Evolution of Soil Models Since the 1970's

By **Robert Pyke**

Outline

- Conclusions
- Effects on site response analyses
- Evolution of a simple hyperbolic model

Conclusions

- "Soil models are like religion. Everyone believes in his own, but not in anyone-else's."
- Neither of the Masing hypotheses is valid.
- While some progress has been made in the last 25 years, in order to make further progress we need more element test data that fully describe complex, cyclic loading in one, two and three-dimensions.

And Last But Not Least

- What we really need is more robust nonlinear analysis tools and well-documented case histories rather than equivalent linear analyses and semi-empirical procedures based on poorly documented case histories or centrifuge tests!

Example Site Response Analysis

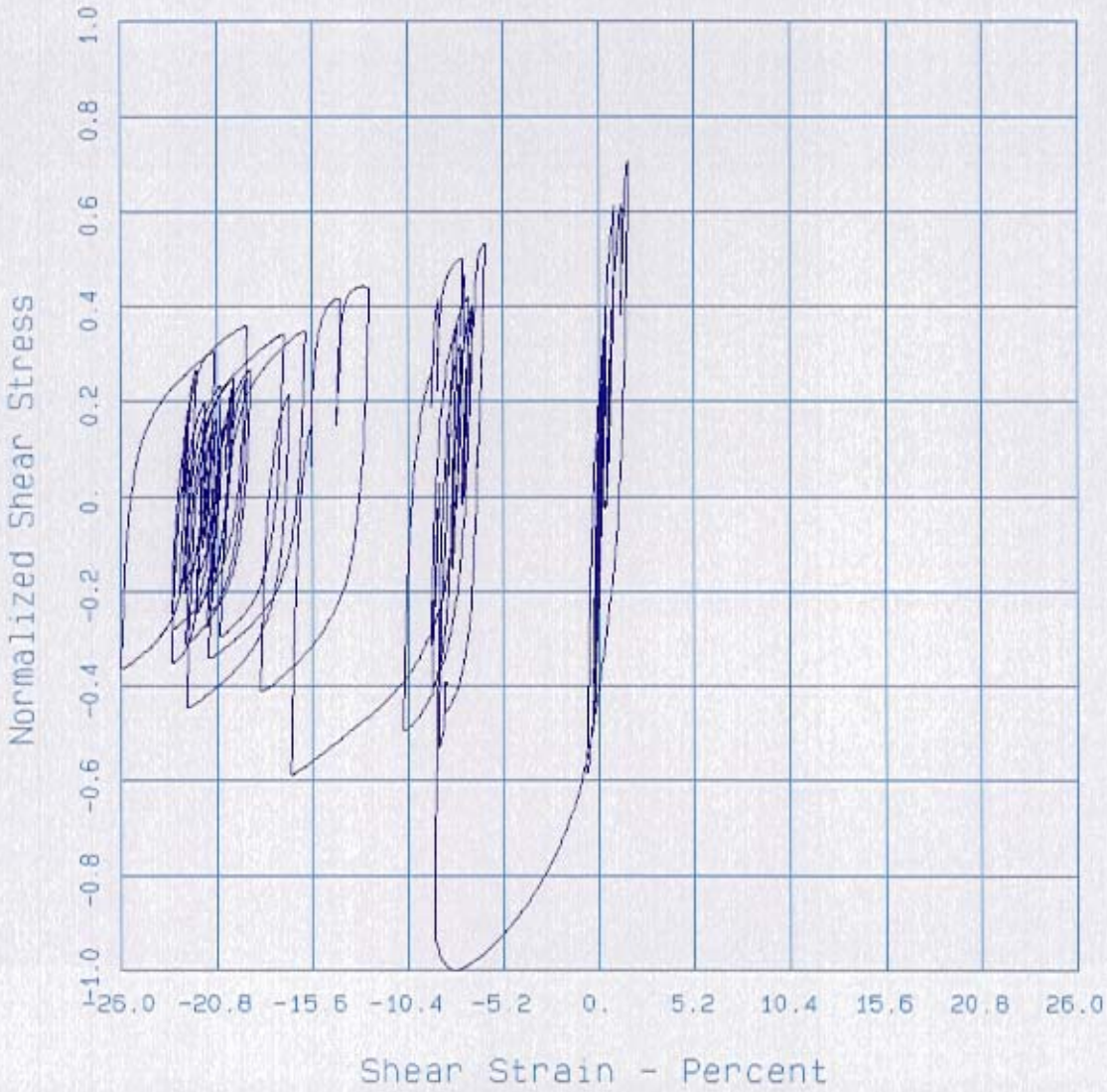
- A real profile from SFO
- 70 feet of young Bay Mud
- 1000 year return period ground motions
- Alternative of concrete deck on large diameter piles
- Displacements are critical

