Use of Geotechnical Site Response Models in Practice

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Historical Development

Equivalent linear anal

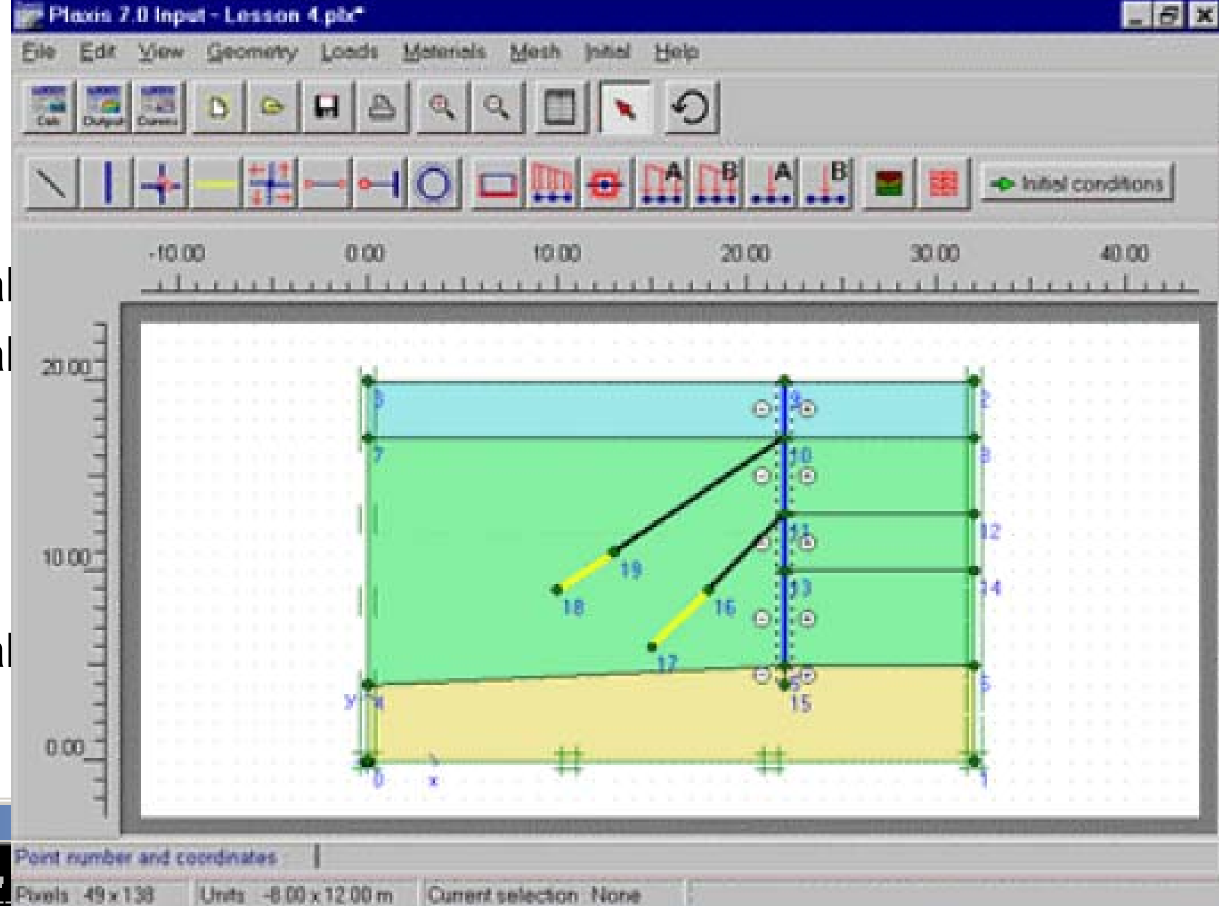
One-dimensional

