Understanding the dynamic properties of soil and rock

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Rupert Taylor Ltd

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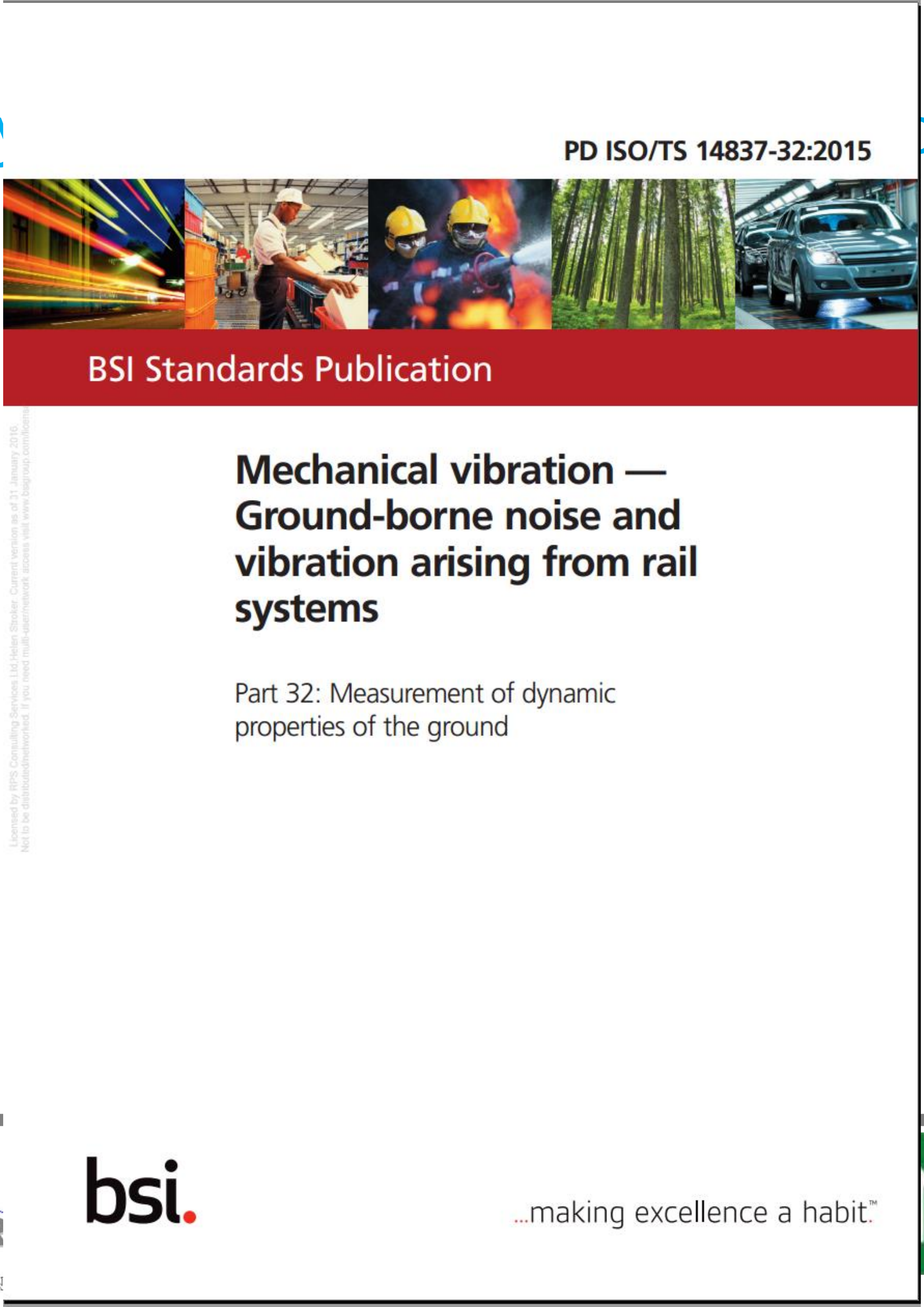
Dynamic properties of soil and rock

What do we need to know?

Why?

Dy ock



PD ISO/TS 14837-32:2015

BSI Standards Publication

Mechanical vibration — Ground-borne noise and vibration arising from rail systems

Part 32: Measurement of dynamic properties of the ground

bsi.

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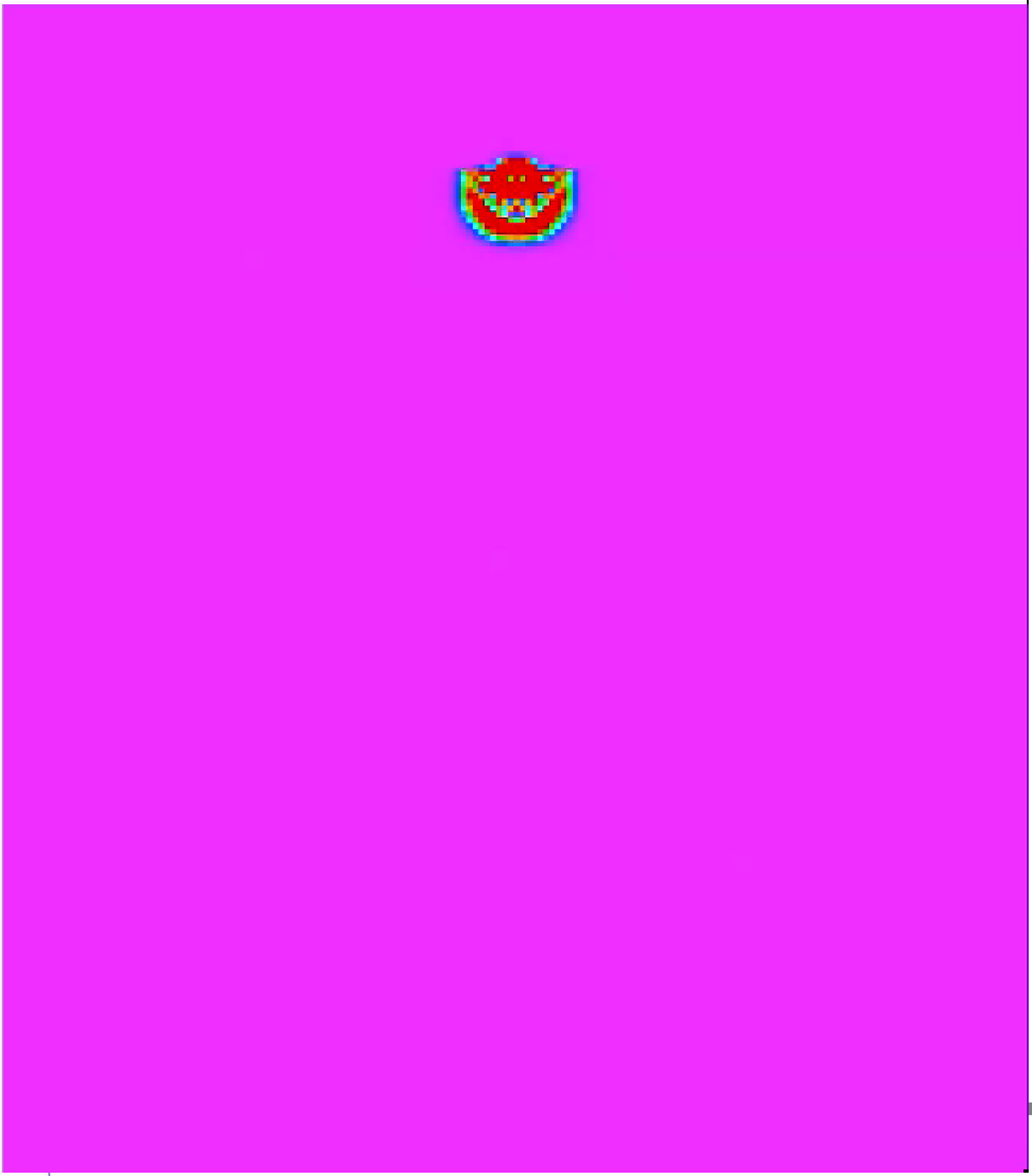
Dynamic properties of soil and rock