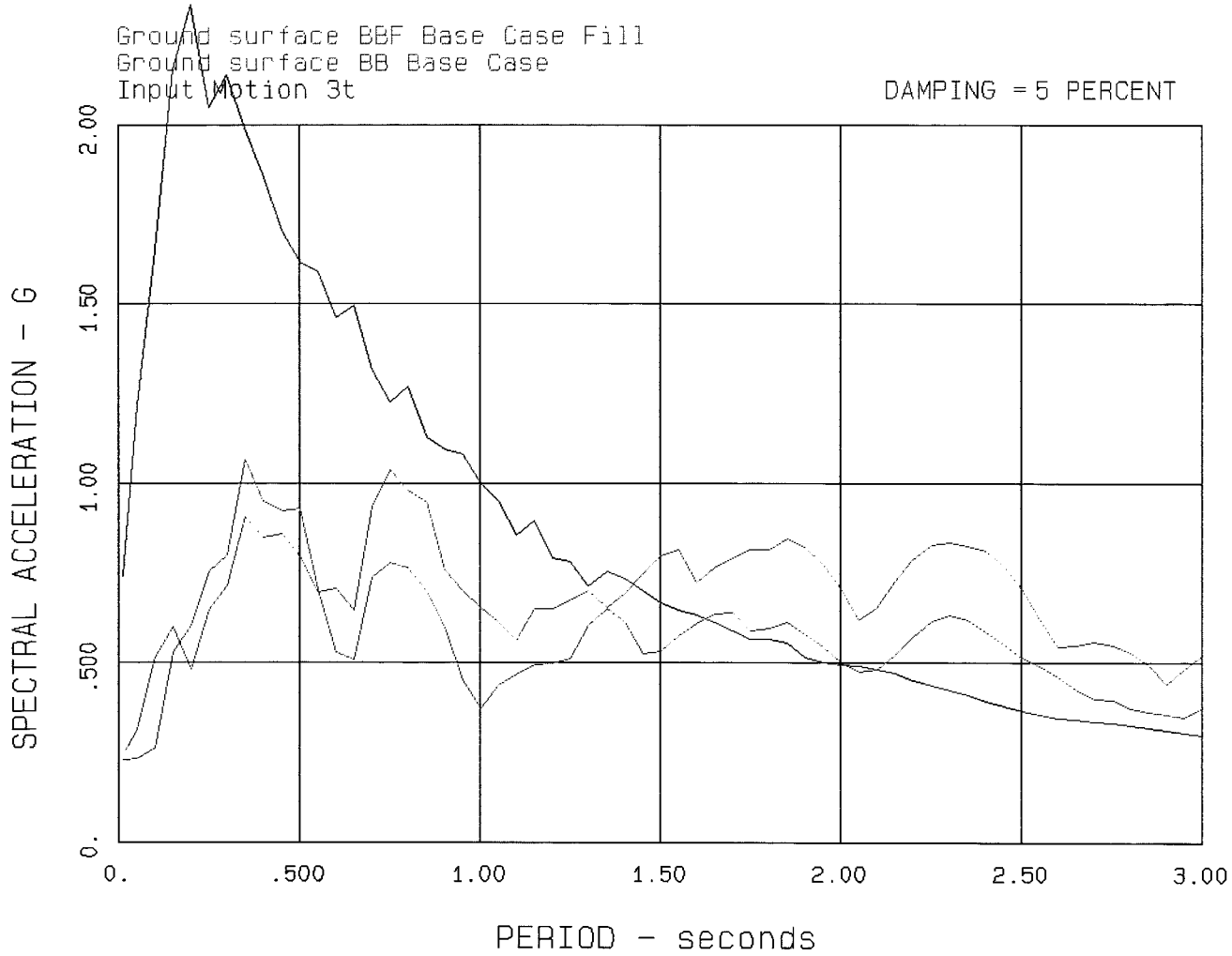
Analyses Conducted Using TESS

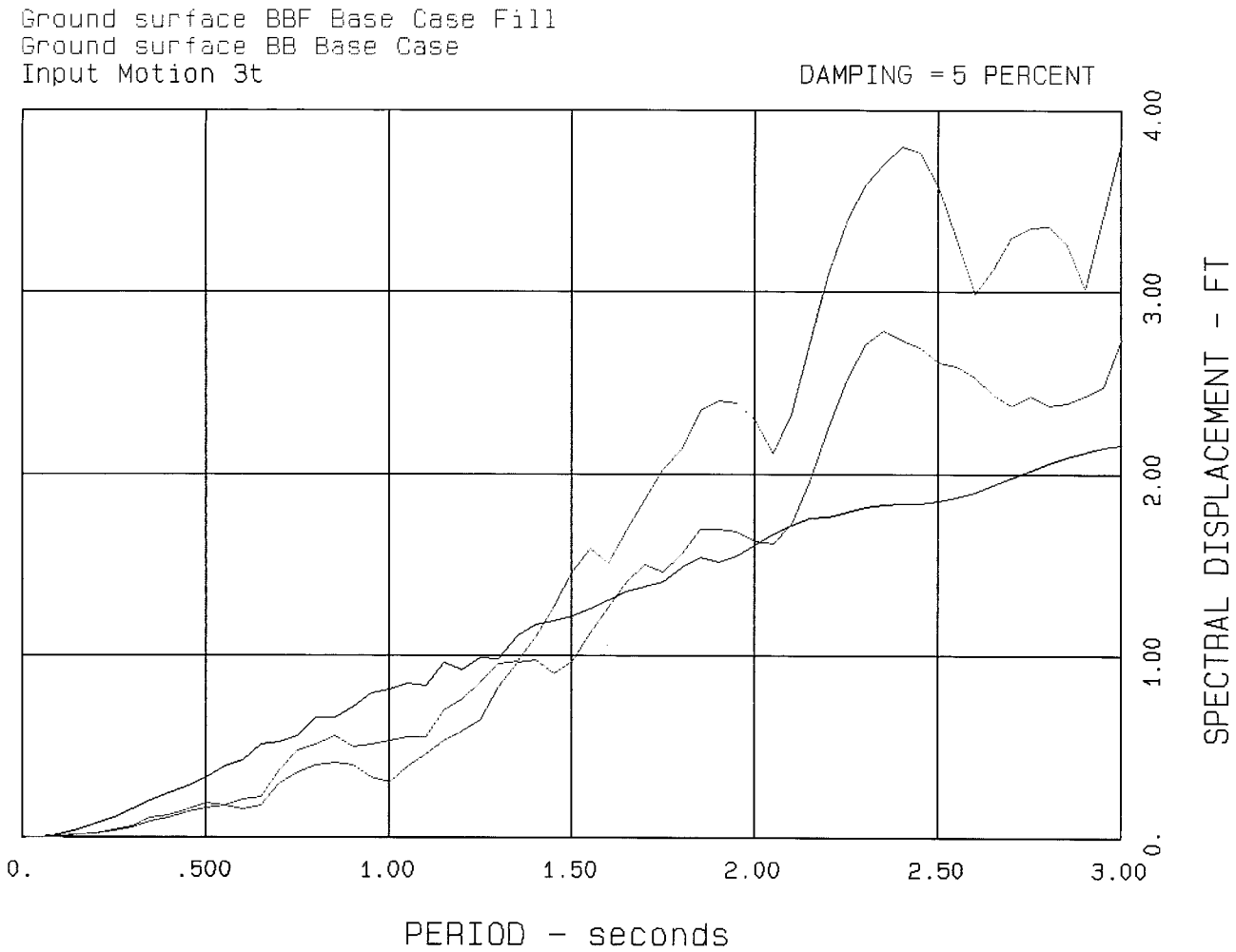
- Explicit finite difference solution
- Simple hyperbolic soil model
- Cycles in accordance with Cundall-Pyke hypothesis
- Older version had roughly twice the damping shown in laboratory tests
- Results best seen as animated displacement profiles, but …

Results Using Old HDCP Model

- Stress-strain loops at base of bay mud
- Acceleration and displacement response spectra
- Natural soil profile plus profile after consolidation under 30 feet of fill
- Level ground surface

