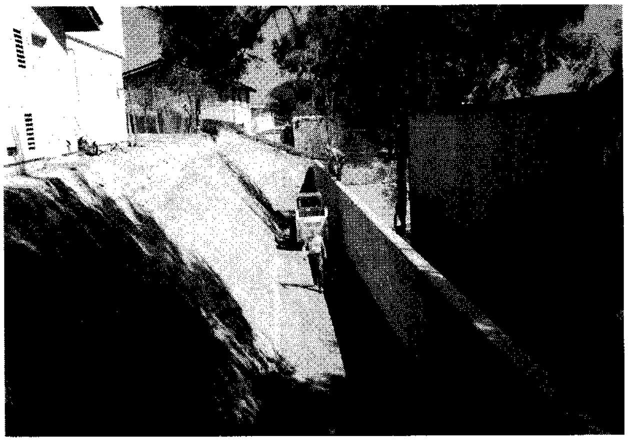

FIG. 23. Compaction of Wall Backfill Using Lightweight Equipment

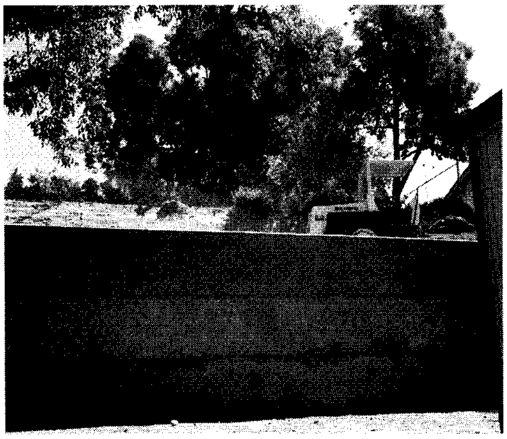

FIG. 24. Compaction of Sloping Backfill Using Heavy Compaction Equipment

FIG. 25. Gap in Front of Wall at Top of Clayey Slope (Arrows Point to Gap)

APPENDIX. REFERENCES

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Closure by Yung-Show Fang,[5] Associate Member, ASCE, Jiung-Ming Chen,[6] and Cheng-Yu Chen[7]

The writers wish to thank the discusser for his interest in their paper. The writers fully agree with the discusser's comment that the process of compaction of backfill can generate wall pressures well in excess of active pressures. However, it is clearly mentioned in the paper that, to limit the scope of this study, only loose cohesionless soil was used as backfill material throughout all experiments. Therefore, the test data obtained do not include any pressure variation due to compaction. The writers agree that, from a practical point of view, when designing a retaining structure it is important to estimate the pressure increment induced by soil densification. The practical and constructive discussions by the discusser significantly enhanced the value of the paper. However, instead of applying an empirical factor of safety to the Coulomb's solution, it is suggested that more analytical, numerical, and experimental studies should be carried out to reveal the mechanism of lateral stress variation as a result of soil compaction.

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CUMULATIVE PLASTIC DEFORMATION FOR FINE-GRAINED SUBGRADE SOILS[a]

Discussion by J. T. Shahu,[3] Yudhbir,[4] and N. S. V. Kameswara Rao[5]

The authors have addressed a very important issue of prediction of cumulative plastic deformation of soils under repeated loading. The authors studied the variation of parameters A and b of model (1) with the soil parameters and soil types. Finally, the comparison between predicted and experimental results was made for the railroad-track subgrade.

However, it may be noted that Shahu (1993) has developed a more generalized model for predicting the cumulative plastic strain in soil under repeated loading of the form

$$\log(\varepsilon_p) = C_P + D_P \log(N_1) + E_P \log(N_2/N_S) \qquad (14)$$

where $N_1 = N$ and $N_2/N_S = 1$ for $N \leq N_S$; and $N_1 = N_S$ and $N_2 = N$ for $N > N_S$. In the equation, C_P = value of log (ε_p) at $N = 1$; D_P = first gradient of the bilinear log-log plot between ε_p and N; E_P = second gradient of the bilinear log-log plot between ε_p and N (for $N > N_S$); and N_S = value of N where the change in gradient from D_P to E_P occurs (Fig. 9).

The discussers have developed model (14) as an improve-

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[a] December 1996, Vol. 122, No. 12, by Dingqing Li and Ernest T. Selig (Paper 11784).