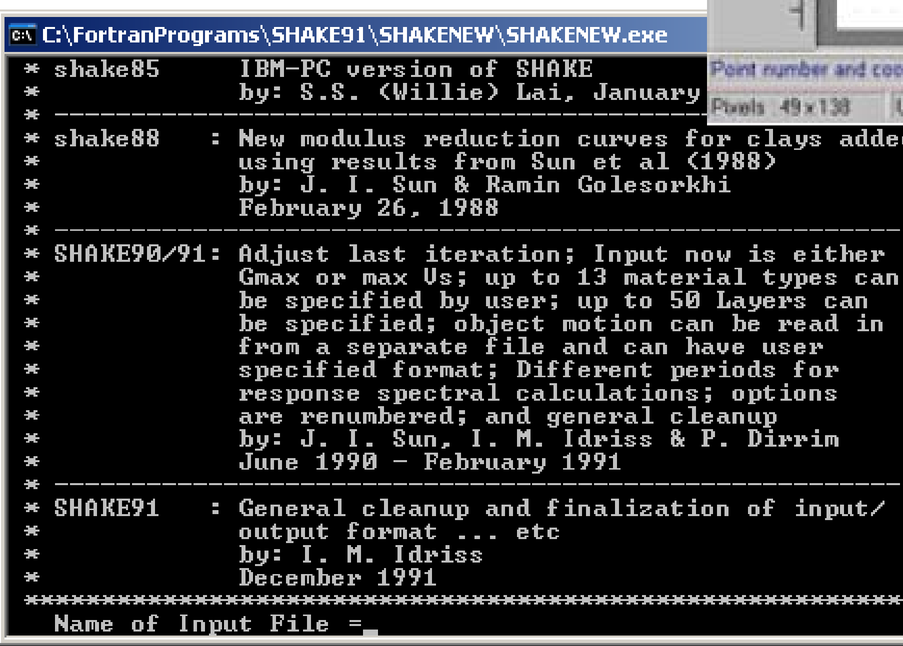
2-D / 3-D –

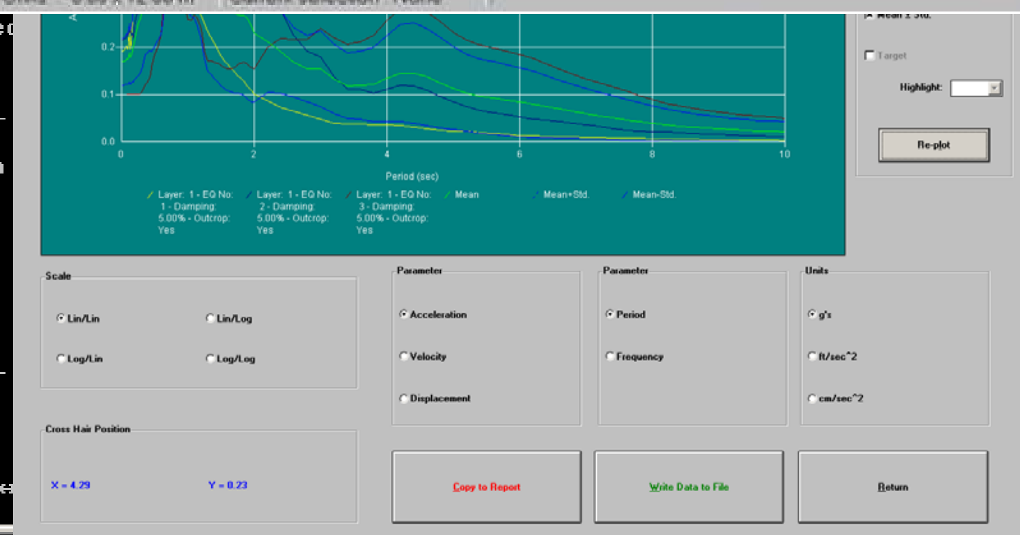
Nonlinear analyses

One-dimensional

2-D / 3-D –







Available Codes

Since early 1970s, numerous computer programs developed for site response analysis