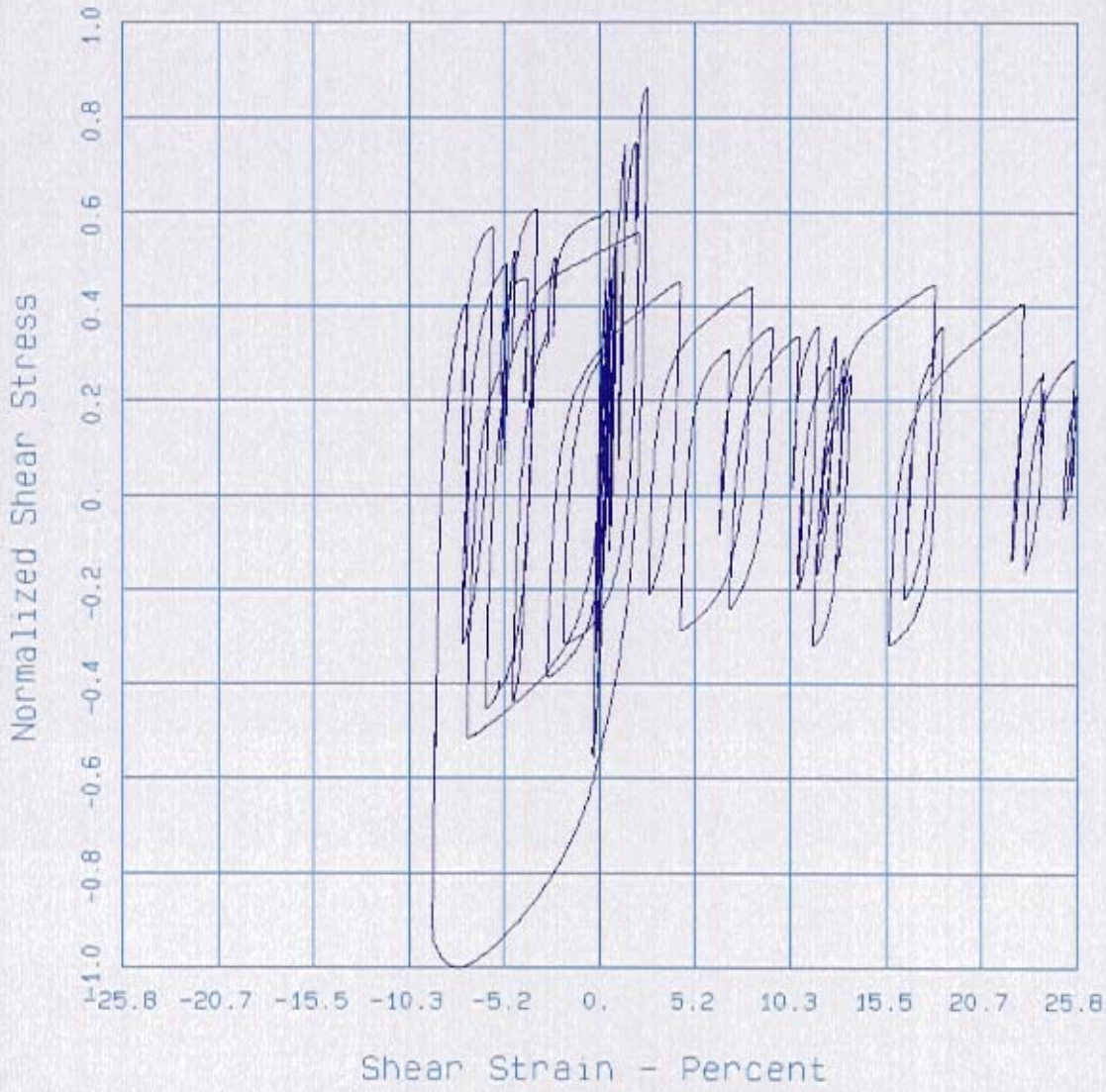

Normalized Shear Stress
1.0
0.8
0.6
0.4
0.2
0.
-0.2
-0.4
-0.6
-0.8
-1.0
-26.0
-20.8
-15.6
-10.4
-5.2
0.
5.2
10.4
15.6
20.8
26.0
Shear Strain - Percent

