TABLE 4. Values of Lateral Loads and Three-Dimensional Spacing

Pile group arrangement (1)	Single pile (N) (2)	Pile group (N) (3)
Series	89	177
Parallel	89	200

consistent with those reported by the authors (Table 2). Similar observations have been made at other displacements and pile spacings. It is not clear how the authors obtained group efficiency factors shown in Table 2. As stated earlier, under static loads, it is understood that the lateral group efficiency is always less than 1.

It is well-recognized that the pile head fixity condition is an important factor in determining load-deflection characteristics of piles. To compare single-pile load test data and pile group load test data, rotations and slopes at the top of a single pile and piles in a group must be consistent. Based on the description of the test setup, it appears that the single piles tested by the authors are free head piles. It is the discusser's opinion that inconsistency in the group efficiency factors reported by the authors is the result of inconsistent pile head fixity conditions.

APPENDIX. REFERENCE

Poulos, H. G., and Davis, E. H. (1980). *Pile foundation analysis and design.* John Wiley & Sons, Inc., New York, N.Y.

Discussion by Athanassios D. Platis,[5] Member, ASCE

The authors have made a valuable contribution to the problem of pile group behavior under lateral loading for which relatively little data have been published as compared to single pile behavior. The discusser wishes to comment on some of the test results and get the authors' feedback.

In respect to the bending moment distributions along the piles in the series arrangements, it is interesting that the higher bending moments develop on the rear pile(s). This alone would indicate that

1. The rear pile(s) share more lateral load than the front one(s).
2. The "point of fixity" of the rear pile(s) is lower than that of the front one(s).
3. Both (1) and (2).

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Since the pile heads are held together by a rigid pile cap in a way that they displace by the same amount, the pile(s) with the "stiffer" behavior would share more of the group load than the one(s) with the more flexible behavior. In this respect, the front pile will be resisted by the "full" soil resistance, while the rear one(s) will be affected by the presence of the front one(s) and by the deformation field created by them. Therefore one would expect that the soil would develop less resistance against the rear one(s), especially at small pile spacings. Consequently, following this line of thinking:

1. The front pile would carry more load and hence develop higher bending moments at ground level (where no soil resistance has yet come into play).
2. The "point of fixity" of the rear pile(s) would be deeper, which could potentially result in a higher maximum bending moment.

However, by observing Figs. 11–14, none of the preceding seems to be satisfied. In fact, the bending moment at ground level is higher in the rear pile(s), which means that they carry higher lateral load(s) than the front one, although they all have approximately the same "point of fixity."

In addition, the total bending moment at ground level should be of the order of (185 ÷ 219) N × 0.20 m = 37 ÷ 42 Nm minus some small pile head bending moment induced by the pile cap, which seems to be of the order of 2 ÷ 3 Nm from Figs. 11–14 [i.e., (37 ÷ 42) − 2x(2 ÷ 3) = 31 ÷ 38 Nm at ground level]. However, adding up the bending moments at ground level for the various piles comprising the group gives lower values than the expected ones (e.g., for the two-pile group from Figs. 11 and 12 we have $M_{total} \approx 8 + 13 = 21$ Nm instead of 31 ÷ 38 Nm).

The authors' comments on these apparent discrepancies would be appreciated, since the conclusion that the rear pile(s) could develop as much as twice the bending moment of the front one would considerably affect the structural design of such piles.

The discusser wishes to offer a couple of suggestions as potential sources of these apparent discrepancies.

1. One is the possibility of some "slack" around the head of the front pile, which would result in a certain amount of lateral movement of the pile cap and a corresponding mobilized reacton force on the rear pile(s) before the front pile starts to react.
2. A second one is the magnitude of the modulus of elasticity of the pile material (mild steel) used to transform strains, measured by the strain gauges, to bending moments.

Finally, the discusser believes that it will be useful if the authors give information on displacement increase ratios as a function of pile spacing and arrangement in addition to the ones given for pile capacities.