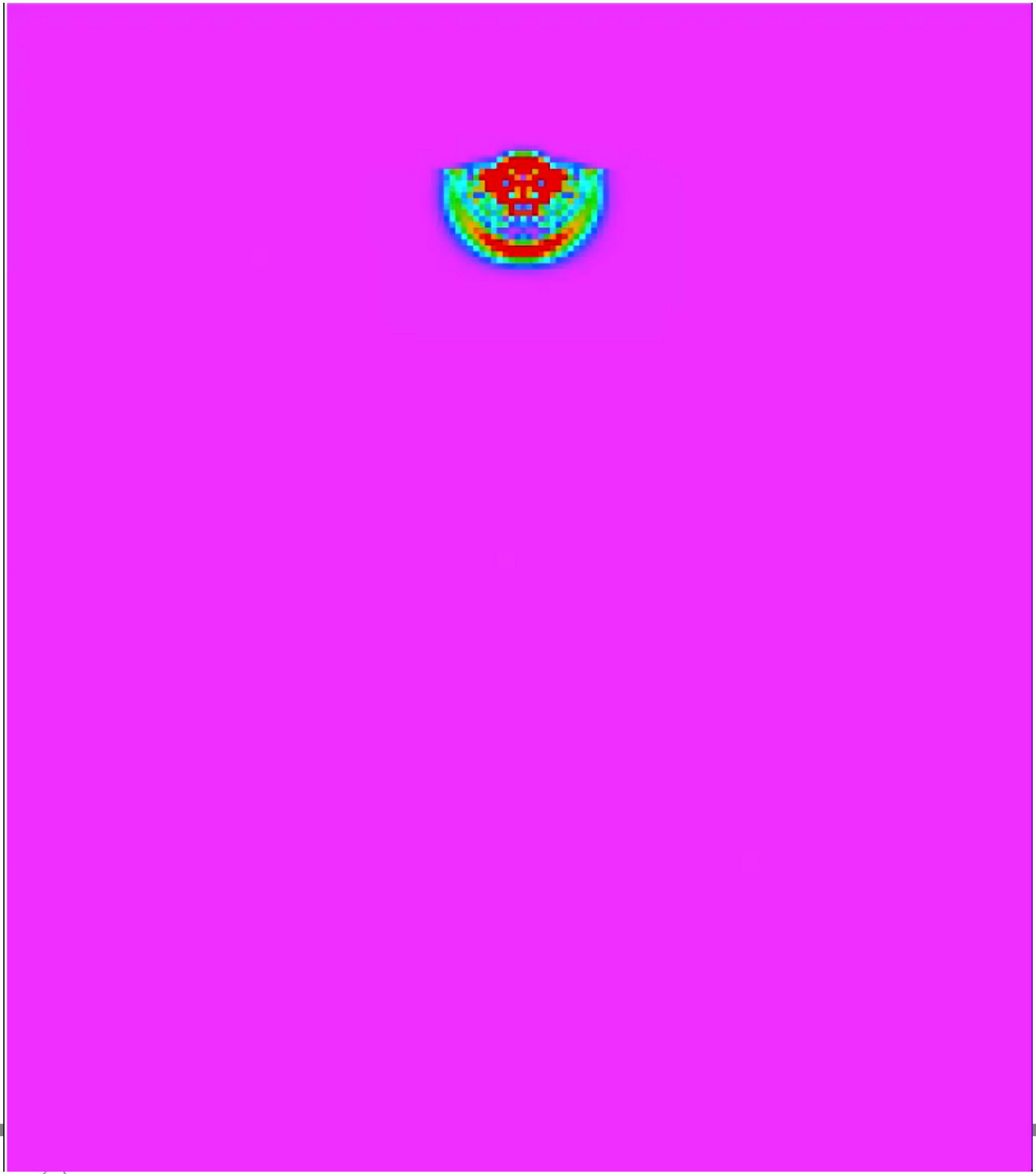
Firstly - Why?

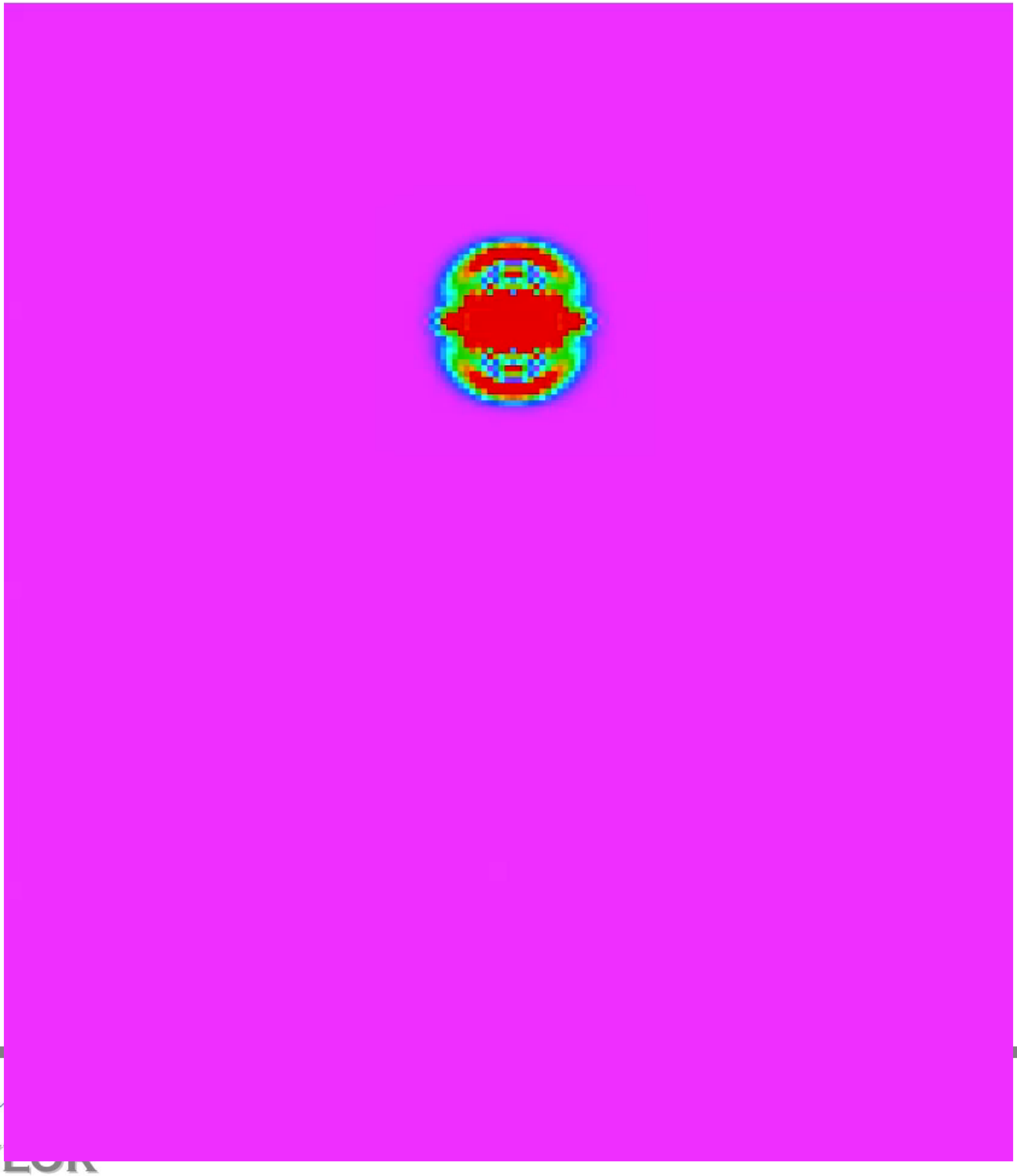
Unlike airborne sound, groundborne noise and vibration is transmitted through a wide range of media with very different properties