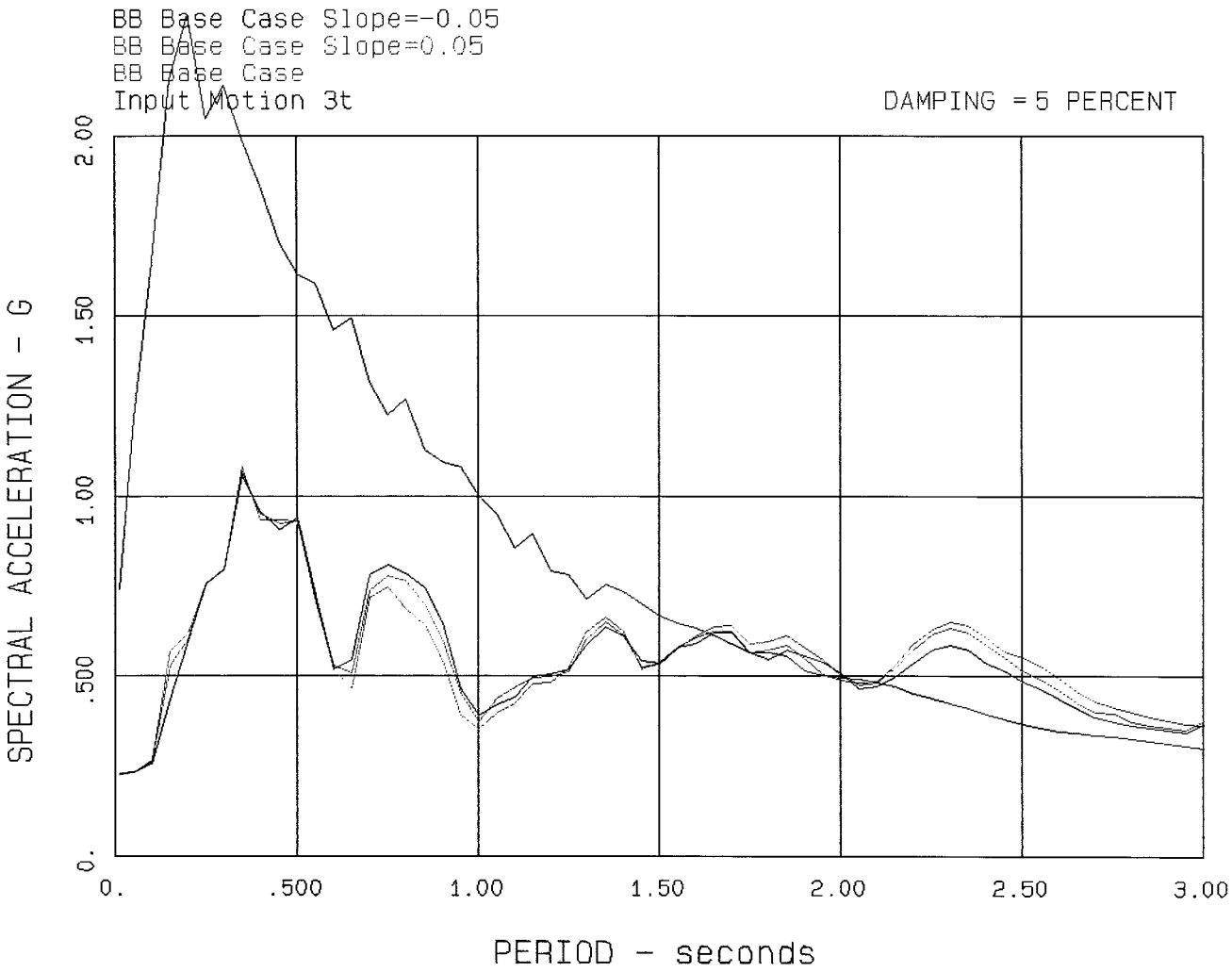

Ground surface BBF Base Case Fill
Ground surface BB Base Case
Input Motion 3t
DAMPING = 5 PERCENT
SPECTRAL ACCELERATION - G
0.
.500
1.00
1.50
2.00
0.
.500
1.00
1.50
2.00
2.50
3.00
PERIOD - seconds

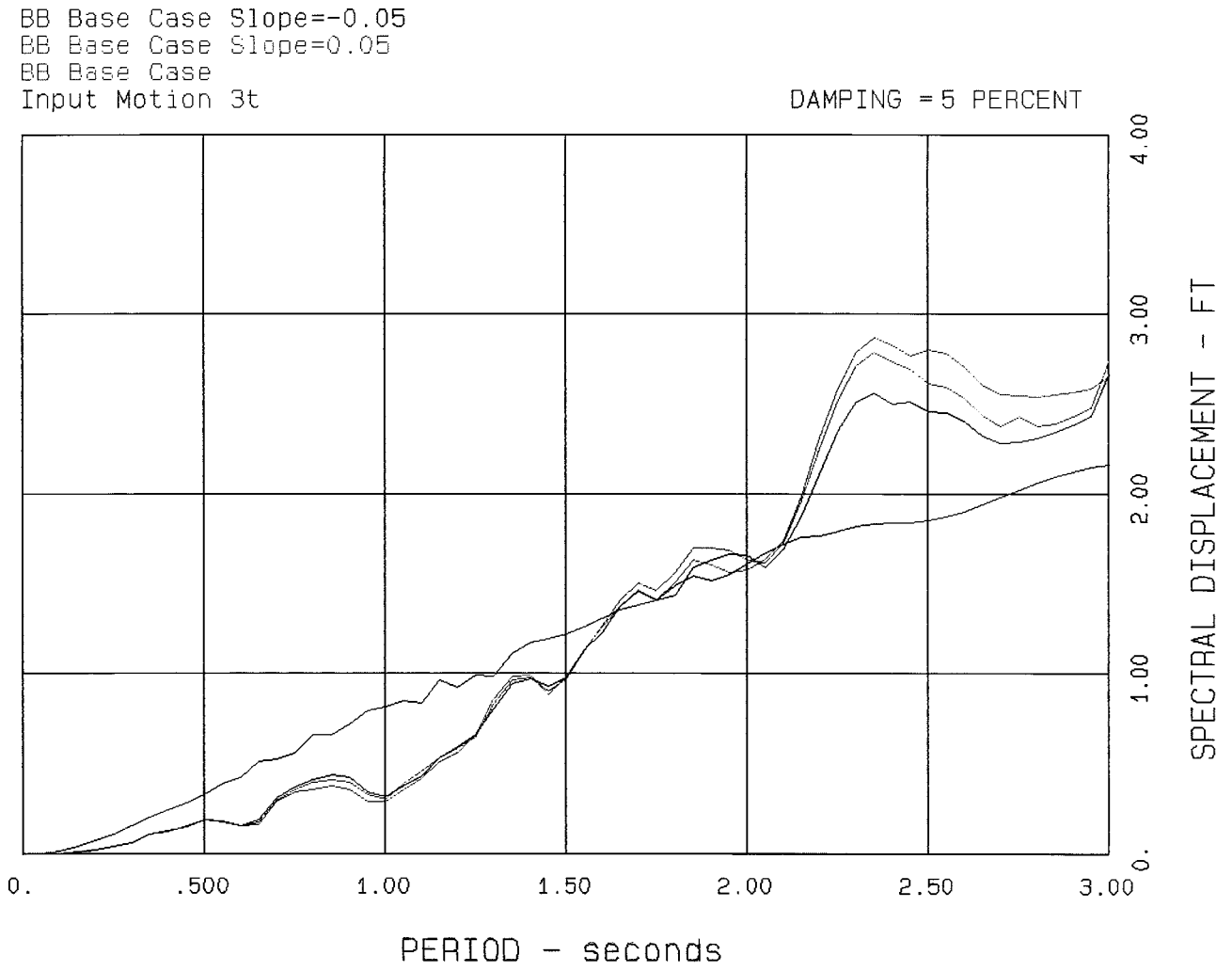

Ground surface BBF Base Case Fill
Ground surface BB Base Case
Input Motion 3t
DAMPING = 5 PERCENT
4.00
3.00
2.00
1.00
0.
SPECTRAL DISPLACEMENT - FT
0.
.500
1.00
1.50
2.00
2.50
3.00
PERIOD - seconds

Effect of Sloping Ground Surface

- Stress-strain loops are shown only for motion in one direction
- Response spectra are shown for the same motion in two directions
- Computed final displacements at mudline are –4.4 ft for level ground, 6.8 and 13.5 for ground sloping at 5 percent
- Pile design is difficult for these displacements

