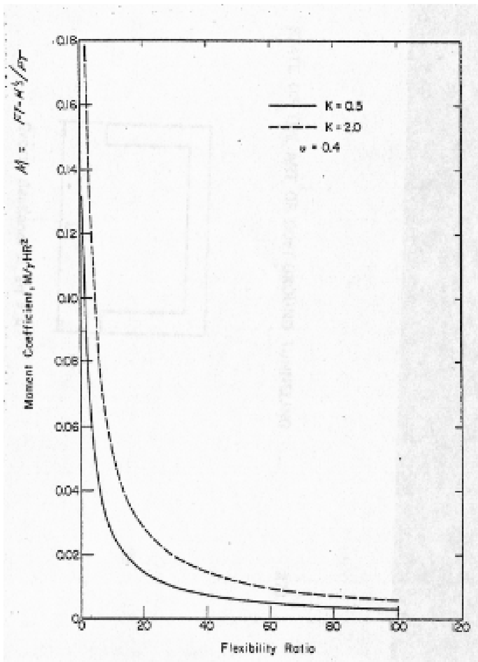
Newsletter #22

Smaller diameter pipes with smaller flexibility ratios

behave in a manner similar to those with larger diameters and larger flexibility ratios.



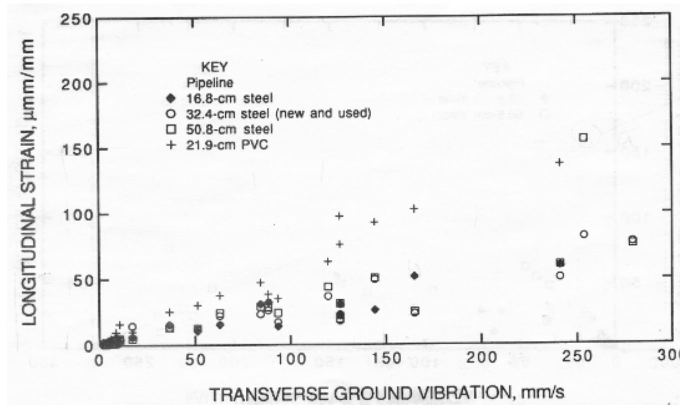


Figure 1 (left) Declination of the moment coefficient with an increasing flexibility coefficient (F) from that calculated from imposition of stresses on a rigid pipe, F = 0 (Peck et al, 1972).

Figure 2 (right) Figure 23 from USBM RI 9523 (Siskind et al, 1994) compares of blast induced strains for a variety of pipes to the same blasts. See Table 1 for F's of the pipes.

Calculation of blast induced strains in buried pipe from peak particle velocity at the pipe is based on the observation (Peck et al, 1972) that underground structures with large diameter to thickness ratios are flexible enough to deform with the surrounding ground. Therefore calculation of ground strains also suffice for the calculation of pipe strains. Application of this observation to a range of pipe geometries requires a method to determine the limit of applicability for small diameter, stiffer pipes.

This newsletter describes the reasons for use ground strains as pipe strains for less flexible small diameter, D, pipes. The logic is based upon field measurements of strains induced in different sized pipes by the same blasts. These observations are balanced by the observation in Figure 1 that induced moments, M, increase in stiffer pipes (smaller flexibility ratios, F) for the same induced ground deformation. In Figure 1 M is normalized for overburden pressure by division by γHR^2 (unit weight x depth of burial x radius squared). The flexibility ratio, F, is the ratio of ground stiffness, $E/(1+\upsilon)$, to pipe stiffness, $6E_lI_l/(1-\upsilon^2)*1/R^3$ for states of pure shear is

$$E/(1+\upsilon) \;/\; 6E_lI_l/(1-\upsilon^2)*1/R^3$$

where E = Young's Modulus, υ=Poisson's Ratio, R = the pipe radius and I = the moment of inertia of the pipe (= $(1/12)*t^3b$) where b is a unit distance along the pipe axis.

As shown in Table 1 the range of F can be large. For instance F's for large diameter steel pipes are above 10, while they dip below 3 for 16.8 cm (6.6 in) diameter steel pipe in soil and remain above 10 for 16.8 cm diameter plastic pipe.