The properties of the media affect:

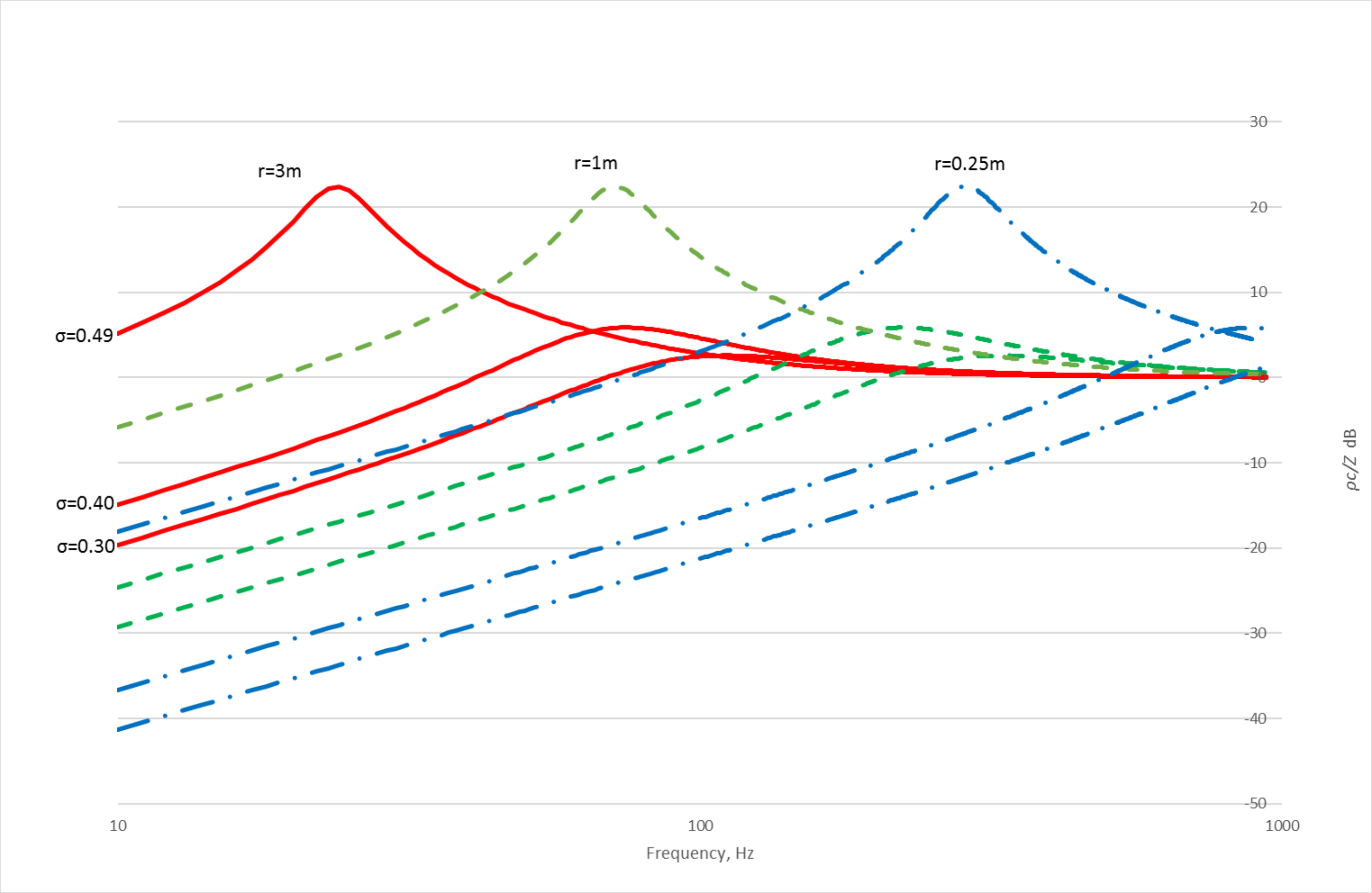
- Emission from the source
- Directivity of the source and transmission paths
- Rate of attenuation in transmission source-receiver
- The response of the receiver
- Measurement uncertainty







Mobility of sphere in an elastic medium



Dynamic properties of soil and rock

What do we need to know?

The fundamentals are:

Bulk density

Shear modulus G_{max} or S-wave velocity
and
Constrained modulus or p-wave velocity
or Poisson’s ratio

Loss factor

Dynamic properties of soil and rock

Bulk density ρ $kg/m3$

Is a function of

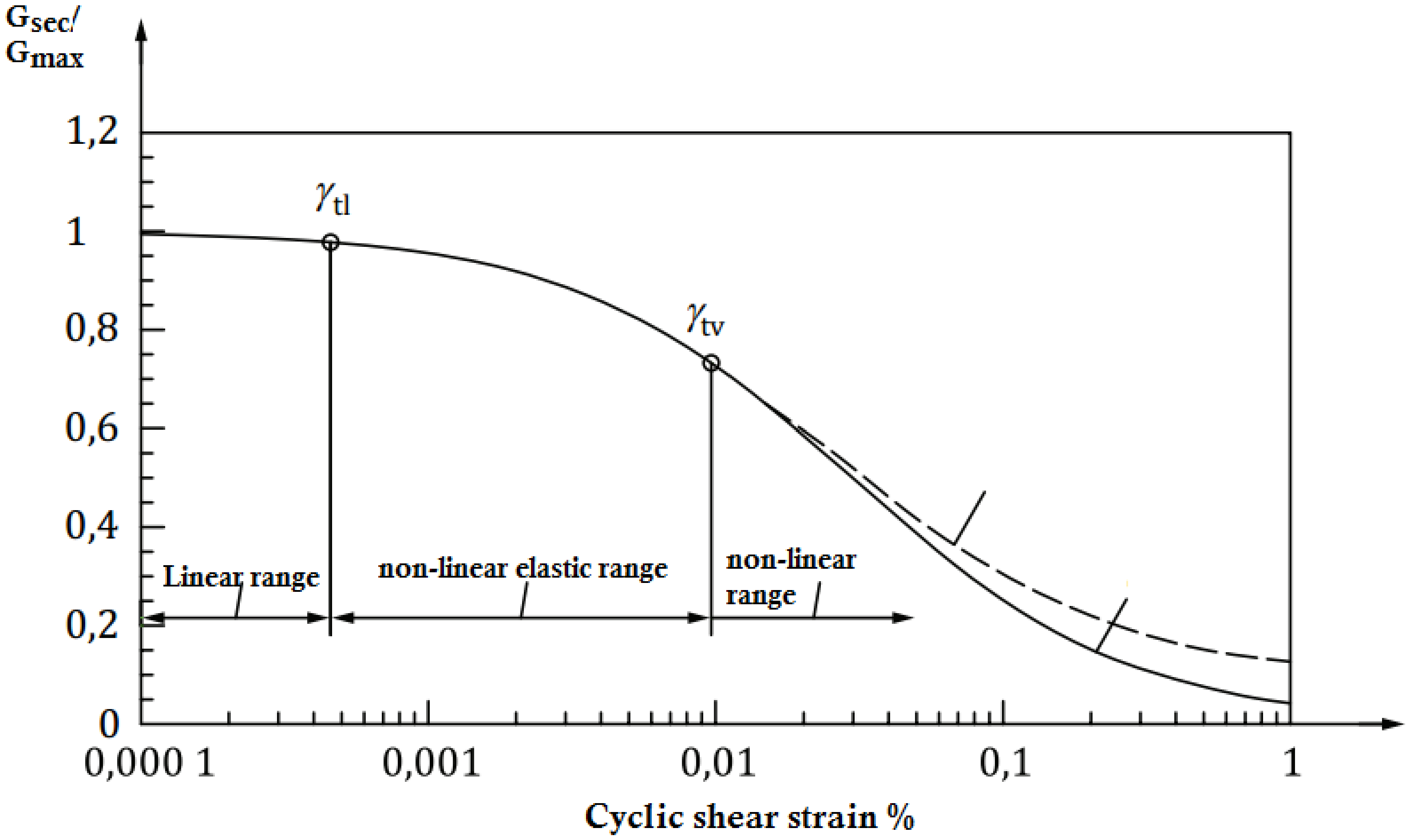
1) The mass density of the mineral $\rho_{mineral}$
2) The porosity Φ
3) The degree of water saturation S_r
4) Water density ρ_{water}

