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Field Shear Wave Velocity Measurements for Seismic Site Class

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SEISMIC DESIGN FACTORS

2000 International Building Code (IBC) introduced the new concept of Seismic Design Category (SDC) to guide seismic structural design.

The SDC is a function of:

- The Seismic Use Group (type/occupancy),
- Site spectral response accelerations (Ss and S1), and
- Soil type (Site Class) – adopted from UBC

Cost impact of the SDC can be large – the choice impacts framing and mechanical bracing ($100,000 to over $2,000,000)

SITE CLASSIFICATION PER IBC 2000 / 2003 / …..

- There are six soil classes (designated A through F)
- The upper 100 feet (30 m) of the soil/rock profile are used to determine the “Site Class”.
- The soil/rock profile is stratified into layers (based on properties) and a weighted average of the properties of the upper 100 feet (30 m).
- Site Class D is the default classification

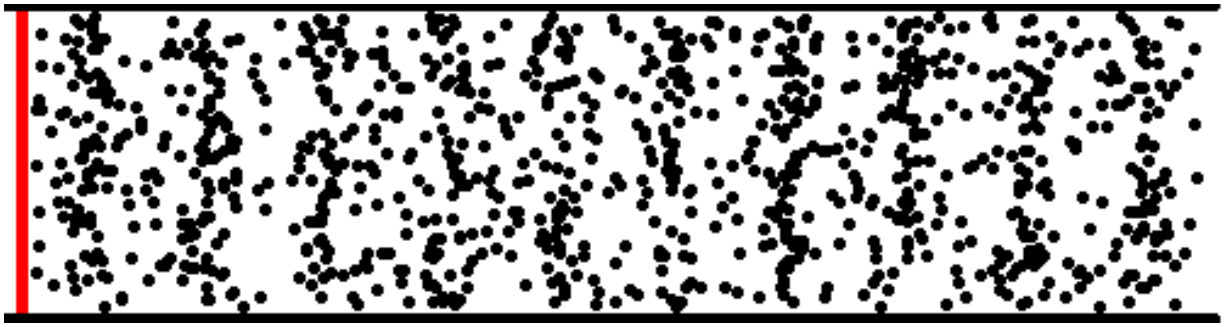
Site Class

Class	*Profile*
A	Hard Rock
B	Rock
C	Very Dense Soil
D	Stiff Soil
E	Soft Soil
F	Collapsible or Liquefiable Soil

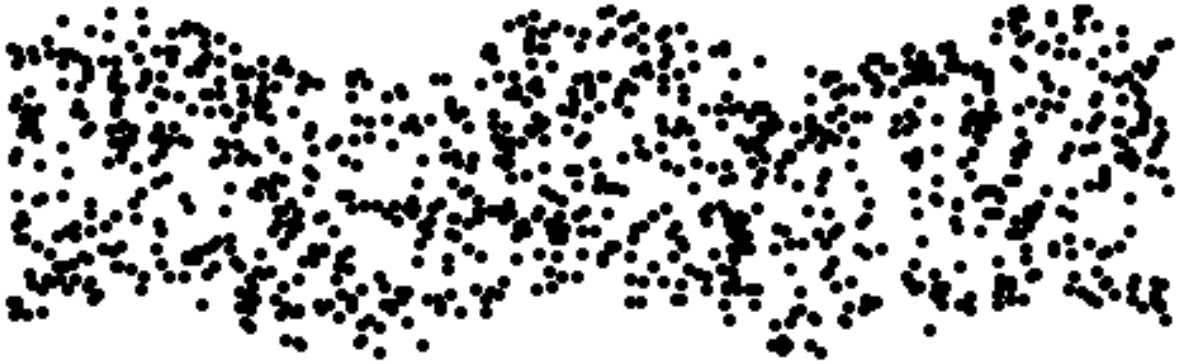
Parameters Required

Class	***Profile***	***Shear Wave Velocity***	***SPT "N" Value***	***Shear Strength***
A	Hard Rock	Required		
B	Rock	Required		
C	Very Dense Soil	Optional, (trumps all)	Granular & cohesive	Cohesive only
D	Stiff Soil	Optional, (trumps all)	Granular & cohesive	Cohesive only
E	Soft Soil	Optional, (trumps all)	Granular & cohesive	Cohesive only

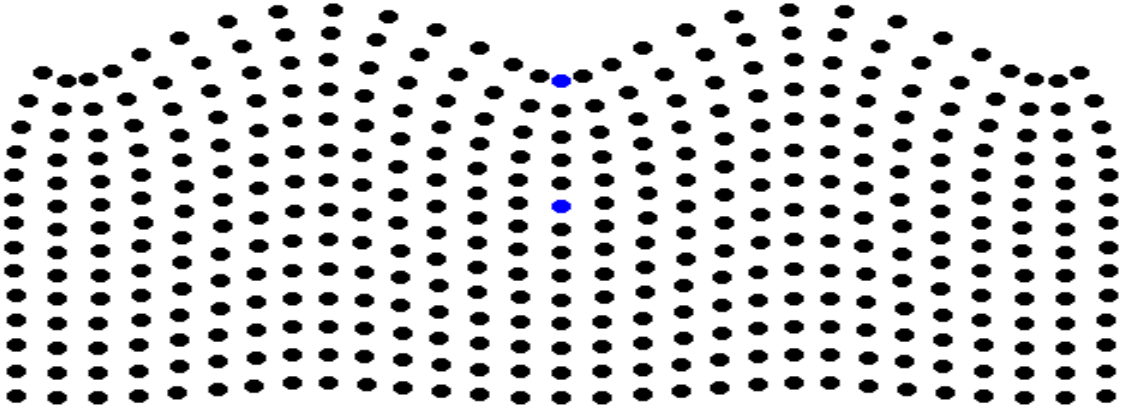
Compression



Shear



Rayleigh



Shear Wave Velocity Measurements

- Applies directly to hard rock and rock sites – may be useful for mixed material (soil and rock) profiles
- Direct indication of soil / rock stiffness

