actively engaged in research to facilitate

35   relaxation of these assumptions by incorporating into the solution wall flexibility, soil nonlinearity,

36   vertical inhomogeneity in soil stiffness for flexible base conditions, gap formation at the soil-wall

37   interface, improvement of impedance functions, and inertial interaction effects associated with the wall

38   itself and attached structures. These extensions will improve model accuracy for situations in which

39   relative wall-soil displacements are expected to be significant (i.e., when $\lambda/H < \sim 8\text{-}10$). However, for the

40   relatively common case of larger λ/H ratios, the physics of the problem will continue to dictate very low

41 earth pressures, as predicted by the framework presented in our paper. In short, the Authors posit that

42 our framework can effectively distinguish cases where kinematic earth pressures are and are not likely

43 to be important. Where they are significant, current procedures provide an admittedly rough estimate,

44 but one that is much more strongly rooted in the physics of the problem than pseudo-static methods

45 associated with an effective acceleration of a soil wedge. We respectfully suggest that this long-held

46 paradigm be gently moved toward retirement.