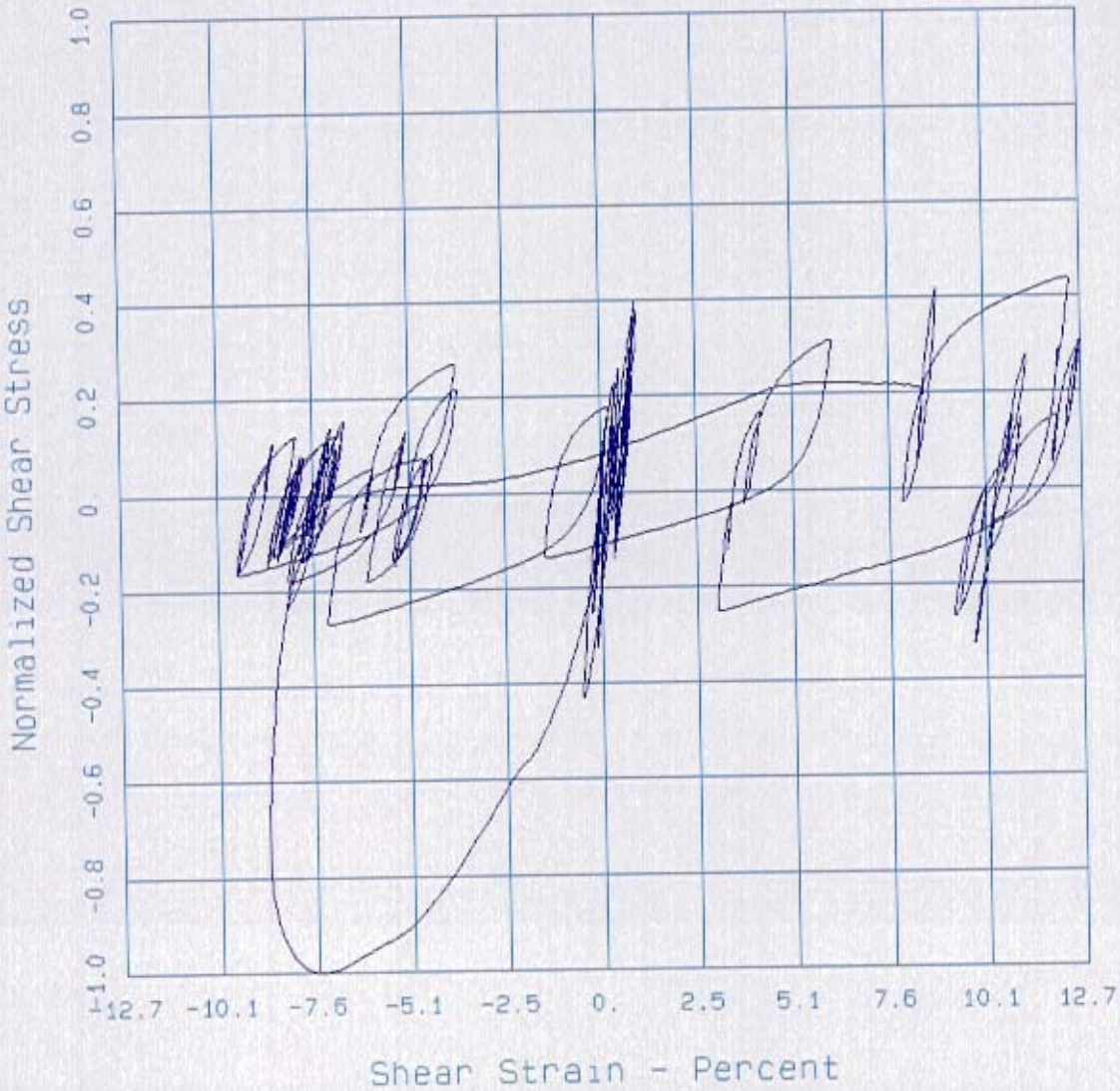

Normalized Shear Stress
1.0
0.8
0.6
0.4
0.2
0.
-0.2
-0.4
-0.6
-0.8
-1.0
-25.8
-20.7
-15.5
-10.3
-5.2
0.
5.2
10.3
15.5
20.7
25.8
Shear Strain - Percent