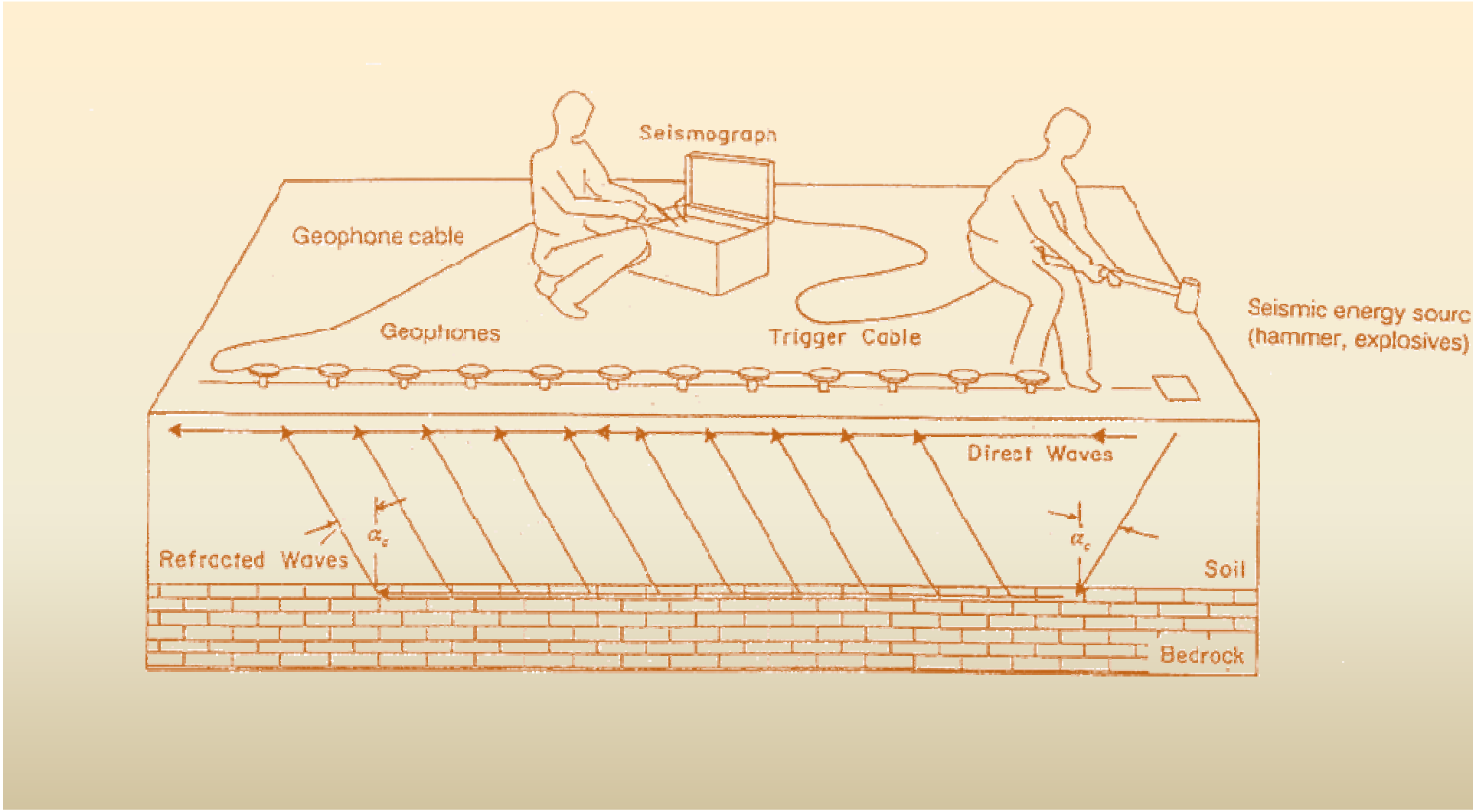
Field Measurements

1. Seismic Refraction Survey : ASTM D5777
2. Crosshole Seismic Test : ASTM D4428
3. Downhole Seismic Test : ASTM D7400
4. Refraction MicroTremor (ReMi)/MASW/SASW
5. Seismic Reflection