$$P = (1-\Phi)\,\rho_{mineral} + \Phi S_r\,\rho_{water}$$

Dynamic properties of soil and rock

Shear modulus, G_{max}

1) The “max” subscript is all-important



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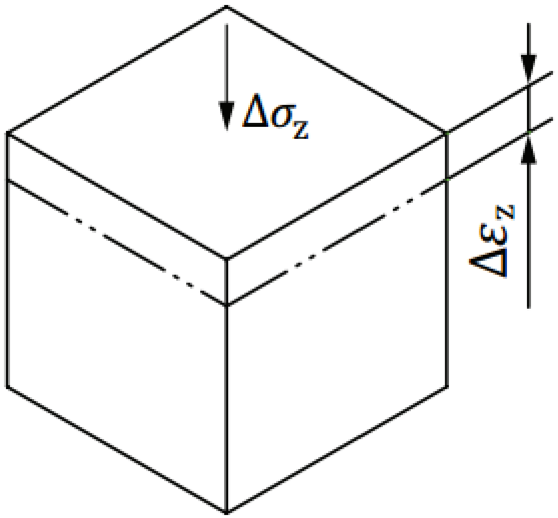
Constrained modulus, M_{max}

1) The “max” subscript is all-important

$$M_{\max} = \frac{2(1-\nu_0)}{1-2\nu_0} G_{\max}$$

$$E_{\max} = 2(1+\nu_0) G_{\max}$$



Constrained modulus $M = \Delta\sigma_z / \Delta\varepsilon_z$

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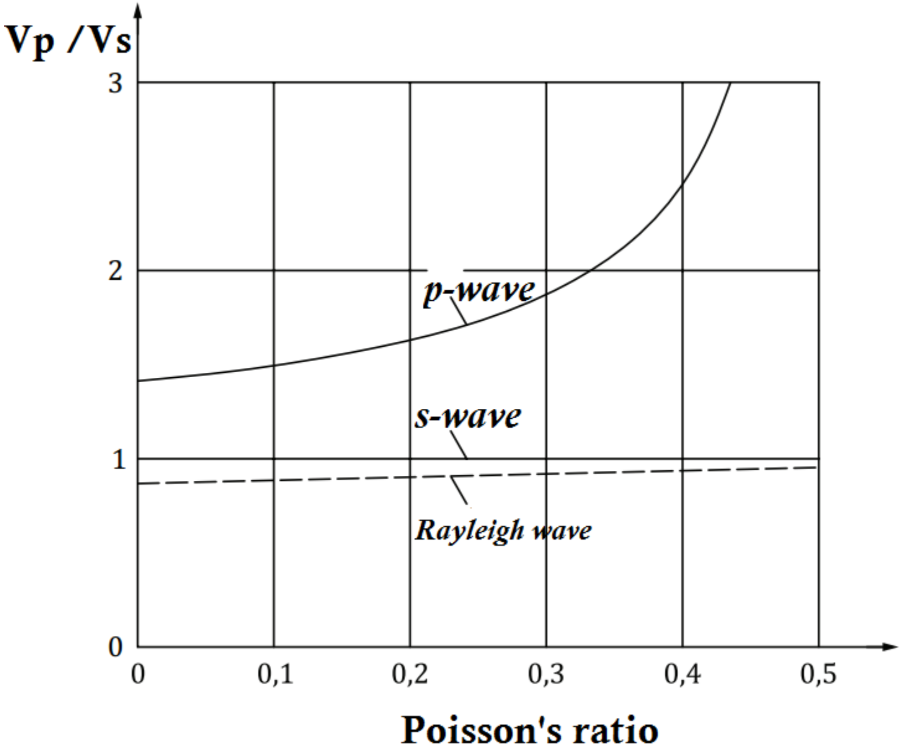
Constrained modulus, M_{max}

1) The “max” subscript is all-important



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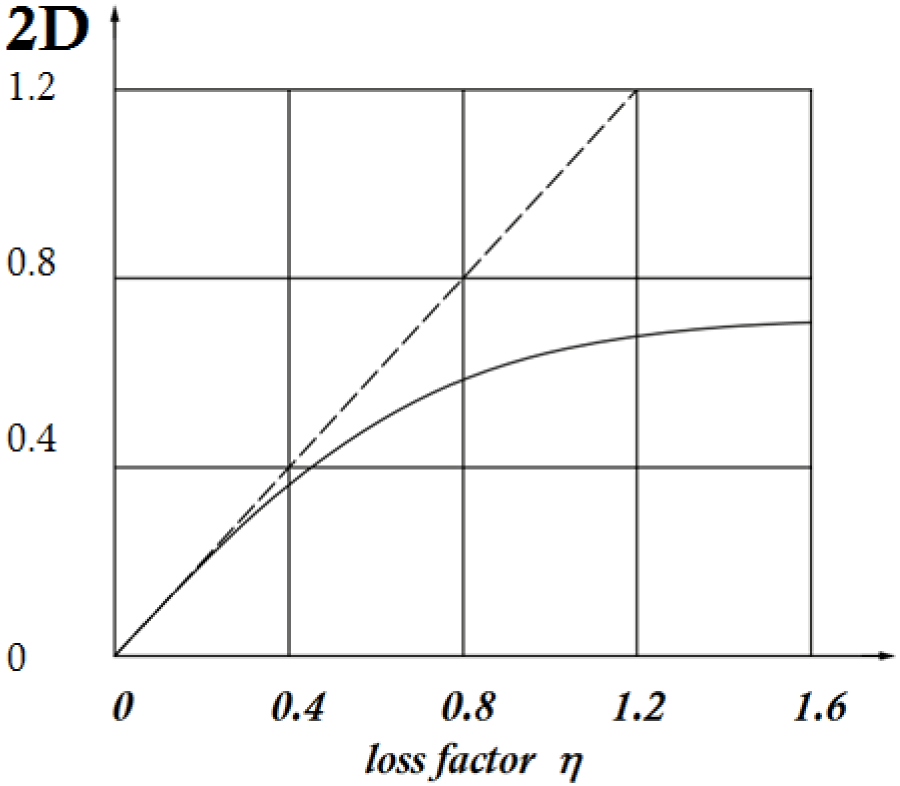
Loss factor, η and distance attenuation, D (cannot exceed 0.35)