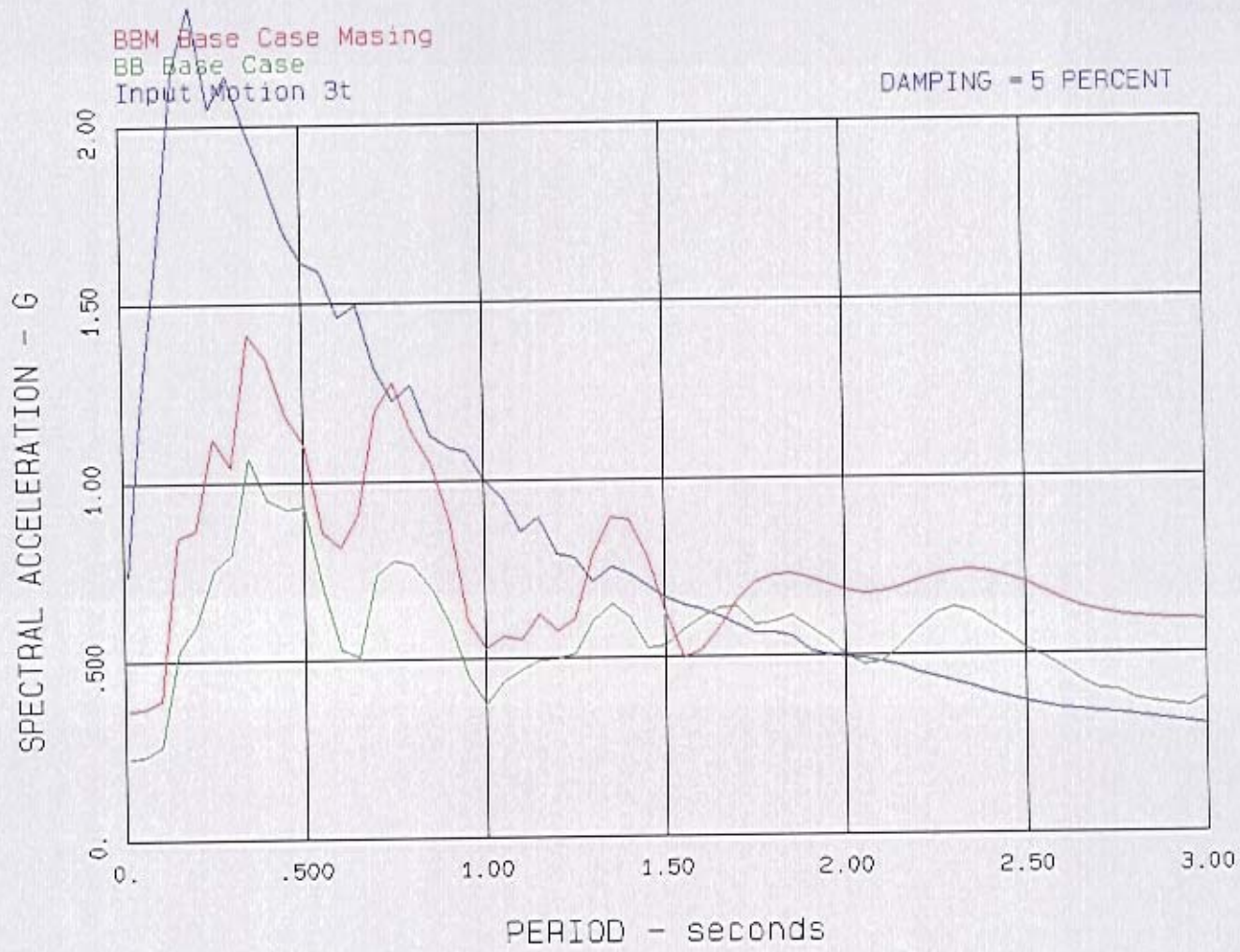

BB Base Case Slope=-0.05
BB Base Case Slope=0.05
BB Base Case
Input Motion 3t
DAMPING = 5 PERCENT
SPECTRAL ACCELERATION - G
2.00
1.50
1.00
.500
0.
0.
.500
1.00
1.50
2.00
2.50
3.00
PERIOD - seconds

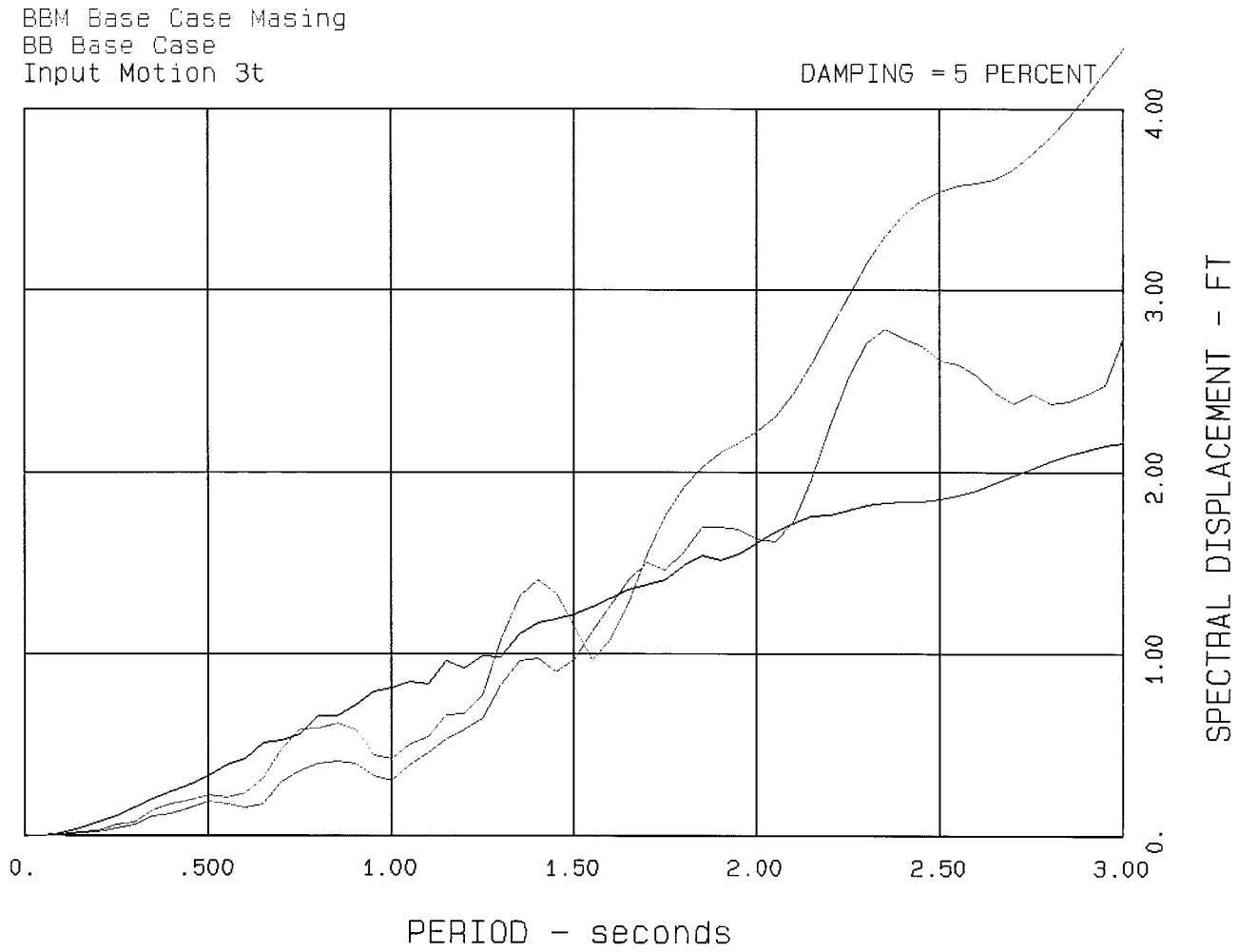

BB Base Case Slope=-0.05
BB Base Case Slope=0.05
BB Base Case
Input Motion 3t
DAMPING = 5 PERCENT
0.
.500
1.00
1.50
2.00
2.50
3.00
0.
1.00
2.00
3.00
4.00
PERIOD - seconds
SPECTRAL DISPLACEMENT - FT

Effect of Masing Hypothesis

- Funny stress-strain loops
- Can’t compute permanent deformations
- Surprising effect on response spectra

