# Introduction to explicit finite difference nonlinear stress analysis programs from Itasca Consulting Group, Minneapolis

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# Geomechanics

- critical issues: stability, factor of safety
- therefore need to perform nonlinear analyses:
  yield of soil and rock,
  slip/separation on joints and faults,
  large deformations
- groundwater pressures often important
- structural elements for support

# Explicit and implicit methods

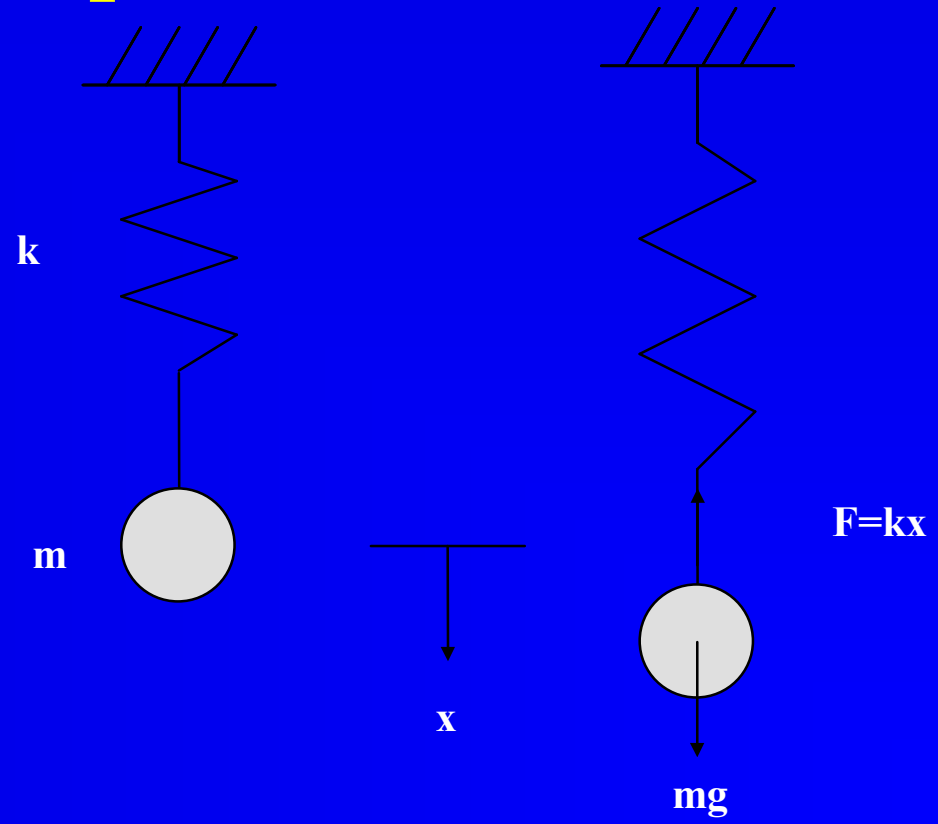



Figure 1. Mass on a spring

# Implicit

- equation of static equilibrium:
  $F = kx = mg, \quad so \quad x=mg/k$
- nonlinear spring: solve via iteration
- finite element stress analysis:
  $\{F\} = [K] \{x\}$
- solve by inversion of stiffness matrix [K]

# Explicit

- start from equation of motion, with boundary conditions
- mass on spring: simple harmonic motion
- damping to represent dissipation of energy
- equilibrium not assumed, so procedure does not break down if system fails
- small time step required for numerical stability

# Programs

Three groups of programs - one 2D, one 3D

- *FLAC* and *FLAC*$^{3D}$: nonlinear continuum
- *UDEC* and *3DEC*: nonlinear discontinuum
- *PFC*$^{2D}$ and *PFC*$^{3D}$: particle flow codes

Educational versions of 2D codes

Regularly updated - available from website

# *FLAC* and *FLAC*$^{3D}$

- nonlinear continuum mechanics, large strains
- transient porous flow, by itself or coupled
- effective stresses for yield
- structural elements, interfaces
- *FISH* programming language
- options: thermal, creep, dynamics, C++ UDM, two-phase flow (*FLAC* only)