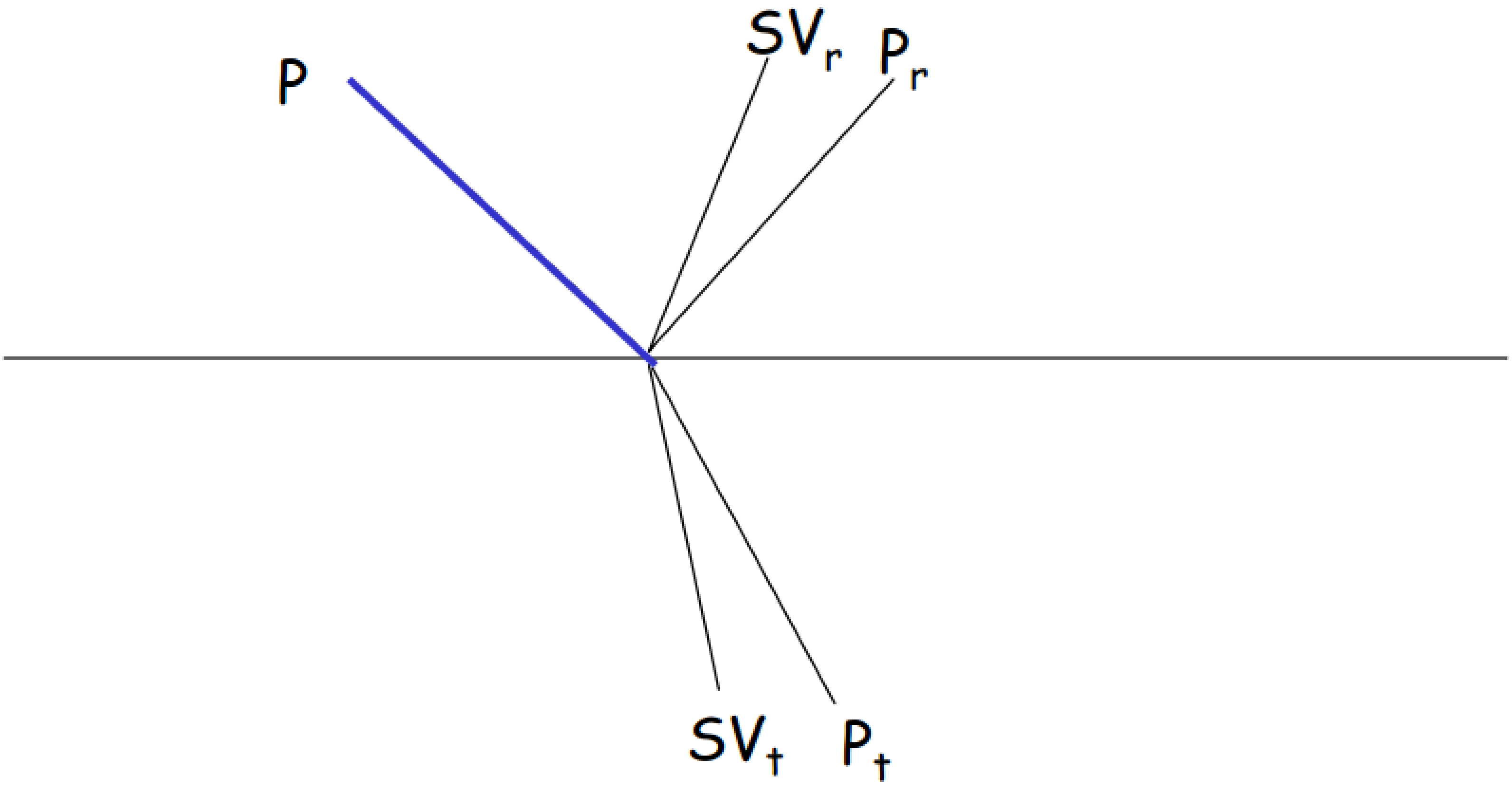
$$D = \sqrt{\frac{\sqrt{1+\eta^2}-1}{2\,(1+\eta^2)}}$$

$$e^{-2\pi D(R-R_0)/\lambda}$$

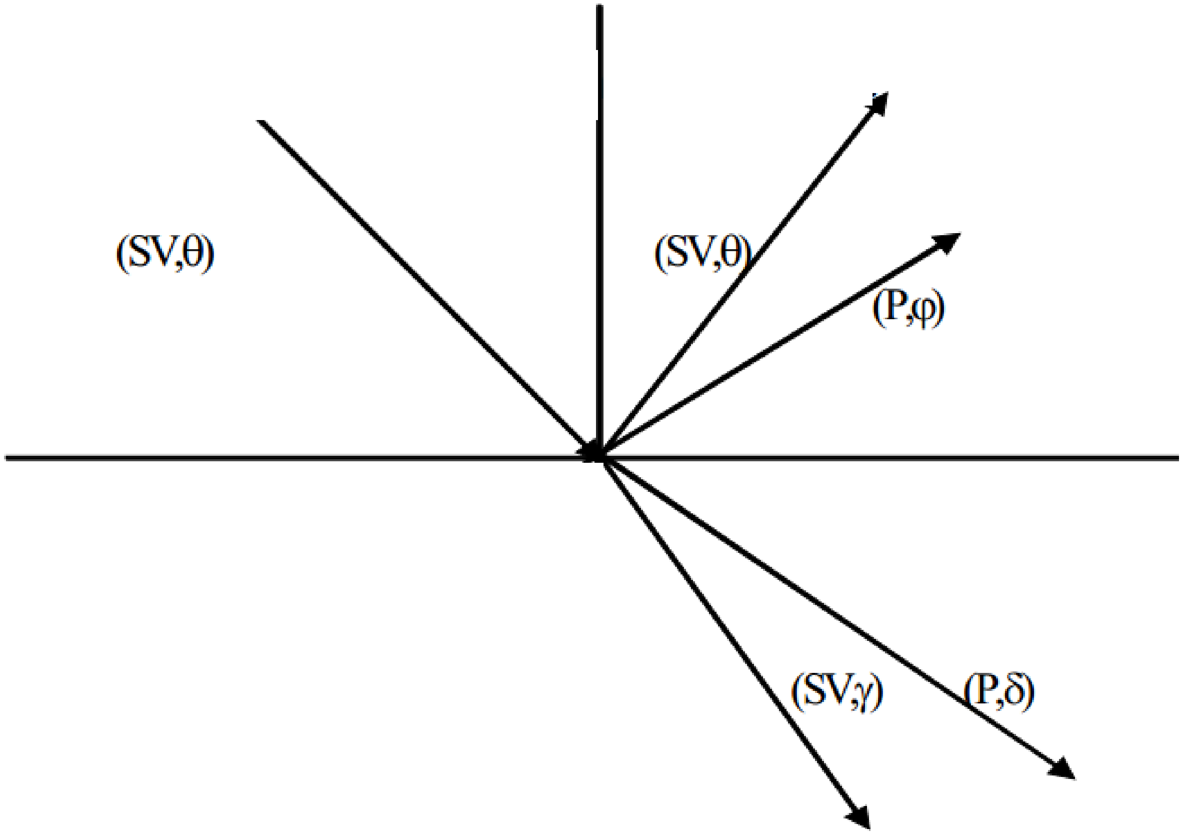
$$\Delta\mathrm{dB} = 8.68\,\omega D(R-R_o)/c$$