Can be categorized according to computational procedure, number of dimensions, and operating system

Dimensions	OS	Equivalent Linear	Nonlinear
1-D	DOS	Dyneq, Shake91	AMPLE, DESRA, DMOD, FLIP, SUMDES, TESS
	Windows	ShakeEdit, ProShake, Shake2000, EERA	CyberQuake, DeepSoil, NERA, FLAC, ShearBeam
2-D / 3-D	DOS	FLUSH, QUAD4/QUAD4M, TLUSH	DYNAFLOW, TARA-3, FLIP, VERSAT, DYSAC2, LIQCA
	Windows	QUAKE/W, SASSI2000	FLAC, PLAXIS

Current Practice

Informal survey developed to obtain input on site response modeling approaches actually used in practice

Emailed to 204 people

- Attendees at ICSDEE/ICEGE Berkeley conference (non-academic)
- Geotechnical EERI members – 2003 Roster (non-academic)

55 responses

- Western North America (WNA)
- Eastern North America (ENA)
- Overseas

} Private firms / Public agencies

Survey Respondents	WNA		ENA		Overseas	
	Private	Public	Private	Public	Private	Public
Number of responses	35	3	6	1	5	5

Current Practice

Method of Analysis

Of the total number of site response analyses you perform, indicate the approximate percentages that fall within each of the following categories:
[ ] a. One-dimensional equivalent linear
[ ] b. One-dimensional nonlinear
[ ] c. Two- or three-dimensional equivalent linear
[ ] d. Two- or three-dimensional nonlinear

Method of Analysis	WNA		ENA		Overseas	
	Private (35)	Public (3)	Private (6)	Public (1)	Private (5)	Public (5)
1-D Equivalent Linear	68	52	86	50	24	5
1-D Nonlinear	11	17	12	0	48	5
2-D/3-D Equiv. Linear	9	28	1	25	6	0
2-D/3-D Nonlinear	12	3	1	25	23	90

One-dimensional equivalent linear analyses dominate North American practice; nonlinear analyses are more frequently performed overseas

Current Practice

Soil Models

```
What soil models do you usually use for equivalent linear site response analyses
(mark each with an X)?
[ ] a. EPRI
[ ] b. Ishibashi-Zhang
[ ] c. Iwasaki
[ ] d. Seed-Idriss sand
[ ] e. Seed-Idriss clay
[ ] f. Vucetic-Dobry
[ ] g. Other (please describe): [
```

Seed-Idriss and Vucetic-Dobry models most commonly used in North American practice; Seed-Idriss clay and other models commonly used overseas

Equivalent Linear Soil Model	WNA		ENA		Overseas	
	Private (35)	Public (3)	Private (6)	Public (1)	Private (5)	Public (5)
EPRI	48	33	17	0	0	0
Ishibashi-Zhang	12	0	0	0	20	0
Iwasaki	9	0	0	0	0	0
Seed-Idriss Clay	91	100	100	17	40	60
Seed-Idriss Sand	76	67	50	17	20	20
Vucetic-Dobry	82	67	83	0	20	0
Other	44	33	33	0	40	20

<u>**Current Practice**</u>

Estimation of Soil Properties

Soil properties commonly obtained by field testing and empirical correlation in North American and overseas practice; laboratory testing much more common in overseas practice.

```
How do you typically obtain soil propert                                    )
for input into your site response analys
    [ ] a. Laboratory tests (cyclic tria
    [ ] b. Measurement using field tests
    [ ] c. Empirical correlation to field test results (SPT, CPT, etc.)
    [ ] d. Empirical correlation to index tests (e.g. to PI via Vucetic-Dobry model)
    [ ] e. Empirical correlation to depth (e.g. as in EPRI model)
    [ ] f. Other (please describe): [      ]
```