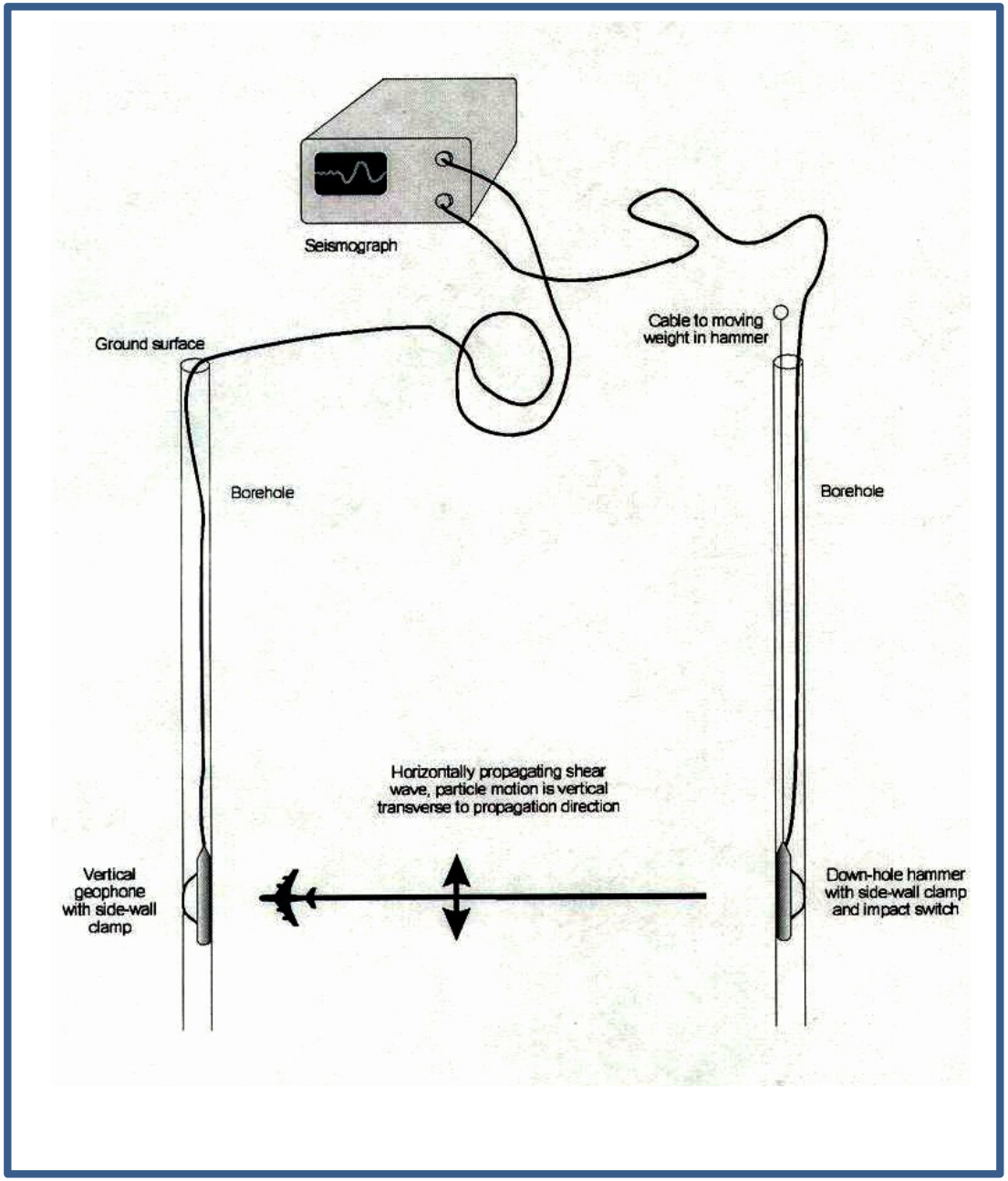
Laboratory Measurement

1. Sonometer : ASTM C215, ISRM
2. Resonant Column Test : ASTM D4015

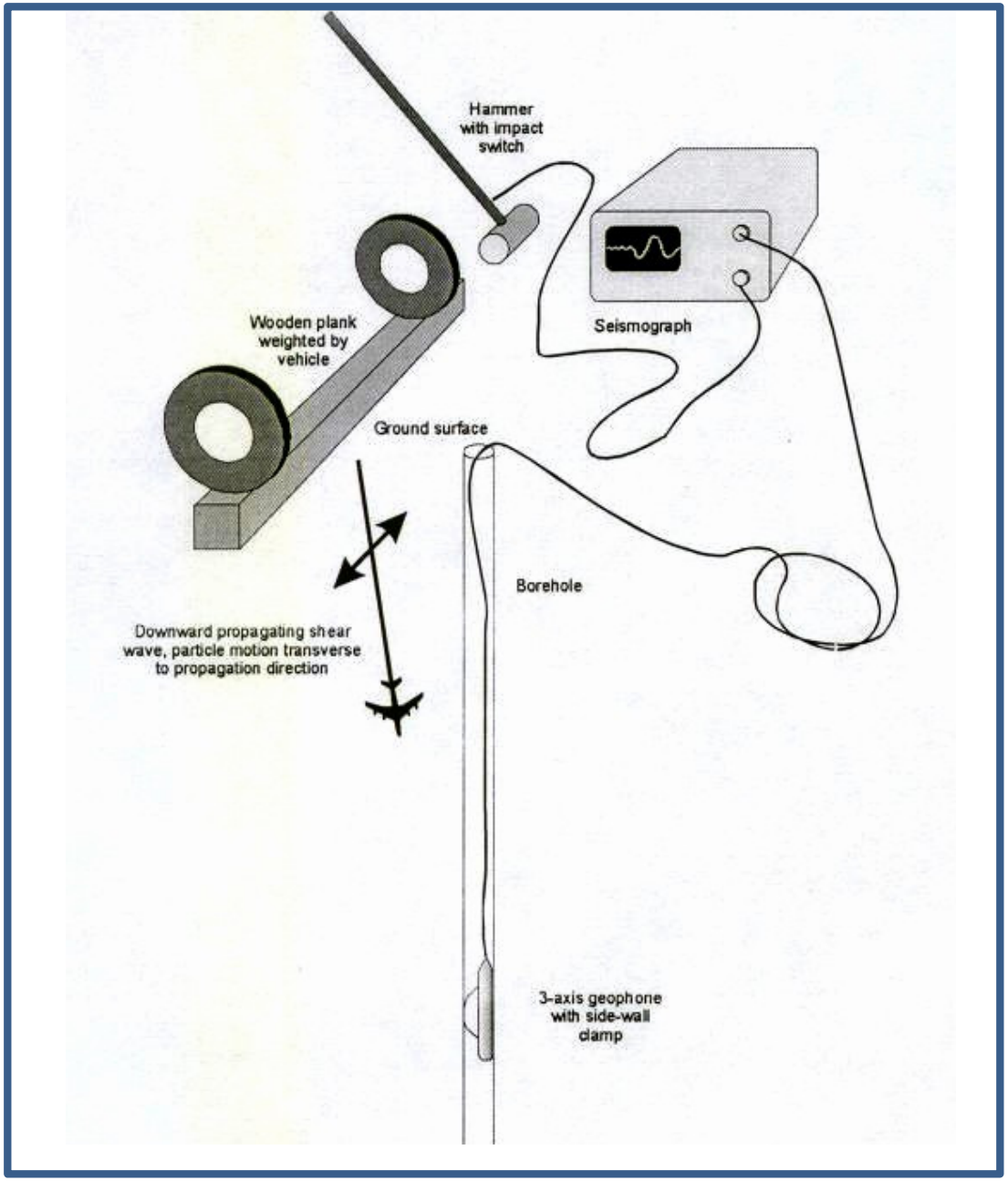
Seismic Refraction Method
ASTM D5777



Crosshole Seismic Method ASTM D4428



Downhole Seismic Method ASTM D7400



