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Discussion on "Dynamic Consolidation of Liqufiable Sands", by R.K.M. Bhandari

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Discussion by Miguel P. Romo,
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on "Dynamic Consolidation of
Liquefiable Sands", by
R.K.M. Bhandari.

In his paper, the author shows how the soils underneath a tank were improved (down to 6 m) by pounding to density levels required to withstand earthquake induced liquefaction.

Although the dynamic consolidation procedure was developed more than a decade ago and has been - used in hundreds of jobs around the world, the procedure is still in evolution and its application to actual problems is mainly based on a - pragmatic approach. Thus, to define the weight and dimensions of the dropping mass, the free - fall height, the grid geometry and separation - between compaction points that should be used for improving the characteristics of a soil deposit to a certain depth, it is necessary to rely upon past experience gained on a site with similar - characteristics or use empirical equations based on the energy delivered to the soil by the dropping mass. Unfortunately, these type of equations are oversimplified and, in general, overestimate the depth of compaction.

The history case reported by the author indica-- tes that dropping a 7 ton weight, measuring 2m x 2m at its base, from a height of about 11 m, the compaction depth achieved was about 4 m. Using the equation $W H = D^2$ (where W is the weight of the mass in tons; H is the free fall height - in m; and D is the depth of compaction in m), - the compaction depth computed corre - - - sponds to about 8.8 m. When a second pass was performed, with compaction points located in between the previous points reducing therby the interval between them to 2.5 m, the compaction depth achieved was about 6 m. However, if the above equation is applied the same 8.8 m depth of compaction is obtained; thus, clearly indicating the limitations of this relationship.

At this point, the writer would like to point out that there are a number of variables, not included in the equation, that affect the compaction depth and its horizontal extent. For example, the soil characteristics before each pounding influence both compaction depth and its horizontal extent. Each pounding generates Rayleigh, shear and longitudinal waves of which the most effective in densifying loose sandy soils are the -- Rayleigh and shear waves due to the shear strains they induce to soil particles as they propagate; however, longitudinal waves also induce relative movements (back and forth displacements) between particles and when coupled with shear or Rayleigh waves may cause additional densification. Since the extent of wave propagation is a function of the characteristics of the propagation medium - then, the stiffness and damping of the soil before each pounding are important factors to be considered in evaluating compaction depth and its horizontal extent.

Another variable that should be accounted for in evaluating the extent of dynamic consolidation is the dimension of the hammer. That the dimension (i.e., base area for a square hammer) of the - - weight affects significantly the extent of compaction is easily comprehended remembering that a pulsating point load generates waves only and that a foundation under cyclic loading causes both -- waves and densification of the soil underneath. In fact there is practical evidence that a hammer with square base is more efficient than a spherical hammer. Hence, for a given energy the compaction depth and its horizontal extent increase, in general, with the base area of the hammer.

It seems to the writer that through a research program involving experimental and analytical aspects these variables could be incorporated - into a procedure to evaluate compaction depth as a function of the soil characteristics, hammer dimensions and separation between compaction - points. This procedure would eliminate much of the empiricism which predominates in the application of dynamic compaction up to now (1981).