Method for obtaining soil properties for site response analysis	WNA		ENA		Overseas	
	Private (35)	Public (3)	Private (6)	Public (1)	Private (5)	Public (5)
Laboratory testing	43	33	33	17	100	80
Field testing	83	100	100	17	80	60
Empirical correlation to field test results	100	67	83	17	80	60
Empirical correlation to index test results	71	100	17	0	40	20
Empirical correlation to depth	26	33	0	0	0	20
Other	11	0	0	0	40	0

Current Practice

Important Uncertainties

```
What do you consider to be the most importan
    seismic site response analysis?
    [ ] a. Low-strain stiffness (represented
    [ ] b.
    [ ] c.
    [ ] d.
    [ ] e.
    [ ] f.
    [ ] g.
    [ ] h.
```

Uncertainty in ground motions considered very important in North American practice; not in overseas practice. Uncertainty in stiffness and damping characteristics also considered important.

Most important uncertainties in site response input	WNA		ENA		Overseas	
	Private (35)	Public (3)	Private (6)	Public (6)	Private (5)	Public (5)
Low-strain stiffness (i.e., G_{max} or V_s)	43	33	67	0	40	20
Higher strain stiffness (i.e. G/G_{max})	51	67	17	17	60	20
Damping behavior	57	0	33	0	40	20
Soil layer thicknesses	17	33	17	0	0	0
Depth to bedrock	20	0	0	0	20	0
Character of bedrock	14	0	0	0	0	0
Input motions	83	100	67	0	20	20
Other	26	67	0	0	40	40

Current Practice

Accounting for Uncertainties

Sensitivity analyses commonly performed in North America, though manner of interpretation not known; no specific approach favored in overseas practice.

How do you typically account for such u

[ ] a. Select reasonably conservat

[ ] b. Use "best estimate" input pa... ults

Method of accounting for uncertainties in design	WNA		ENA		Overseas	
	Private (35)	Public (3)	Private (6)	Public (6)	Private (5)	Public (5)
Select reasonably conservative values of input parameters	20	0	0	0	20	20
Use "best estimate" values of input parameters, then apply conservatism to results	34	67	50	0	20	20
Perform sensitivity analyses	74	100	67	100	0	0
Perform probabilistic analyses (e.g. FOSM, Monte Carlo)	11	33	0	0	20	0
Don't address uncertainties explicitly	0	0	0	0	0	20
Other	17	0	17	0	20	20

Current Practice

Summary and Conclusions

Computational procedures for site response analyses have developed significantly over the years; DOS- and Windows-based codes now available for equivalent linear and nonlinear site response analysis in one or more dimensions

Improved hardware and software make computations easier and faster – allow more sensitivity analyses and "what if" analyses

One-dimensional, equivalent linear analyses dominate practice in North America; less apparent reliance in overseas practice

Equivalent linear analyses frequently performed using older soil models; adoption of newer models (e.g. coupled plasticity and confining pressure effects) has been slow

Nonlinear analyses have been available almost as long as equivalent linear analyses, but not frequently used in North American practice; more commonly used overseas

No consensus on appropriate nonlinear soil models/analysis codes appears to exist; practitioners express uncertainty about how to use/calibrate/interpret nonlinear soil models

Current Practice

Summary and Conclusions

Low strain dynamic soil properties commonly obtained by field testing (V_s) and/or by empirical correlation to field test (e.g. SPT, CPT) results

Higher strain behavior (e.g. modulus reduction and damping) commonly obtained by correlation to index tests

Uncertainties in ground motions considered most significant source of uncertainty in North American practice; not in overseas practice

Uncertainties frequently dealt with by means of sensitivity analyses in North American practice

Analytical procedures for site response analysis have advanced more quickly than (a) procedures for developing input parameters for those analyses, and (b) progress toward validation of the accuracy and reliability of those analyses.

Use of more advanced site response analysis tools and procedures in practice will require development, calibration, and validation of advanced soil models and analytical procedures. Until these are available, it appears unlikely that computational advances will be embraced by practitioners.