Downhole Triaxial Geophone

Downhole Seismic Traces

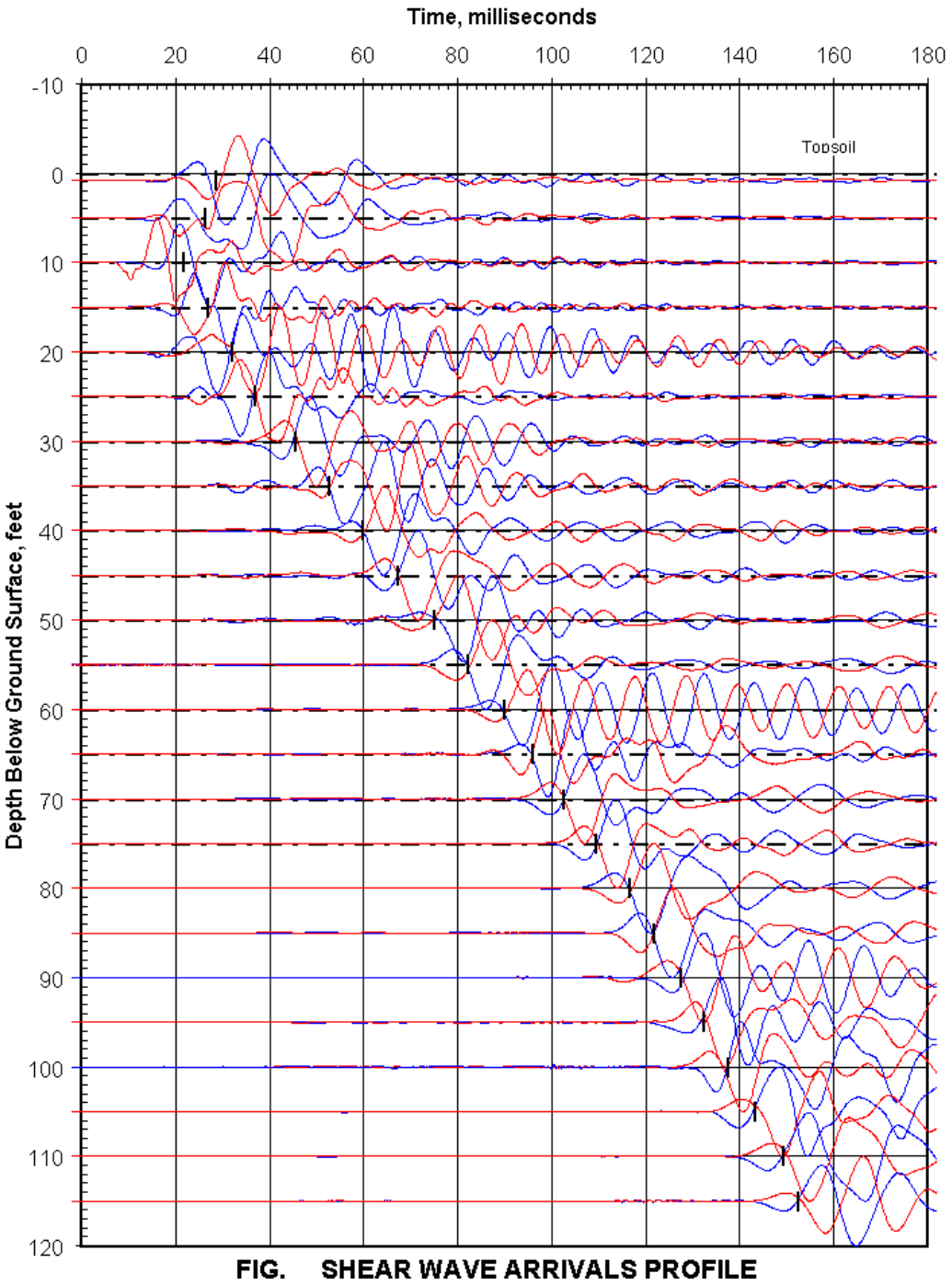


FIG. SHEAR WAVE ARRIVALS PROFILE

Interpreted Shear Wave Velocity Profile

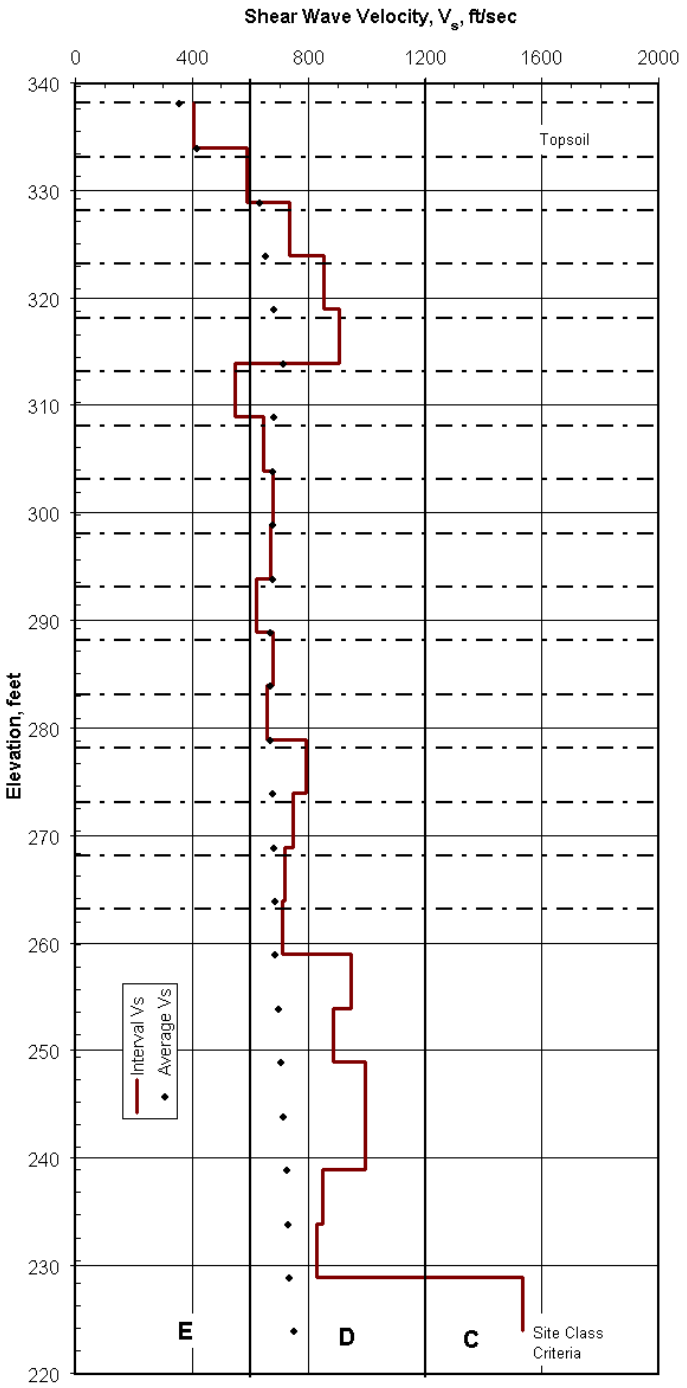


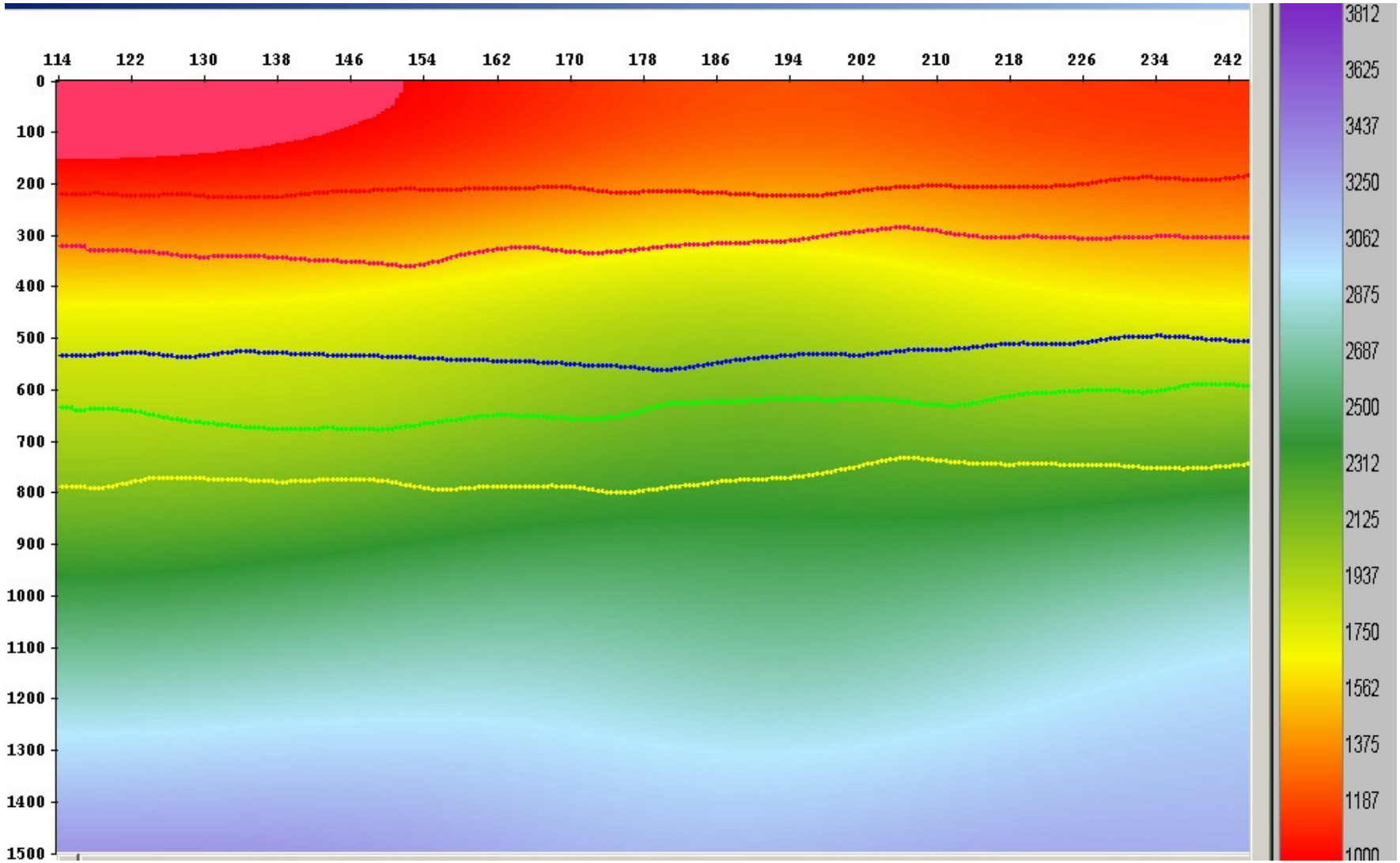
FIG. _ SHEAR WAVE VELOCITY PROFILE

Seismic Recorder (SmartSeis) and Hammer Source

Horizontal 14 Hz Geophone


Cabling, Geophone and Sandbag Anchor

Seismic Reflection Data



Case Studies

- Hospital Addition - Fairfield, OH

  Preliminary Site Class C => SDC C
  Seismic Refraction => Site Class B => SDC A
  Study Cost = $8,000, Savings > $100,000