Interface between two elastic half spaces

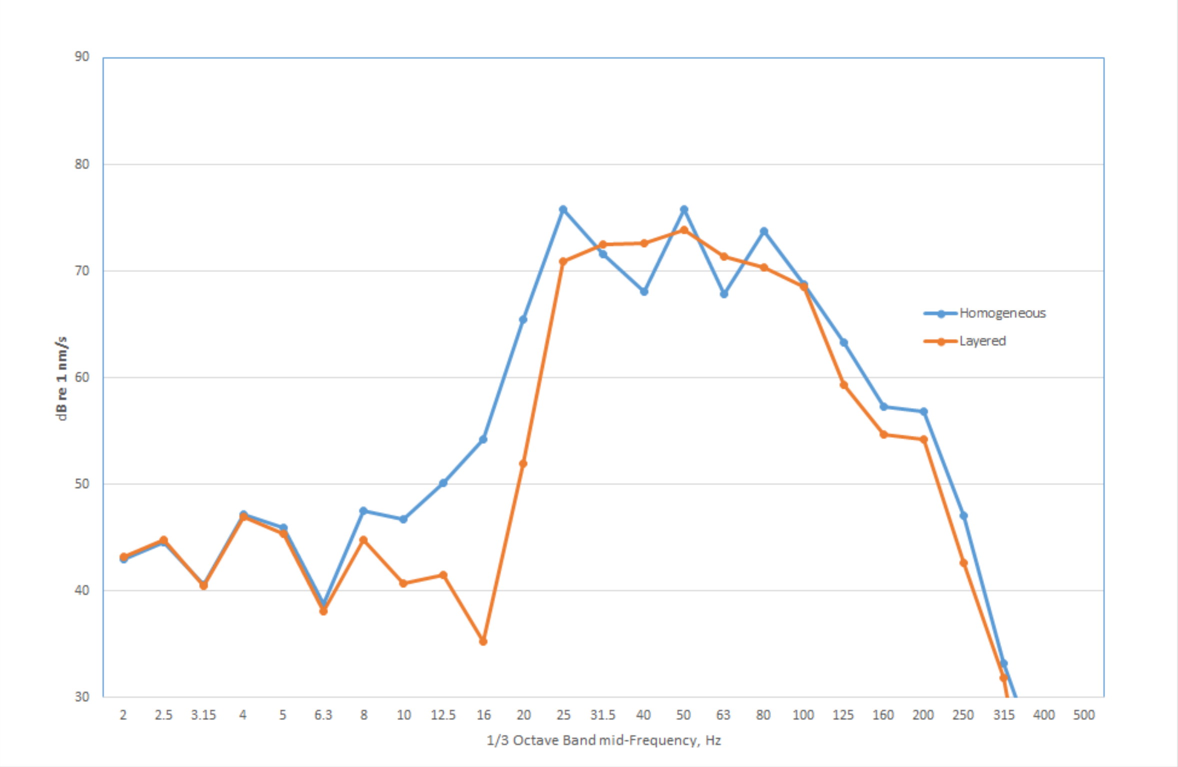


Interface between two elastic half spaces

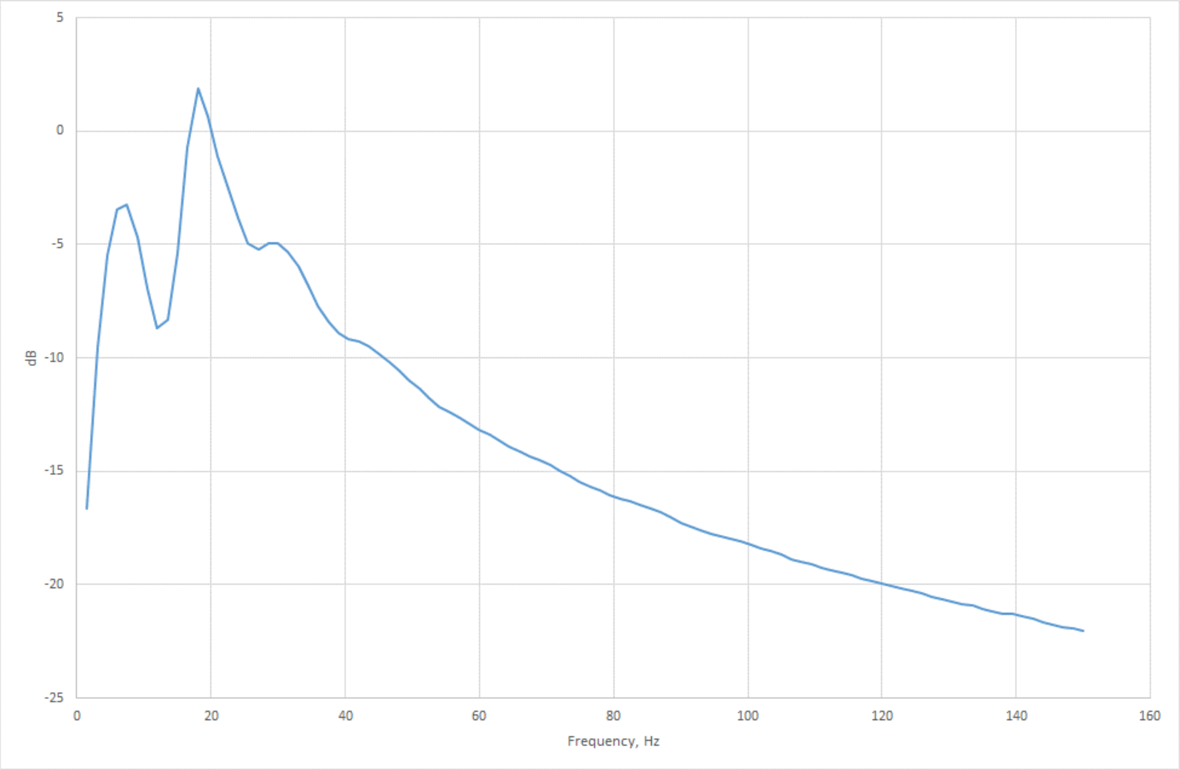


Dynamic properties of soil and rock

Effect of layering



Coupling loss factor



Coupling loss factor on transmission of vibration from an elastic halfspace of clay to a load of 150MN resting on a circular base of average radius 18m

