Although the nondimensional curves of Matlock and Reese were widely used, the author has never recommended their use. A pile foundation is costly, and computers have been available—together with computer programs—for this type of analysis since at least 1960. That is, better tools are now available for these analyses.

THE p–y METHOD. The initial work on the FDM lateral pile solution [see McClelland and Focht (1958)] involved using node springs p and lateral node displacements y, so that users of this method began calling it the "p–y method." Work continued on this FDM computer program to allow use of different soil node springs along the pile shaft—each node having its own p–y curve [see Reese (1977)]. Since p–y curves were stated by their author to represent a line loading q (in units of kip/ft, which is also the unit of a soil spring), user confusion and uncertainty of what they represent has developed. This uncertainty has not been helped by the practice of actually using the p part of the p–y curve as a node spring but with a 1-ft node spacing so that it is difficult to identify exactly how p is to be interpreted. The product of node spring and node displacement y gives $p \cdot y$ = a node force similar to spring forces computed in the more recognizable form of force $= K \cdot X$.

The data to produce a p–y curve are usually obtained from empirical equations developed from lateral load tests in the southwestern United States along the Gulf Coast. In theory, one obtains a p–y curve for each node along the pile shaft. In practice, where a lateral load test is back-computed to obtain these curves, a single curve is about all that one can develop that has any real validity since the only known deflections are at or above the ground line unless a hollow-pipe pile is used with telltale devices installed. If the node deflection is not known, a p–y curve can be developed with a computer, but it will only be an approximation.

The FDM is not easy to program since the end and interior difference equations are not the same; however, by using 1-ft elements, interior equations can be used for the ends with little error. The equations for the pile head will also depend on whether it is free or either translation and/or rotation is restrained. Other difficulties are encountered if the pile section is not constant, and soil stratification or other considerations suggest use of variable length segments. Of course, one can account for all these factors. When using 1-ft segments, just shift the critical point: The maximum shift (or error) would only be 0.5 ft.

The FDM matrix is of size $N \times N$, where N = number of nodes. This matrix size and a large node spacing were advantages on early computers (of the late 1950s) with limited memory; however, it was quickly found that closer node spacings (and increases in N) produced better pile design data. For example, it is often useful to have a close node spacing in about the upper one-third of a pile.

The FDM would require all nodes to have equal spacing. For a 0.3-m spacing on a 36-m pile, 121 nodes would be required for a matrix of size $N \times N$ = 14 641 words or 58.6 kbytes (4 bytes/word in single precision). This size would probably require double precision, so the matrix would then use 117 kbytes.

THE FEM LATERAL PILE/PIER ANALYSIS. The author initially used the FDM for lateral piles (see first edition of this text for a program); however, it soon became apparent that the FEM offered a significant improvement. Using the beam element requires 2 degrees of freedom per node, but the matrix is always symmetrical and can be banded into an array of size

$$2 \times \text{number of nodes} \times \text{Bandwidth}$$