- Mid-Rise Office Building – Ft. Mitchell, KY

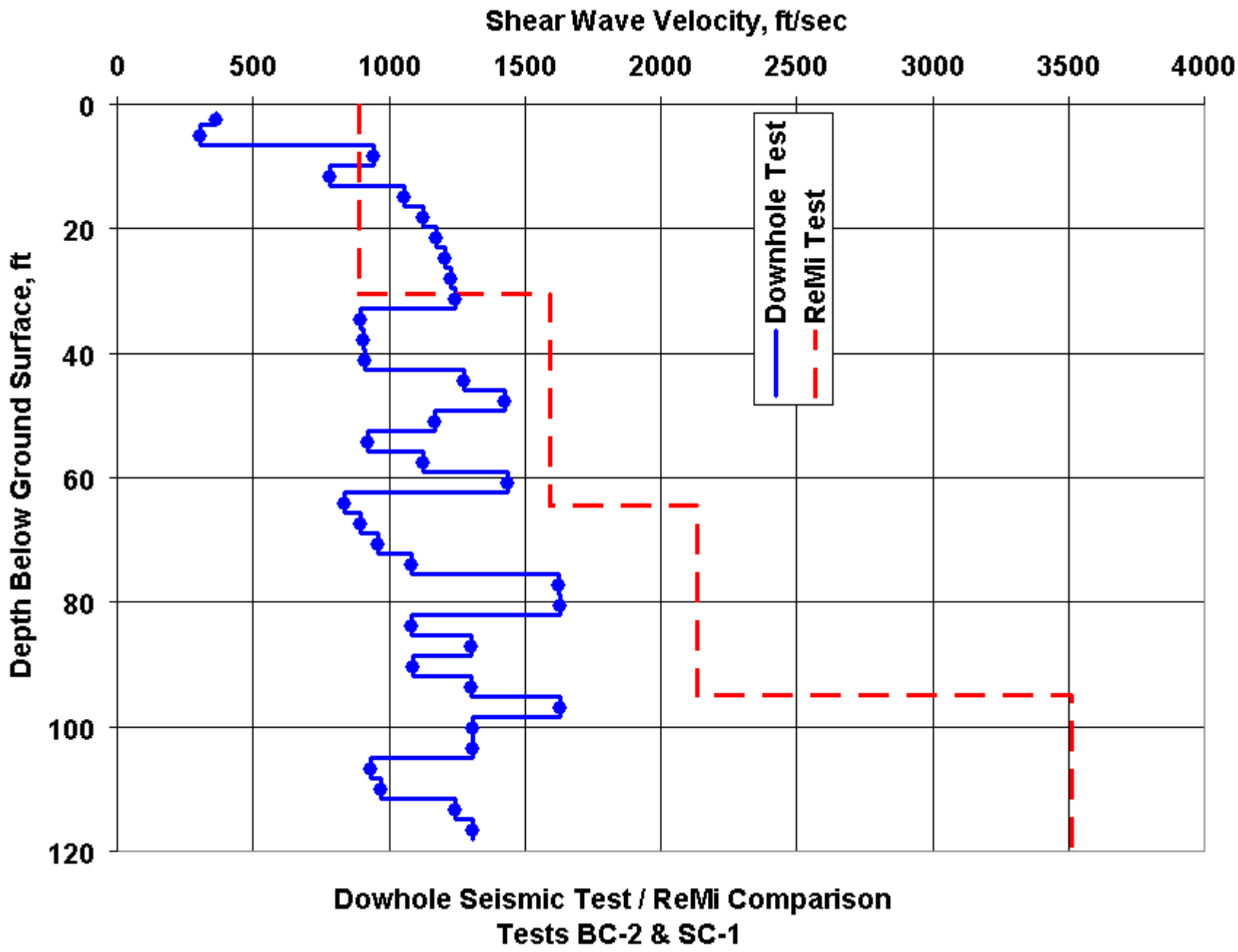
  Preliminary Site Class E => Site-specific study
  CPT Study => Site Class D => SDC C
  Study Cost = $6,000, Savings > $100,000

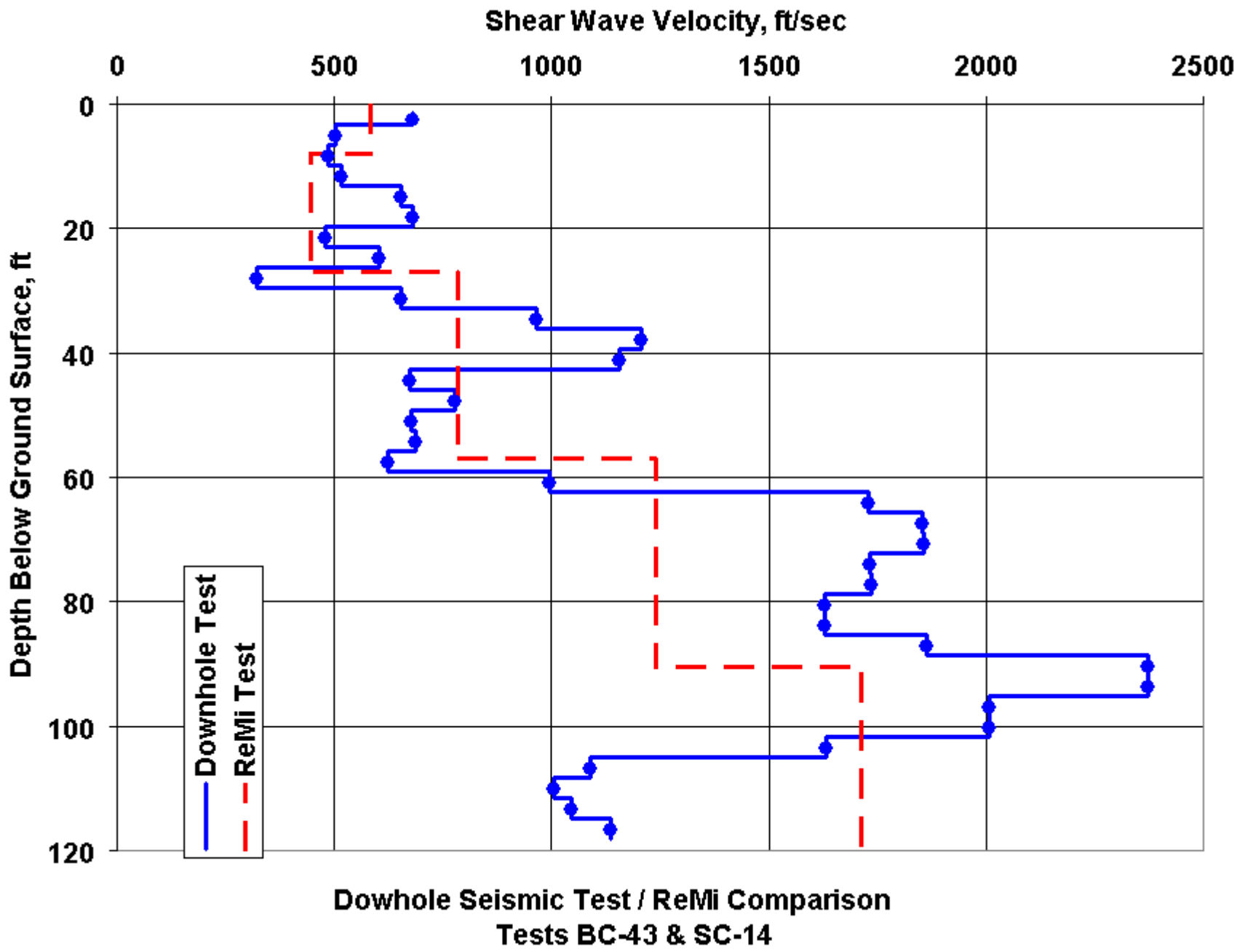
- Mid-Rise Parking/Retail/Residential – Cincinnati

