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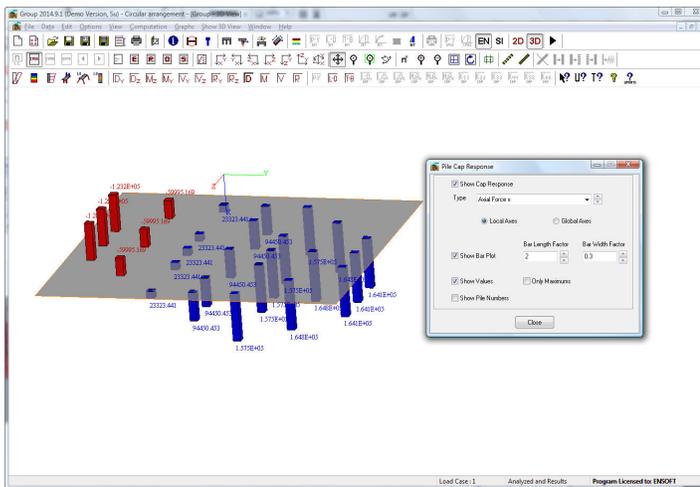
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## GROUP v2014 (v9)

### A Program for the Analysis of Piles in a Group

#### GENERAL DESCRIPTION

*GROUP* has been well accepted as a valuable design tool for analyzing the behavior of piles in a group subjected to both axial and lateral loadings. The program computes the distribution of loads (in six degrees of freedom) applied from any multiple locations in the pile cap to piles arranged in a group. A new feature for user-specified displacements and rotations (in 3D) from *GROUP* v2014 resolves the forces that are generated with such movements/rotations.



Visualizations of 3D Model in *GROUP* displaying distribution of axial forces at pile cap

Piles may be installed vertically or on a batter and their heads may be fixed, pinned, or elastically restrained by the pile cap. The pile cap may settle, translate, and/or rotate and is assumed to act as a rigid body.

The program generates internally the nonlinear response of the soil, in the form of  $t-z$  and  $q-w$  curves for axial loading, in the form of  $p-y$  curves for lateral loading, and in the form of  $t-r$  curves for torsional loading. A solution requires iteration to accommodate the nonlinear response of each pile in the group model. Program *GROUP* solves the nonlinear response of each pile under combined loadings and assures compatibility of deformations and equilibrium of forces between the applied external loads and the reactions of each pile head.

For closely-spaced piles, the pile-soil-pile interaction (group

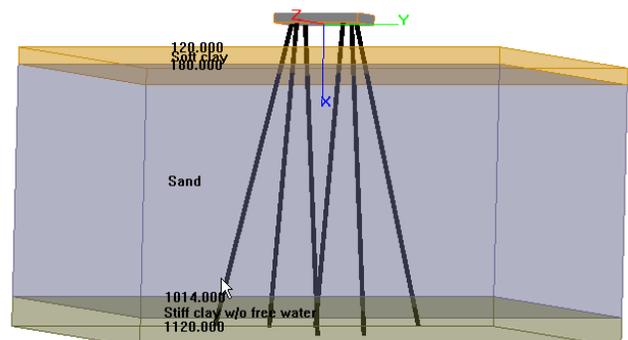
*Program GROUP allows the input of groups of straight or batter piles, layered soil profiles, various cross-sections of pile sub-groups, and several loading arrangements*

effects) can be taken into account by introducing reduction factors for the  $p-y$  curves used for each single pile. As an option, the user may ask the program to automatically generate suggestions of  $p$ -multipliers for the internal reduction of the soil resistance in closely-spaced piles. In *GROUP* the user may enter  $p-y$  modification factors that can vary along the length of each pile in the model.

The program allows the user to select computations of the required unit side friction at the top and bottom of each soil layer along with a unit tip resistance. The program employs commonly-accepted equations to compute internally the estimated unit side friction and unit tip resistance based on the soil properties that are specified by the user for each soil layer. However, users may also input external nonlinear curves of axial load versus settlement for each pile in the group. Those external curves can be obtained by the user based on load tests or using the Ensoft programs *APILE* and/or *SHAFT*.

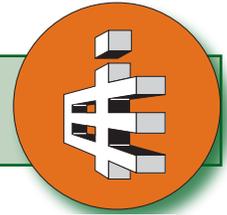
Amongst several new features, with *GROUP* the foundation stiffness can be generated based on equivalent elastic stiffness (thus generating a symmetric stiffness matrix). Users of *GROUP* v2013 are also able to select to print out a text file (response file) with equivalent nonlinear springs along the pile, which is useful for performance of complete soil-structure interaction analyses using other structural software.

The previous *GROUP* introduced several enhancements: Use of multiple load cases representing concentrated loads at the pile cap and/or distributed lateral load at the piles; Concentrated loads at the pile cap may be defined at any position; Distributed lateral loads at the piles can be defined by local or global axes; Load combinations can be specified by the user and are set by load factors applied at the defined load cases; Maximum and minimum envelopes may be computed for both load cases and load combinations; *GROUP* can provide flexibility and stiffness matrices (in 2D or 3D models) for different levels of loading.