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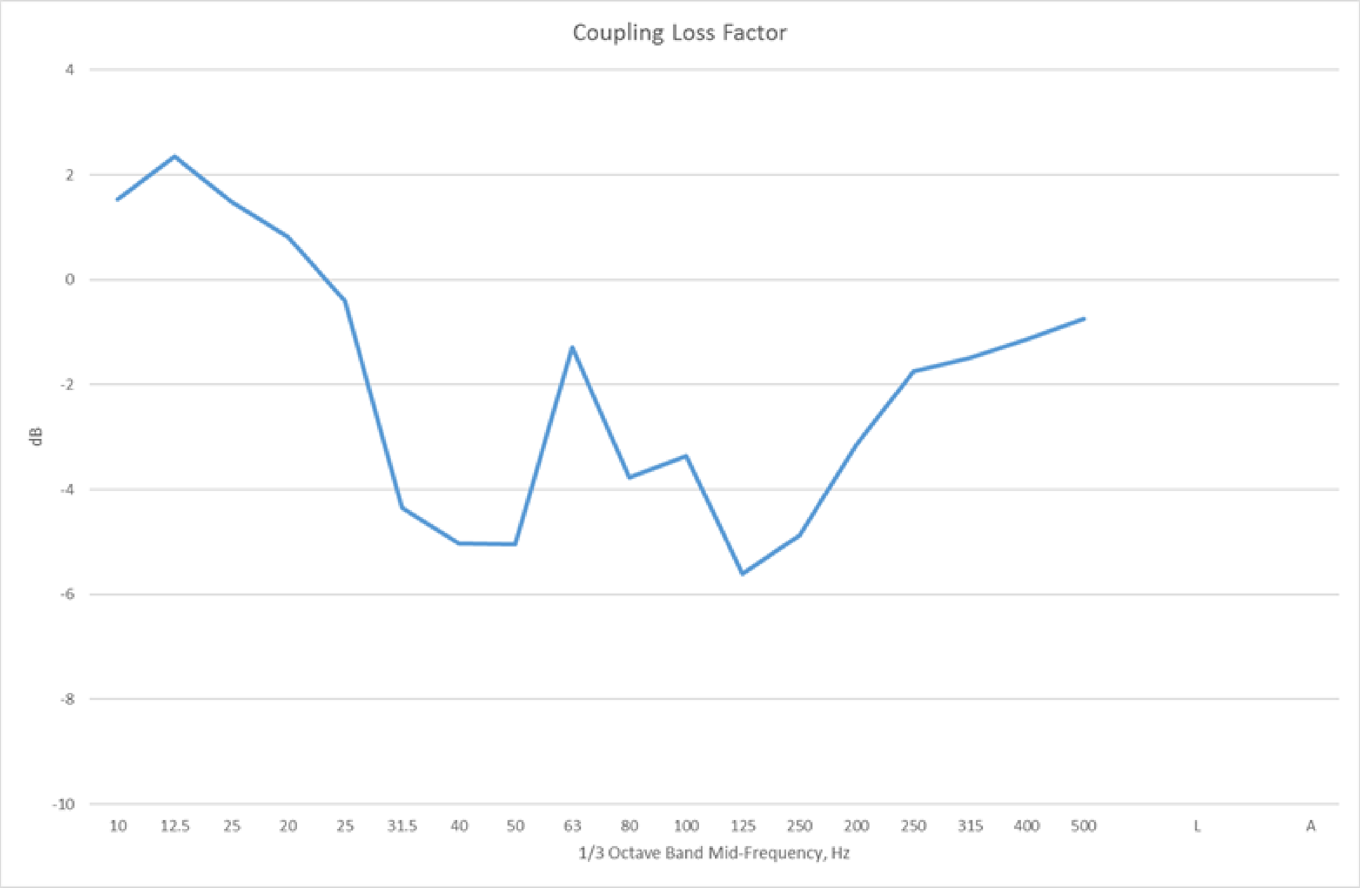


Dynamic properties of soil and rock

Where do you get the parameters from?

1) Don’t use E or G from geotechnical reports unless they are explicitly small strain
2) Beware of deriving G from values of E for water saturated soil
3) Ideally get velocities v_p and v_s from cross-hole or downhole measurements
4) Get bulk densities ρ from core samples
5) Calculate M_{max} and G_{max} from v_p, v_s and ρ
6) Assume η for soil to be 0.05 (worst case) 0.1 (best case)
7) Assume η for rock to be 0.05

Dynamic properties of soil and rock

What is soil and what is rock and how are they different?

Soil includes clays, sands, gravels

Rock may be sedimentary rock –sandstone and mudstone, and carbonate such as limestone, forest marble, hard chalk

Or it may be igneous such as granite

HOWEVER

Above most rockheads are layers of weathered rock which become progressively more like soil with reduced depth, and weathered chalk in particular can be soft.

Greensand and other highly compacted sands, the other hand, are more like sandstone

Dynamic properties of soil and rock

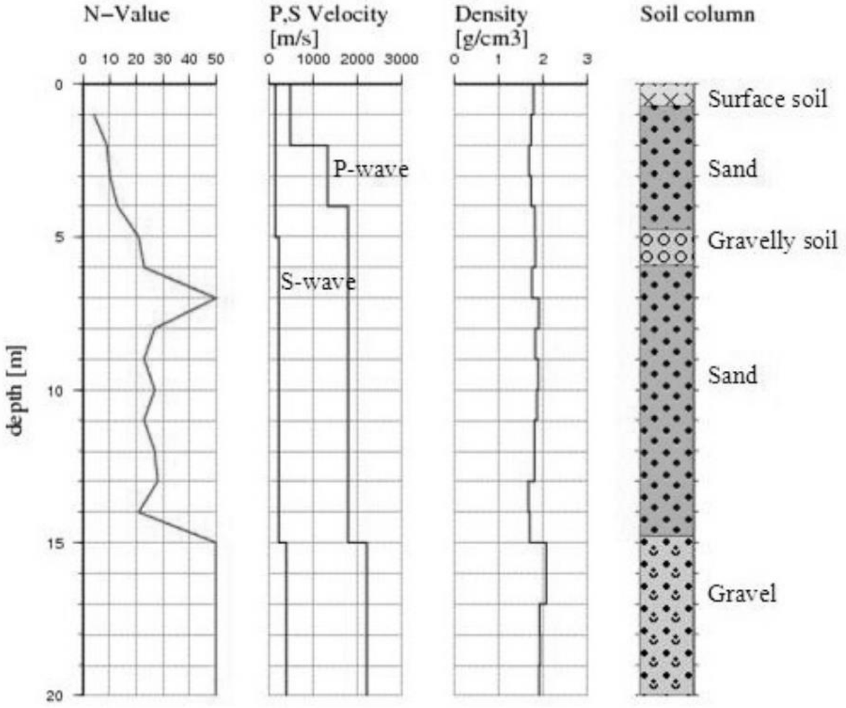
How to measure dynamic properties of soils?