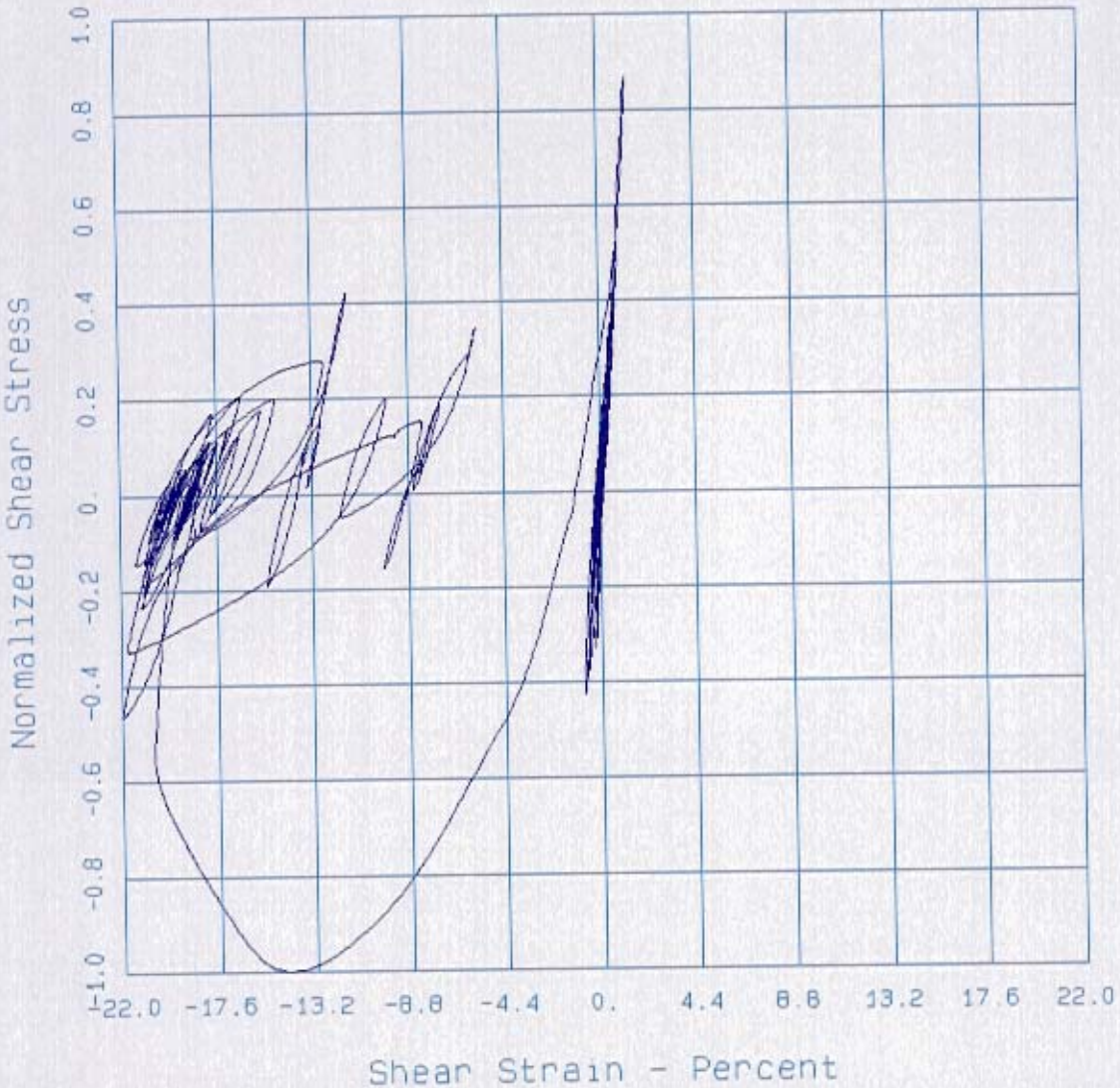

Normalized Shear Stress
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
-12.7
-10.1
-7.6
-5.1
-2.5
0.
2.5
5.1
7.6
10.1
12.7
Shear Strain - Percent