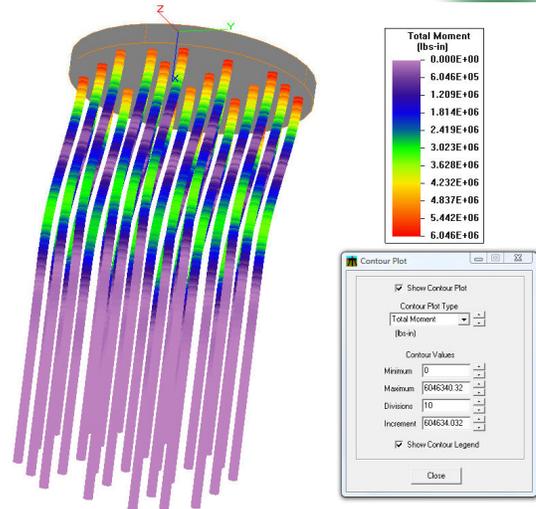
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### LIST OF FEATURES

- A new pile cross-section dialog is included to allow the user define piles with circular, rectangular and wide-flange sections. In addition, GROUP v2013 introduces the ability to analyze tapered pile sections.
- A template option is added so the program will generate basic rectangular or circular pile group layouts easily. This is particularly useful for models with large number of piles.
- Batter and vertical piles can be included in the same group analysis. Up to 1000 piles can be modeled in a group and piles can have different EI values in orthogonal directions.
- Parallel-processing in GROUP v2014 allows for efficient usage of multi-core processors and considerable reductions in computing time on large models.
- Pile-head connections to the rigid cap may be selected as: pinned, fixed, or elastically restrained.
- Soil Movement can be specified as part of the loading.
- $p$ - $y$  curves may be inputted by the user or may be automatically generated by the program and printed for review. User-defined soils (user-inputted lateral, axial and/or torsional curves) can be mixed with soil layers having response curves that are automatically generated.
- Points of  $p$ - $y$  curves (that were internally generated by GROUP) but requested as output/printout can be generated according to user-defined levels of deflections ( $y$  values).
- GROUP provides stiffness and/or flexibility matrices for foundations in 2D or 3D models. Users may define specific points on secant stiffness and obtain off-diagonal terms.
- The type and number of graphs generated by GROUP have been increased over previous versions. The program plots the force and displacement on the pile cap, such as the axial force



Contoured graphics of total pile moments for foundation models in GROUP

(tension and compression) of each pile on the pile cap, the lateral forces (shear and moment) of each pile on the pile cap, and the displacement of the pile cap in different directions.

- 3D View graphics has been enhanced extensively to include various new features for inquiring of results and visual presentations for any load case/combination.
- The program can use a nonlinear bending stiffness (EI) of each pile during computations. The user can enter nonlinear moment-curvature curves under different axial loads for each pile type.
- GROUP provides a summary table of output data, which includes maximum and minimum effects for pile heads and over the pile length.

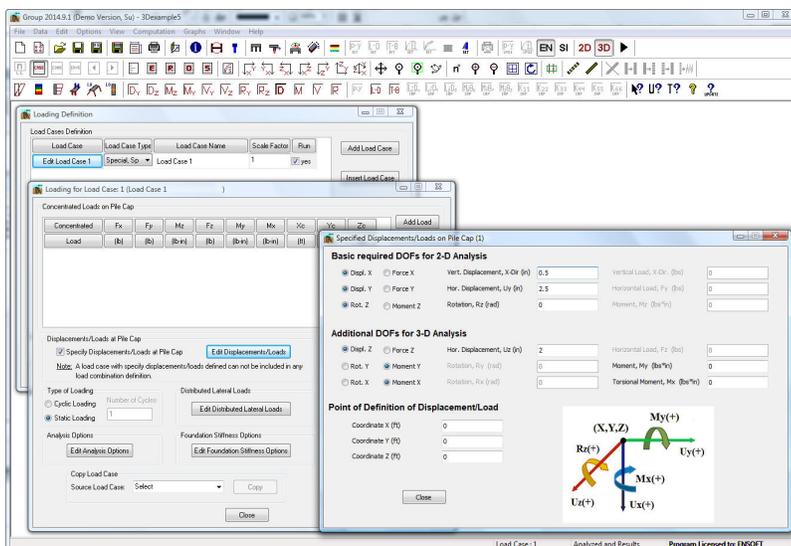
• More efficient algorithms are used to improve significantly the accuracy of the solution of a problem due to iterations because of the non-linearity of soil parameters.

• GROUP can consider lateral soil resistance against embedded pile caps and option to specify a reduction factor on the axial capacity of each individual pile.

The output file includes the passive soil resistance that is computed internally against embedded pile caps.

• User can select the information to be printed, for convenience when the size of the output file becomes very large due to large number of piles and/or number of load cases.

• Models can be made in English or SI Units (w/ automated conversion), while GROUP v2014 introduces more traditional units for inputs of various parameters.



Sample windows used for data input