Cone Penetration Tests

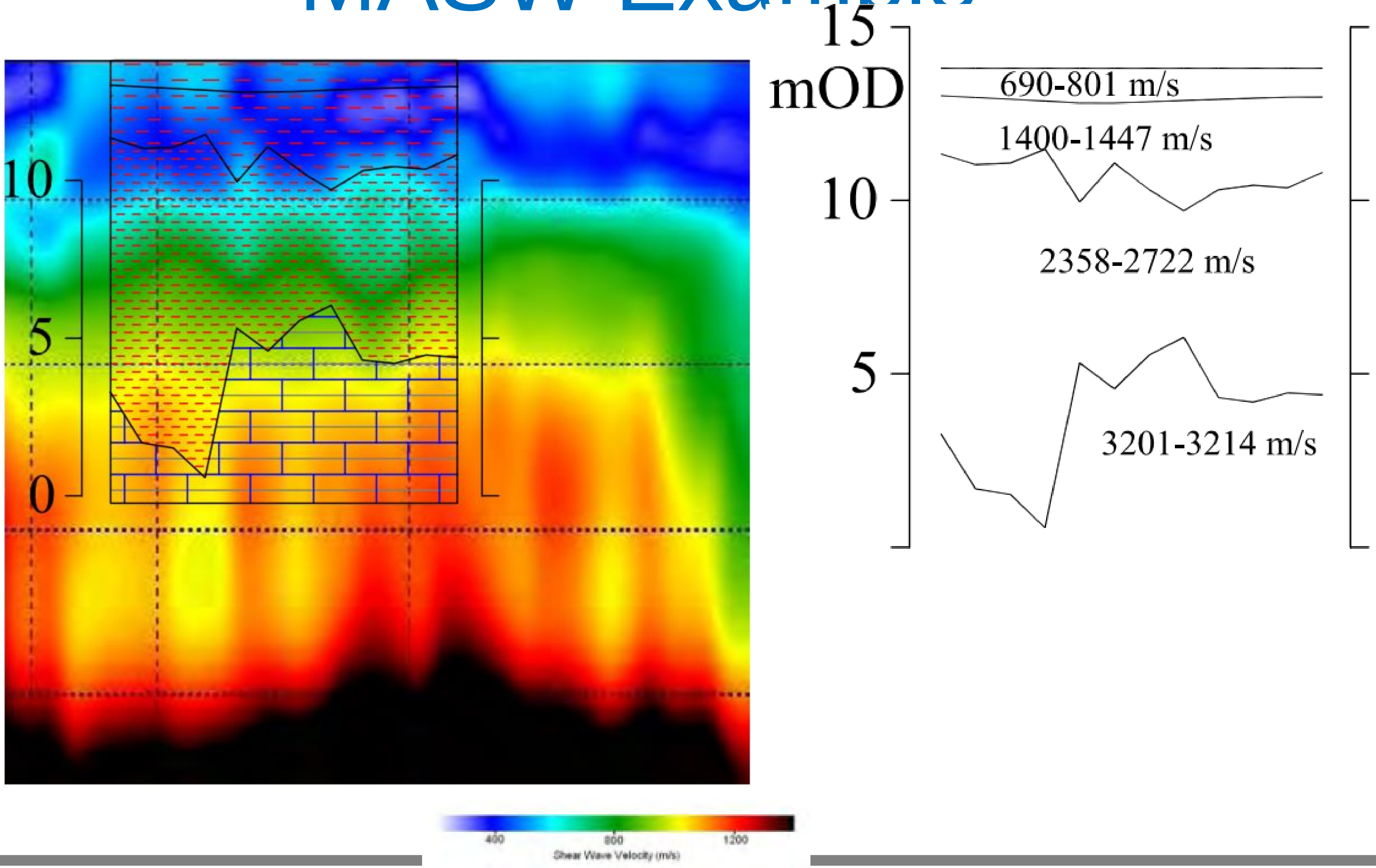
SPT N-value

Undrained shear strength and

Overconsolidation Ratio



MASW Example



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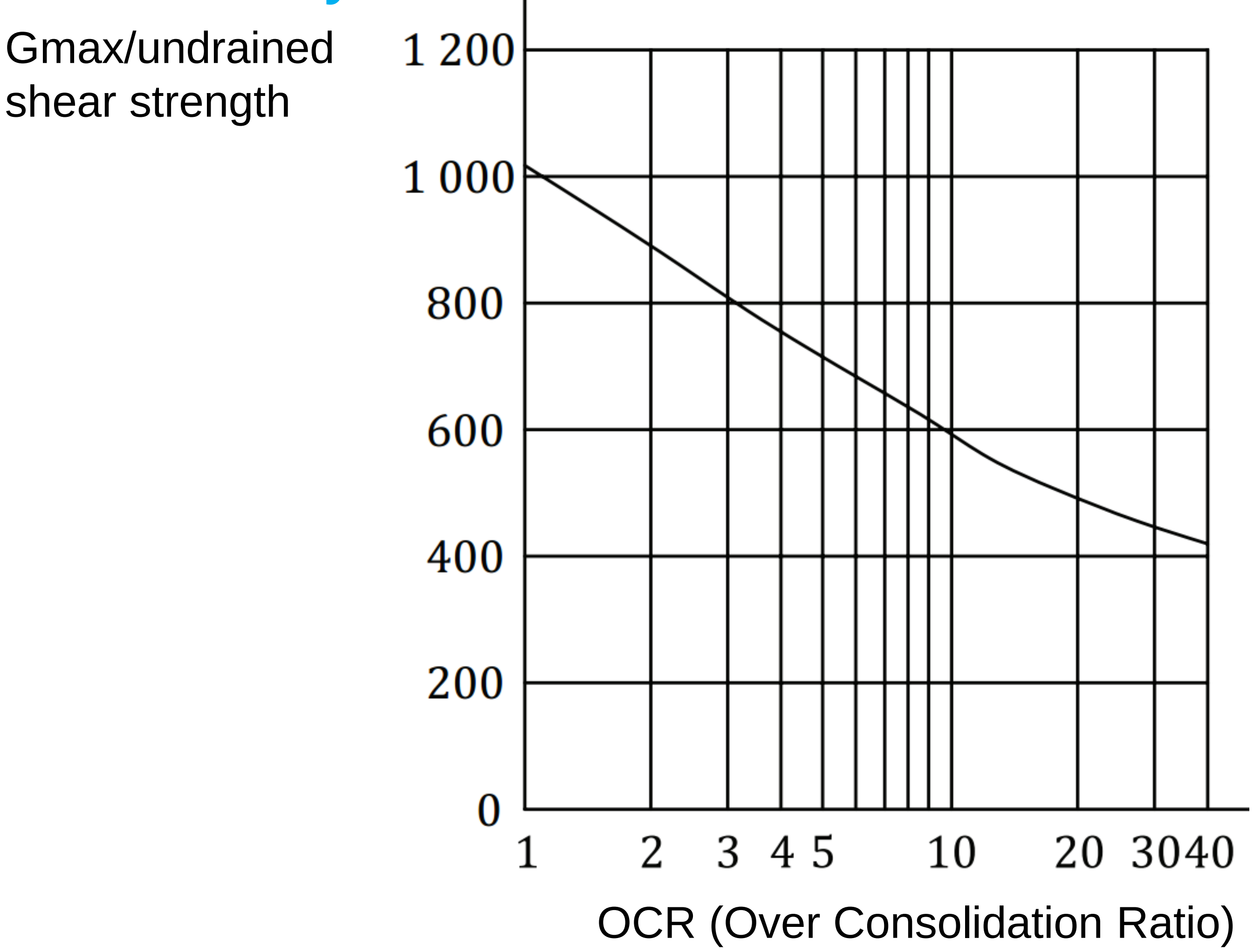
	Bulk density Kg/m³	**M_{max},** GN/m²	**G_{max},** GN/m²	**Poisson's ratio**	**V_p**	**V_s**
Made Ground	1500	0.3	0.068	0.35	447	213
Peat	1000	0.2	0.05	0.33	447	224
Chalk, hard	2000	14.6	2	0.42	2702	1000
Chalk,soft	1750	3.7	0.717	0.38	1454	640
Clayey Silt	1700	0.5	0.153	0.28	542	300
Sand	1500	3.4	0.046	0.49	1506	175
Sand	1930	5.8	0.452	0.46	1734	484
Medium dense Sand	1800	0.2	0.047	0.35	333	162
Silty Sand	1800	0.3	0.11	0.21	408	247
Lower Tunbridge Wells Sands	2243	1.5	0.578	0.19	818	508
Gault Clay	1900	1.5	0.082	0.47	889	208
London Clay	1700	4.4	0.735	0.4	1609	658
Lambeth Group	2100	5.9	0.58	0.45	1676	526
Gravel	2000	1	0.27	0.32	707	367
Terrace Gravels	1800	1	0.27	0.32	745	387
Thames Gravels	1600	2.8	0.2	0.46	1323	354
River Terrace Deposits	2000	1	0.27	0.32	707	367
Limestone	1750	2.7	0.503	0.39	1242	536
Mudstone	2480	1.2	0.2	0.4	696	284
Ragstone	2300	13.7	2.258	0.4	2441	991
Sandstone	2000	15.1	5.024	0.25	2748	1585
Granite	2660	89.5	22.662	0.33	5801	2919
Granite, slightly weathered	2540	79.7	21.335	0.32	5602	2898
Granite, moderately weathered	2430	56	12.2	0.36	4801	2241

Dynamic properties of soil and rock



Conclusions

To minimise uncertainty in the prediction of vibration it is necessary to know a substantial amount of information about the properties of the medium through which the vibration is transmitted.

That information can be hard to come by, and it may have to be obtained by indirect means.

An understanding of basic geotechnical principles is essential