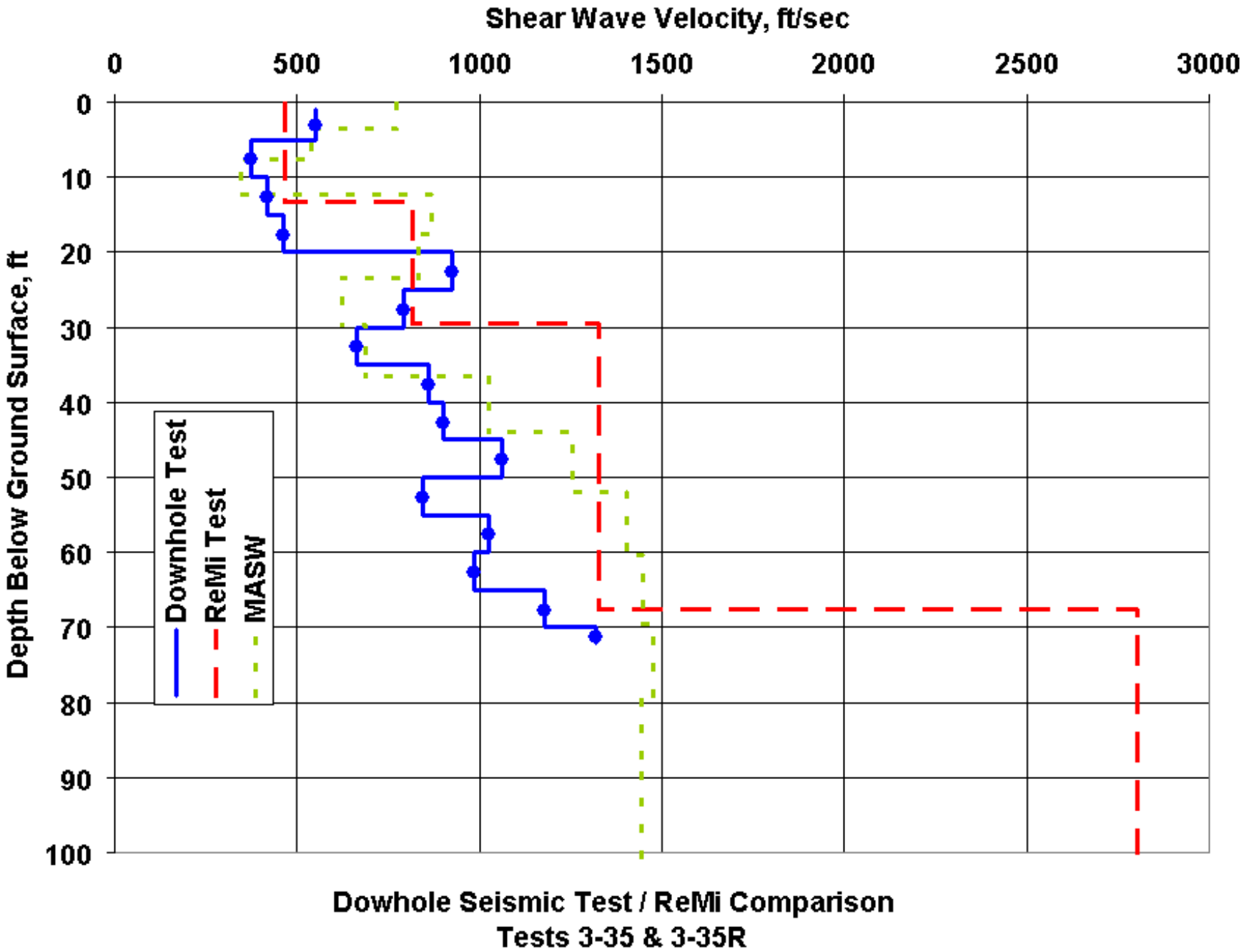
  Preliminary Site Class C => SDC B
  Downhole Test => Site Class B => SDC A
  Study Cost = $10,000, Savings > $400,000