Table 1: Calculation of Flexibility Ratio, F, for wide range of pipe

		Steel 30 in diam	Steel 20 in diam	6.6 in diam	4 in diam	PE Plastic 2 in diam	PVC 8.6 in diam	HDPE 6.6 in diam
			USBM	USBM			USBM	
			56 ksi yield	42 ksi yield			7 ksi yield	1.6-6.2 Ksi yield
		76.2 cm	50.8 cm	16.8 cm	19 cm	5 cm	21.9 cm	16.8 cm
		soil	soil	soil	Soft Rock	soil	soil	soil
		7.6 mm t	6.63 mm t	4.78 mm t	6mm t	1.8 mm t	8.43 mm t	15.27 mm t
E ground	psi	10,000	10,000	10,000	100,000	10,000	10,000	10,000
υ ground		0.25	0.25	0.25	0.25	0.25	0.25	0.25
E_l liner	psi	30,000,000	30,000,000	30,000,000	30,000,000	200,000	400,000	200,000
t liner	in	0.3	0.26	0.19	0.226	0.07	0.33	0.6
r liner	in	15	10	3.3	2	1	4.3	3.3
υ liner		0.3	0.3	0.3	0.3	0.46	0.32	0.46
b liner	in	1	1	1	1	1	1	1
I liner		$(t^3b)/12$	(t3b)/12	(t3b)/12	(t3b)/12	(t3b)/12	(t3b)/12	(t3b)/12
1+υ		1.25	1.25	1.25	1.25	1.25	1.25	1.25
E/(1+υ)		8000	8000	8000	80000	8000	8000	8000
t^3		0.027	0.017576	0.006859	0.011543176	0.000343	0.035937	0.216
t^3b		0.027	0.017576	0.006859	0.011543176	0.000343	0.035937	0.216
$(t^3b)/12$		0.00225	0.00146467	0.000571583	0.000961931	2.8583E-05	0.0029948	0.018
$1/r^3$		0.0002963	0.001	0.027826474	0.125	1	0.0125775	0.027826
$6E_lI$		405000	263640	102885	173147.64	34.3	7187.4	21600
$1-\upsilon^2$		0.91	0.91	0.91	0.91	0.7884	0.8976	0.7884
$6E_lI/1-\upsilon^2$		445054.945	289714.286	113060.4396	190272.1319	43.5058346	8007.3529	27397.26027
$[6E_lI/1-\upsilon^2]1/r3$		131.868132	289.714286	3146	23784	44	101	762
F == E/(1+υ)/[6EII/1-υ2]1/r3		60.7	27.6	2.5	3.4	183.9	79.4	10.5

While Figure 1 provides a method to account for declining F for smaller diameter steel pipe, results of USBM field measurements do not demonstrate that strains are larger in less flexible pipes for the same blast. As shown in Figure 2 strains induced in the 16.8 cm diameter steel pipe (F = 2.5) are less than the those induced in the more flexible 50.8 cm diameter steel pipe (F = 27.8) for the same blasts . Using F of 10 as a baseline for ground strain = pipe strain, Figure 1 describes how the moment coefficient, $M/\gamma HR^2$ for K = 2, increases from 0.057 for F = 10 to 0.125 for F = 2.6. Thus for the 16.8 cm diameter pipe in soil with an F of 2.5, the moment coefficient should increase by a factor of 2.2 over a pipe with an F of 10. Since pipe strain will increase proportionately to an increase in imposed moment from blast induced ovalling, measured strains in the stiffer 16.8 mm diameter pipe should have been twice those of the more flexible pipe 50.8 cm diameter pipe. Yet they were statistically equal to or less than that for the more flexible 50.8 cm pipe.

Based on the response of the 16.8 cm pipe, USBM field measurements indicate that pipes with smaller flexibility ratios respond in a manner similar to those with larger flexibility ratios.

References

Peck, R. B., Hendron, A.J. and Mohraz, B. (1972) State of the Art of Soft Ground Tunneling, Proceedings, North American Rapid Excavation and Tunneling Conference, Chicago