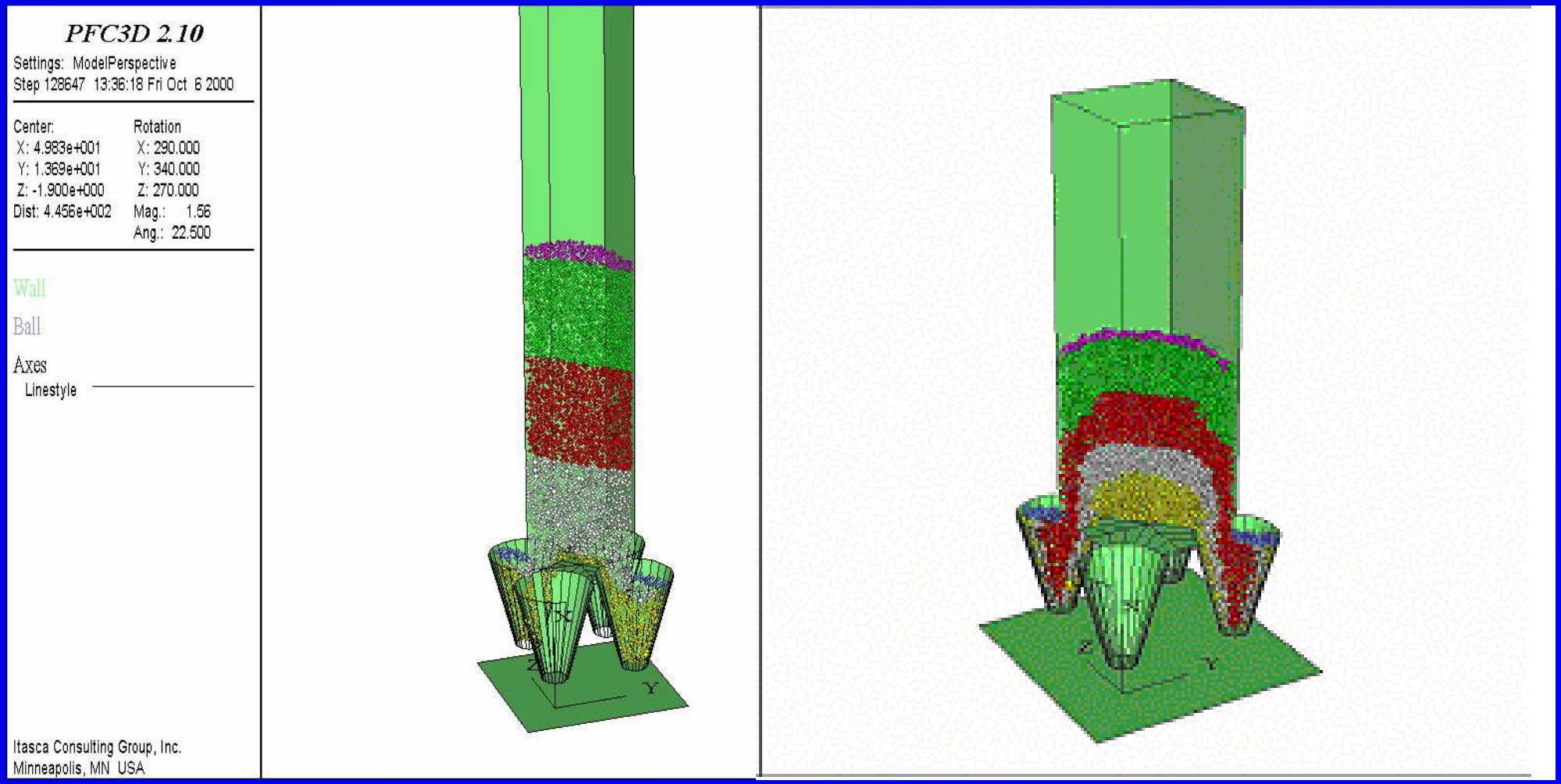
# *UDEC* and *3DEC*

- nonlinear discontinuum mechanics of jointed rock
- large displacements
- transient flow in joints, effective stresses
- structures - cables, beams, liner (*UDEC* only)
- *FISH* programming language
- options: Barton-Bandis, UDM (*UDEC*);
  thermal, dynamics, structures, UDM (*3DEC*)

