Newsletter #36

Non-synchronous Excitation & Differences in Ratios of Wavelength to Structure Size Can Lead to Differences in Type of Response for Large Urban and Residential Structures

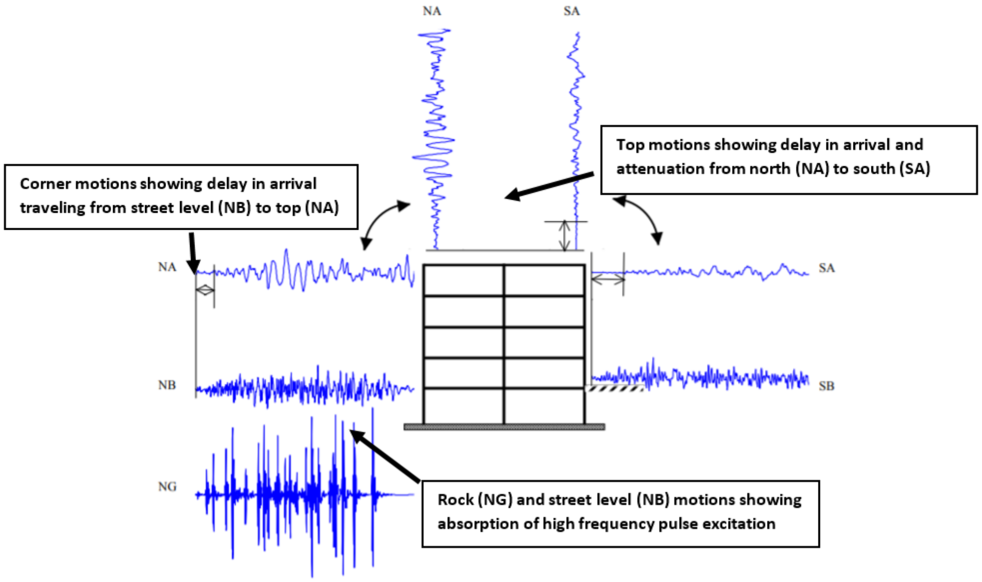

Figure 1 Comparison of Arrival Times and Amplitudes of the 06/02 shot showing:
a. (bottom) absorption of high frequency pulse energy by basement between rock and street level;
b. (top left) delay in arrival traveling from street level to top; and
c. (top right) delay in arrival and attenuation between north and south ends of the building.
From Hamdi (2016)

This newsletter introduces common time base records of response of a large urban structure to small charge weight, close-in blasting vibrations. Resulting ultra-high frequency (> 300 Hz) excitation does not contain enough energy to simultaneously excite the structure and produces such small wavelength pulses that there is significant amplitude decay from one end of the structure to the other.

		Velocity Amplitude			Arrival Time		
Building	Blast	NAT (mm/s)	SAT (mm/s)	SAT/NAT %	NAT (ms)	SAT (ms)	SAT - NAT (ms)
1	a	4.4	1.7	38.6	-22.46	31.74	54.2
1	c	10.2	1	9.8	3.42	31.25	27.8
1	e	6.1	0.9	14.8	7.81	83.98	76.2
1	f	19.8	1.7	8.6	6.34	58.11	51.8
1	g	8.5	1.1	12.9	12.7	75.2	62.5
1	h	4.1	1.1	26.8	7.81	35.63	27.8
2	h	8.3	2	24.1	-66.41	-40.53	25.9

Time correlated comparisons of rock excitation and building response in Figure 1 and Table 1 (below) demonstrate that large urban buildings do not respond synchronously. Nonsynchronous in this context means that at the time building response near the blast begins, there may be no response at the distant end of the building for up to 60 milliseconds. This time difference is large enough to encompass some 3 separate pulses of the ultra-high frequency excitation pulses shown at the bottom of Figure 1. Responses showing large deamplification and significant delays in building response are more reflective of wave transmission than synchronous dynamic response.