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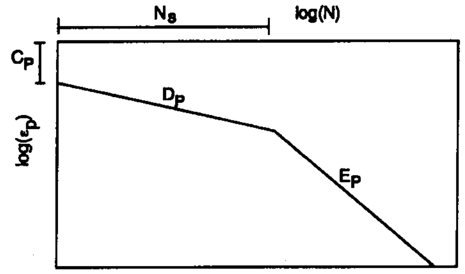

FIG. 9. Parameters of Model (14)

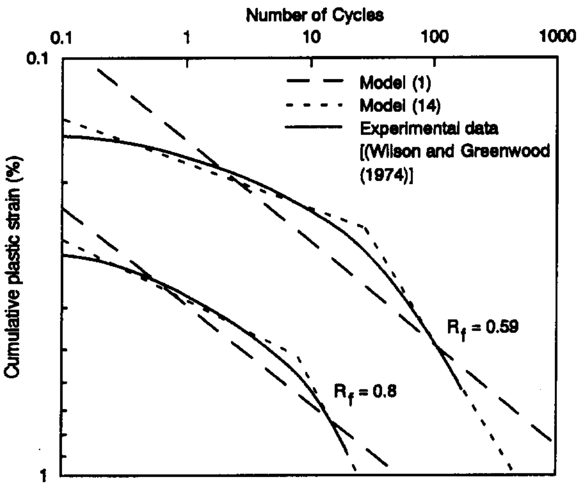

FIG. 10. Comparison of Models (1) and (14)

ment over model (1) and recommend the use of model (14) for generalization purposes because of the following advantages.

First, model (1) and its variations have been used by many investigators for prediction of cumulative plastic deformation. However, model (1) was found to be unsatisfactory for prediction of results of fine-grained soils from many other sources [e.g., Wilson and Greenwood (1974), ORE (1983), and Shahu (1993)]. Fig. 10 presents the comparison of predictive capabilities of model (1) and model (14) for experimental data by Wilson and Greenwood (1974). In this figure, cyclic stress ratio, R_f, is the ratio of cyclic stress to the ultimate static failure stress.

It may be noted that model (1) is a particular case of model (14) with $D_P = E_P$. Model (14) can also predict the results of fine-grained soils from the aforementioned sources successfully.

Second, bilinear representation on log-log plot [model (14)] has an important physical significance. For cyclic stress level less than threshold stress (also known as critical level of repeated stress), the E_P value is found to be less than the D_P value or equal to zero and a stable deformation behavior is indicated representative of cumulative compaction mechanism. On the other hand, for cyclic stress greater than or equal to threshold stress, the E_P value is found to be either equal to or greater than the D_P value, indicating cumulative plastic shear strain mechanism.

Shahu (1993) also investigated the variation of model parameters C_P and E_P. C_P [similar to A in model (1)] was found to be dependent upon cyclic stress level, and E_P [similar to b in model (1)] was found to be constant for a given soil type for cyclic stress greater than threshold stress. The authors arrived at similar conclusions and lend support to the observations by Shahu (1993). However, parameters C_P and E_P are strongly dependent upon threshold stress of soil, and the variation of C_P and E_P values with cyclic stress undergoes sudden changes for cyclic stress greater than threshold stress of soil. Hence, threshold stress of soil should be considered as an important parameter in any study on generalization of model parameters.

APPENDIX. REFERENCES

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Closure by Dingqing Li,[6] Member, ASCE, and Ernest T. Selig,[7] Fellow, ASCE

The writers wish to thank the discussers for their interest in the paper and for bringing their work to the writers' attention. In their discussion, model (14) was considered as an improvement over model (1). The writers agree that model (14) appears more precise when large strain accumulation occurs, but is not necessarily more accurate because of the need to know more model parameters.

As also pointed out by the discussers, model (1) has been used by many investigators. The writers further confirmed its validity with various soil test results, although this model may become less satisfactory in some cases when a soil is near failure. Based on the fact that model (1) has been accepted as reasonable and simple, it was selected for general use and its two parameters A and b were quantified, as discussed in the original paper. Soil cyclic stresses, soil physical states, and soil type were represented in terms of their quantitative effects on cumulative strain. Furthermore, a procedure was incorporated to calculate cumulative deformation due to multiple levels of deviator stresses and multiple soil physical states that can result from load-level variations, as well as seasonal and weather changes throughout traffic.

Instead of two parameters (A and b), model (14) introduces four parameters (C_P, D_P, E_P, and N_S). The discussers mentioned that parameters C_P and E_P are similar to A and b in terms of the effects of cyclic stress and soil type on their variations. However, the discussers did not mention how these four parameters can be determined or quantified. Furthermore, the discussers did not mention how to consider multiple stress levels and multiple soil physical states if model (14) is used.

The writers believe that more elaborate models including model (14) can improve the prediction of cumulative plastic strain, but nonetheless lead to more difficulties in quantifying model parameters for practical applications.

As mentioned previously, model (1) is less satisfactory in predicting cumulative deformation when cyclic deviator stress is greater than or equal to soil threshold stress (i.e., at failure). However, it is the writers' opinion that a model such as (1) or (14) for predicting cumulative deformation is less meaningful once a soil is considered at or near failure. Further, the bilinear log-log model (14) gives the appearance of sudden change of deformation accumulation rate, when it is actually gradual without the breaking point indicated by model (14).

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