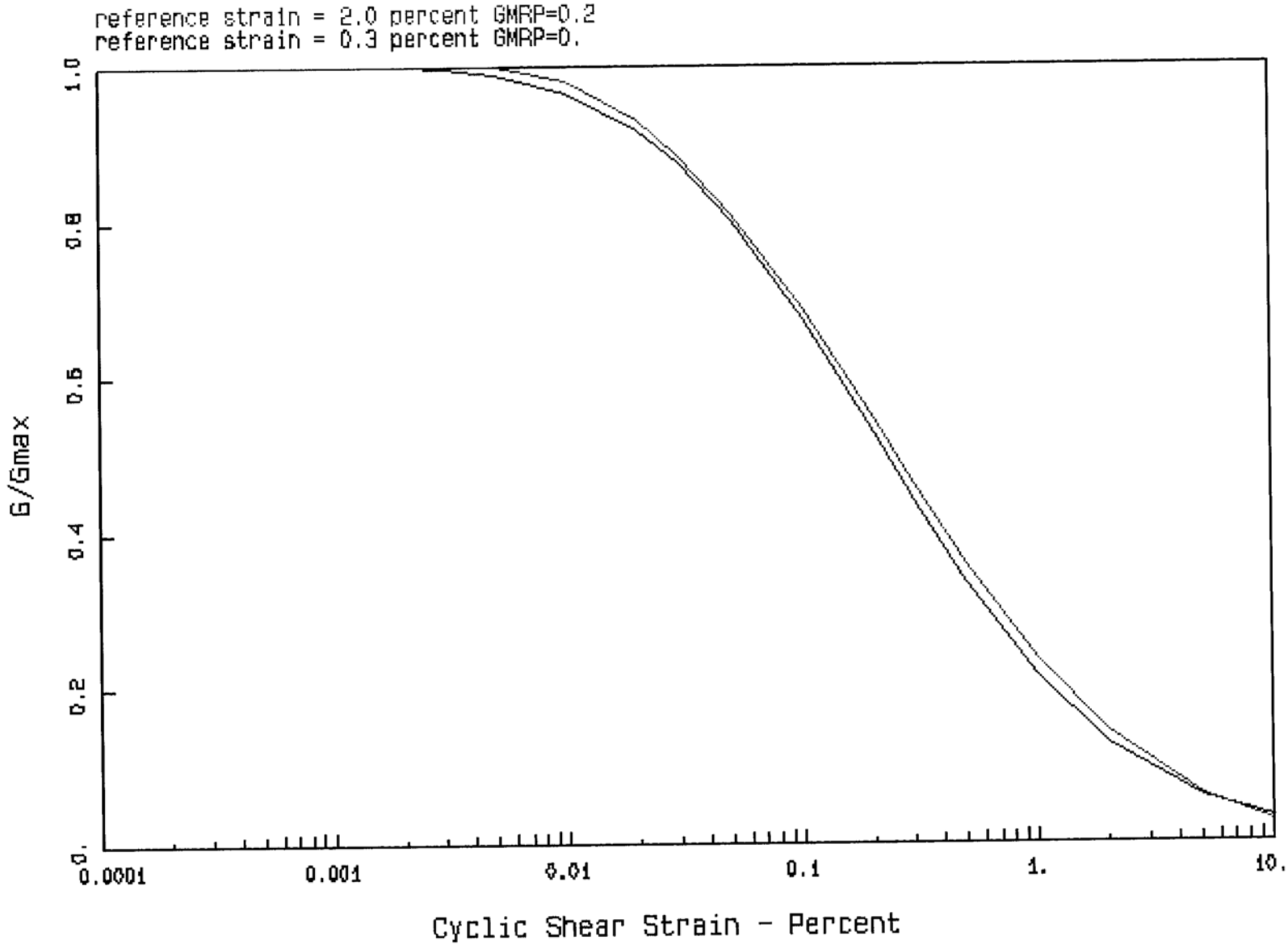

BBM Base Case Masing
BB Base Case
Input Motion 3t
DAMPING = 5 PERCENT
SPECTRAL ACCELERATION - G
2.00
1.50
1.00
.500
0.
0.
.500
1.00
1.50
2.00
2.50
3.00
PERIOD - seconds

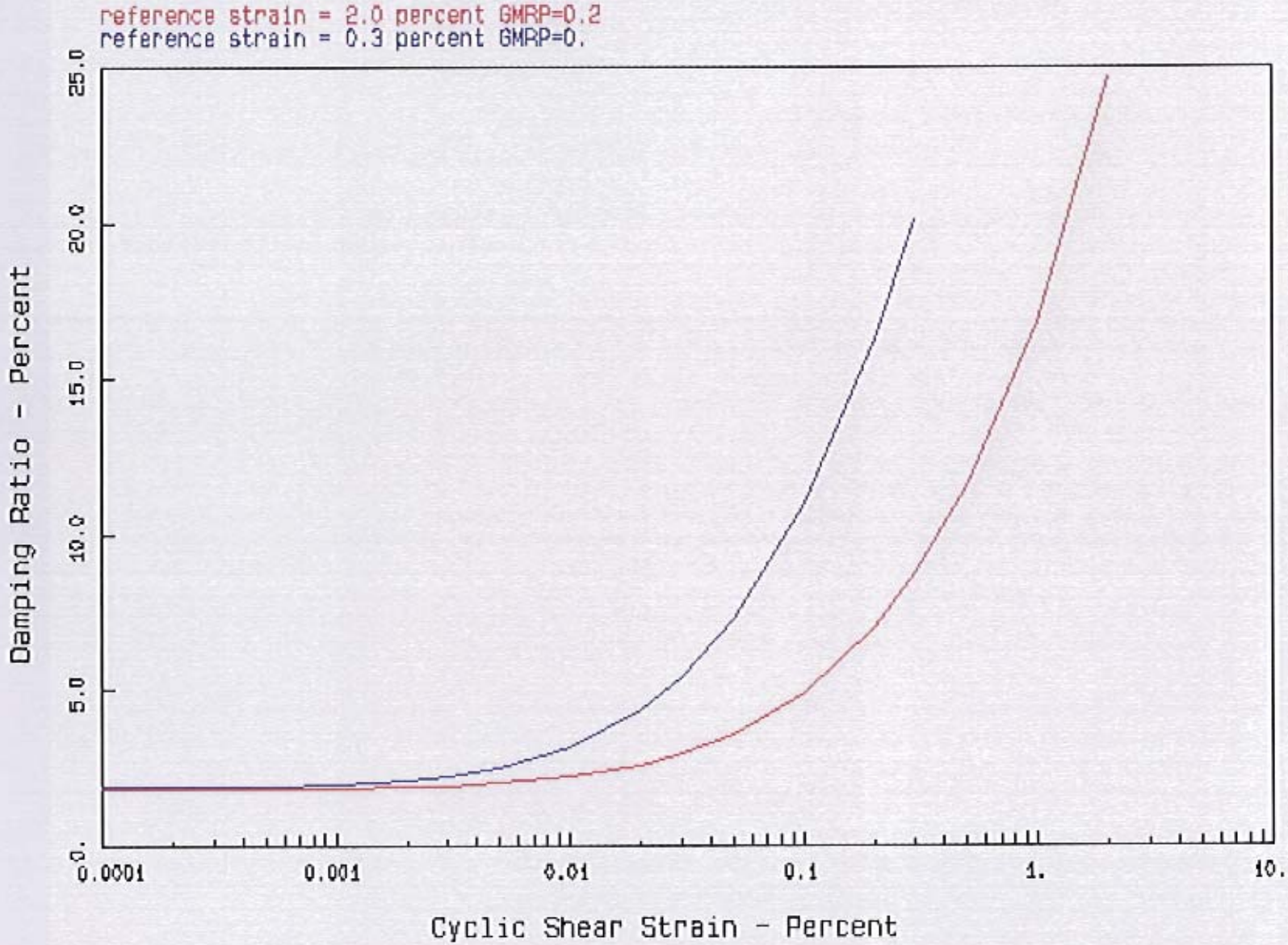

BBM Base Case Masing
BB Base Case
Input Motion 3t
DAMPING = 5 PERCENT
SPECTRAL DISPLACEMENT - FT
0.
1.00
2.00
3.00
4.00
0.
.500
1.00
1.50
2.00
2.50
3.00
PERIOD - seconds

Effect of New HDCP Model

- Nicer, tighter, stress-strain loops
- Written paper says that permanent displacements are lower but this may be in error …


Normalized Shear Stress
1.0
0.8
0.6
0.4
0.2
0.
-0.2
-0.4
-0.6
-0.8
-1.0
-22.0
-17.6
-13.2
-8.8
-4.4
0.
4.4
8.8
13.2
17.6
22.0
Shear Strain - Percent


reference strain = 2.0 percent GMRP=0.2
reference strain = 0.3 percent GMRP=0.
G/Gmax
1.0
0.8
0.6
0.4
0.2
0.
0.0001
0.001
0.01
0.1
1.
10.
Cyclic Shear Strain - Percent


reference strain = 2.0 percent GMRP=0.2
reference strain = 0.3 percent GMRP=0.
Damping Ratio - Percent
25.0
20.0
15.0
10.0
5.0
0.
0.0001
0.001
0.01
0.1
1.
10.
Cyclic Shear Strain - Percent

So …

- With new model a larger reference strain must be specified in order to match the desired modulus reduction curve …
- But I forgot to change the reference strains specified for the profile so it was too soft!
- However, conclusions remain the same. Results, especially permanent deformations, will be sensitive to how well the model fits the actual stress-strain relationship.