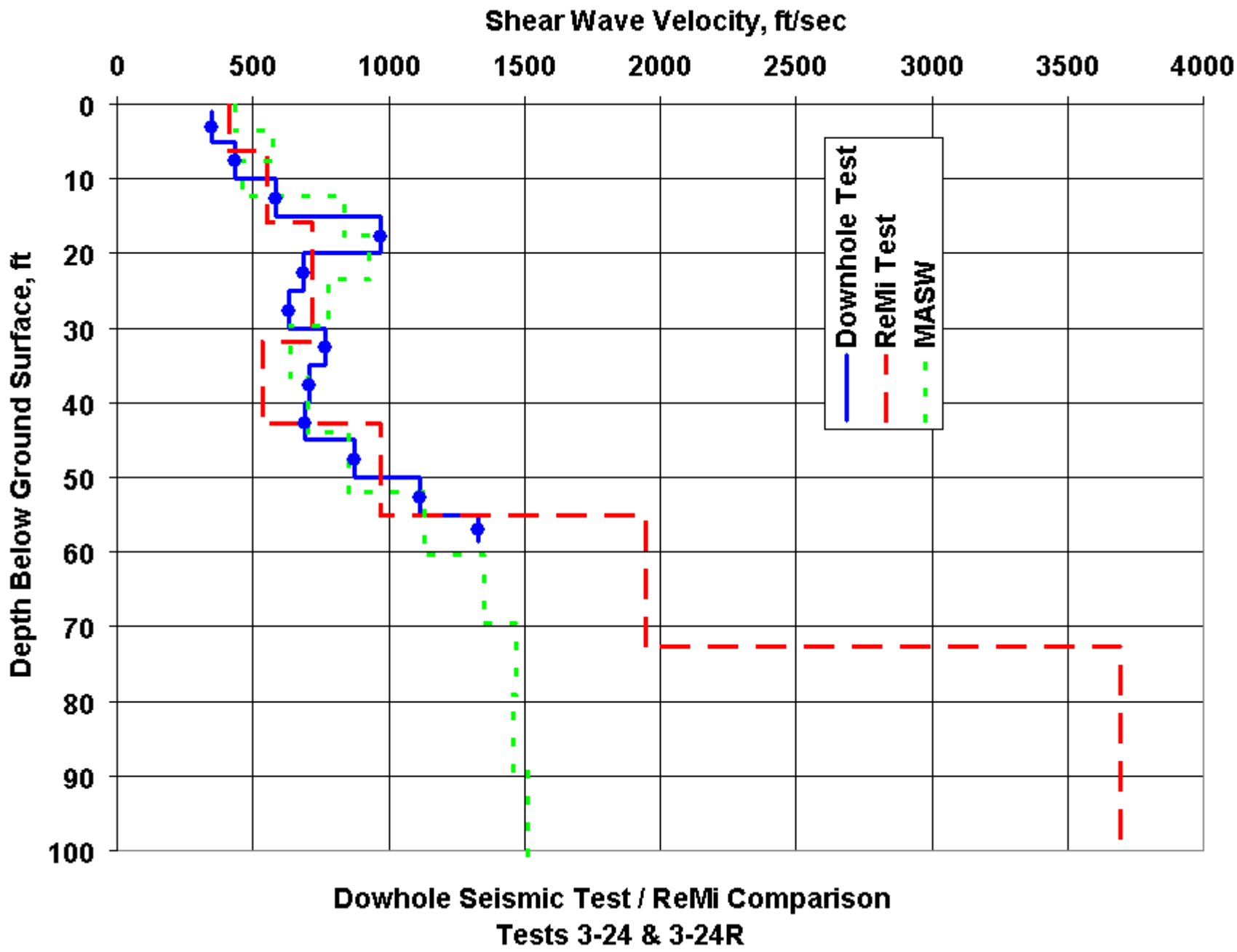
- High-Rise Heart Center – Cleveland, OH

  Preliminary Site Class D => SDC D
  Downhole / Site Response Analyses => Site Class C => SDC B
  Study Cost = $27,000, Savings = $2,000,000


Shear Wave Velocity, ft/sec
0
500
1000
1500
2000
2500
3000
3500
4000
Depth Below Ground Surface, ft
0
20
40
60
80
100
120
Downhole Test
ReMi Test
Dowhole Seismic Test / ReMi Comparison
Tests BC-2 & SC-1


Shear Wave Velocity, ft/sec
0
500
1000
1500
2000
2500
Depth Below Ground Surface, ft
0
20
40
60
80
100
120
Downhole Test
ReMi Test
Dowhole Seismic Test / ReMi Comparison
Tests BC-43 & SC-14


Shear Wave Velocity, ft/sec
0
500
1000
1500
2000
2500
3000
Depth Below Ground Surface, ft
0
10
20
30
40
50
60
70
80
90
100
Downhole Test
ReMi Test
MASW
Dowhole Seismic Test / ReMi Comparison
Tests 3-35 & 3-35R



Dowhole Seismic Test / ReMi Comparison
Tests 3-24 & 3-24R

Comparison Summary

Site Designation	Soil Profile Depth (ft)	Average Shear Wave Velocity, Vs		ReMi/DST
		DST (ft/sec)	ReMi (ft/sec)	
BC-2/SC-1	120.0	1019	1559	1.53
BC-15/SC-6	120.0	928	1109	1.20
BC-32/SC-11	120.0	932	960	1.03
BC-43/SC-14	120.0	902	865	0.96
B-3/P-1	89.5	1632	1464	0.90
Oregon State	50.0	763	947	1.24
3-24	58.6	685	654	0.95
3-35	72.0	717	916	1.28
			Minimum	0.90
			Average	1.14
			Maximum	1.53

Shear Wave Velocity Measurements – Advantages/Disadvantages

- Crosshole – most direct / accurate interval shear wave velocities - requires 2 to 3 cased boreholes – samples relatively small volume
- Downhole – reasonably direct / accurate shear wave velocities – requires 1 cased borehole or deploy with CPT or dilatometer – samples relatively small volume
- ReMi – less accurate, can't tell if you're high or low – uses surface deployment of receivers to pick up ambient noise – samples relatively high volume

SUMMARY

- Site class selections can be made based on conventional data for routine projects
- For complex projects (Seismic Use Group III) on most sites, use site-specific field data to obtain most accurate site class-can save $100k or more on framing
- Many tools are available – selection is dependent on good dialog between owner, architect, structural engineer and geotechnical engineer
- Large sites with variable soil / bedrock conditions use DST/CST with surface method
- ReMi may overpredict by as much as 50% so don't rely on this data solely

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Field Shear Wave Velocity Measurements for Seismic Site Class

QUESTIONS?