Table1 Comparison of amplitudes and times of arrival of motions at transducers located at the north (NAT) and south (SAT) western top corners of the urban structures 1 and 2. Structure 2 was located north of the large urban structure shown in Newsletter #34 and Figure 2 below. For additional information see Hamdi (2016)

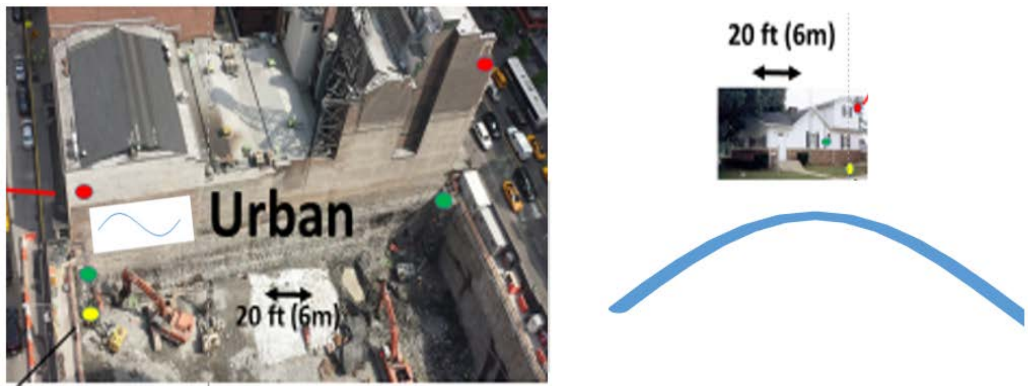

Table 1 compares peak velocity amplitudes and arrival times of the blast-induced structure motions at the north top (NAT) and the south top (SAT). These differences are visually displayed in Figure 1. Differences in times of arrival are illustrated by the arrows. Differences in amplitude are illustrated by differences in amplitude of the time histories. Arrival times can be delayed by some 60 milliseconds (ms). Amplitudes and dominant frequencies decline both up-ward and across (north to south) the structure. Structure response amplitudes and dominant frequencies decline by factors of 5 at the north, which is closest to the blast. Dominant rock excitation frequency is 333 Hz and the dominant response frequency is only 60 Hz.

Figure 2 visually compares the excitation wavelength (blue) to structure length of the urban building – urban blast (in white box in left photo) to that of the residential building to surface coal mine blast (below right photo) showing that the residential structure is excited synchronously with the same excitation amplitude.

Now consider attenuation. These urban structures have a large foot prints (65 x 15 m) compared to a residence (8 x 10 m). They are excited by high frequency pulses (= ½ a wave length) that are short. Wave lengths can be calculated as the product of the propagation velocity, c , times the wave period, T, which is 1/f. For the urban structure, If the metamorphic rock propagation velocity were 6000 m/s and the excitation frequency were 300 Hz, the pulse width would be = ½*c/$f_{excitation}$ = ½*6000 m/s/300 cycles/sec. = 10m. The distance from the north to the south of the urban building is 6 pulse widths or 3 wave lengths. This short wavelength is plotted in the white box in the lower left of the urban structure photo in Figure 2 above left.

According to Woods and Jedele (1985) peak particle velocities (PPV) of waves traveling 3 wave lengths could attenuate by factor of 10. Thus during the 06/02 blast the PPVs would decline across the structure from 52 mm/s at the north near the detonation to 5 mm/s at the south by the time the wave reached the opposite of the building, 65 m away.

In comparison, a 20 Hz surface coal mining excitation of the 10m residential structure on sedimentary rock in Figure 2 shows that the pulse width would be = ½*c/$f_{excitation}$ = ½*2000 m/s/20 cycles/sec. = 100m. As shown in Figure 2, a 100m pulse width is more than 5 times the long dimension of the house. Thus in this case the entire structure was perturbed by the same PPV. There is no instantaneous attenuation across the structure.

One of the implicit assumptions of a SDOF analysis is that the excitation occurs at a single point, or in other words the entire base of the structure is excited in the same, synchronous way. As illustrated in Figure 2 above, this assumption is valid for residential structures perturbed by typical frequency waves traveling through rock with typical propagation velocities. For large urban structures perturbed by ultra-high frequency ground motions this assumption does not hold. It fails for large urban structures for two reasons both derived from the ultra-high excitation frequencies: non-synchronous excitation and attenuation of peak particle velocity across the structure.

References

Hamdi, E. (2015) Analysis of Urban Structures Response to Ultra-High Frequency Excitation from Close-in Blasting. Visiting Fulbright Report. http://www.civil.northwestern.edu/people/dowding/acm/hamdi/hamdifulbright.pdf.

Woods, R. and Jedele (1985) Energy-Attenuation Relationships from Construction Vibrations, in *Vibration Problems in Geotechnical Engineering* (Gazetas and Selig Eds) Special Technical Publication, ASCE