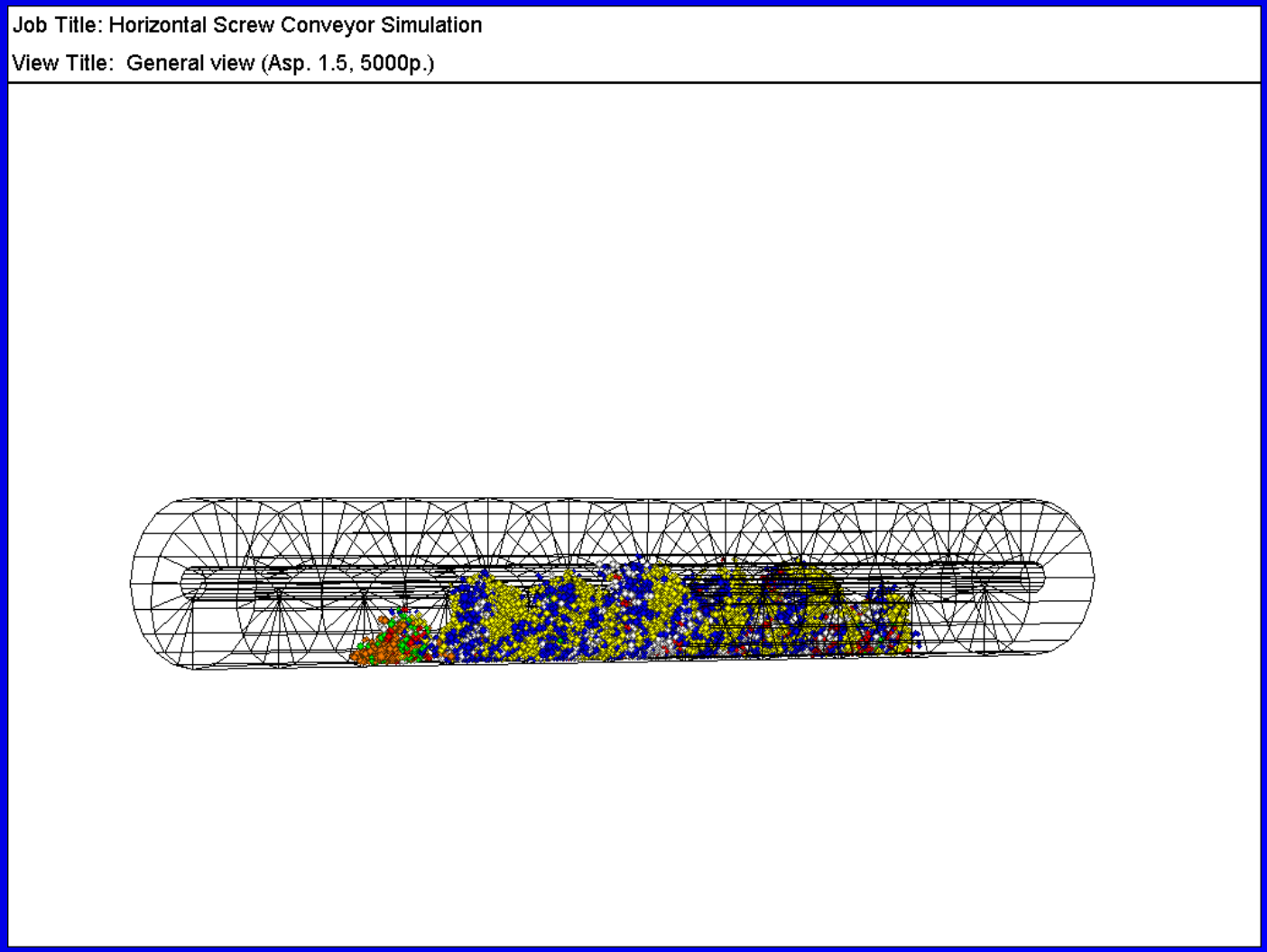
# *PFC*$^{2D}$ and *PFC*$^{3D}$

- micromechanical analysis of geomaterials and particulate systems
- clump logic, generalised walls
- dynamic loads, fracture propagation
- particle flow: caving; bulk handling
- *FISH* programming language
- options: thermal, UDM, parallel processing, fluid flow

# *PFC*$^{3D}$ example: interaction between 4 drawpoints



# *PFC*$^{3D}$ example: bulk material handling



# *FLAC* demonstration analysis: spoil pile

- observed spoil pile failures could not be explained by "slip circle" stability analysis
- field observations revealed two-wedge mechanism
- back analysis and design (1978) via two-wedge limiting equilibrium analysis
- simple model with *FLAC* naturally develops observed mechanism of failure

# *UDEC* demonstration analysis: jointed slope

- slope with underlying weakness plane and steeply-dipping joints
- toppling failure if base strong, joints weak
- sliding failure if base weak, joints strong

# *FISH* programming language

- powerful facility allows users to add new features to programs
- examples:
  - statistical variability of material properties in *FLAC*
  - initialisation of in situ stresses to reflect surface profile in *UDEC*

# Other lectures

- Case studies of use of *FLAC* and *FLAC*$^{3D}$
  slope stability at Ok Tedi mine;
  undermining of an unlined tunnel in rock;
  3D modelling of excavation adjacent to a bridge
- Case studies with *UDEC*
  flexural toppling slope failure at Savage River mine
  stress-related low-wall failure at Leigh Creek mine