Newsletter 39

Successful Blasting Within Grand Central Station Train Shed New York City. NY

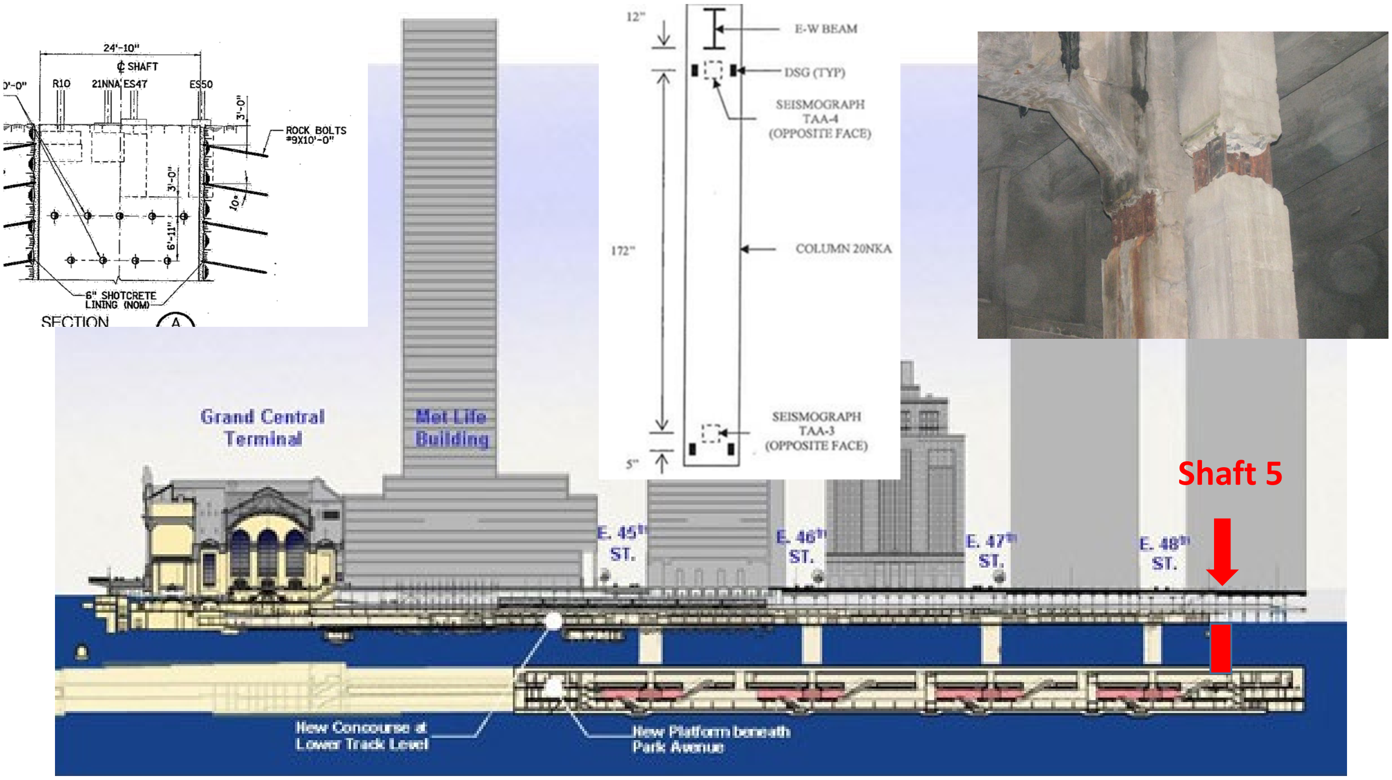

Figure 1 Cross section showing location of blasting for shaft connecting Long Island RR and Grand Central Train Shed (ENR 2018). Upper left inset shows column footings of both train shed and overlying buildings (dotted lines) and pit prexcavated with expansive cement before blasting. Middle inset shows the columns fitted with strain gauges and seismograph triaxial transducers. Upper right inset shows fire proofing concrete stripped from column to expose steel for attaching strain gauges.

This newsletter is the first of four that describes vibratory and strain response of columns shown in the upper left inset in Figure 1 within 2 horizontal meters (6 ft) of blasting within the train shed of Grand Central Terminal (GCT) in New York City (NYC), one of the busiest train stations in the world. These blasts produced peak particle velocities of 50 mm/s (2 in/sec) or more at the rock foundations of the columns. Rock fragmentation was necessary to provide another complete station below GCT and its train shed shown in Figure 1 for an East Side Access (ESA) for the Long Island railroad, as an alternative to the overcrowded Penn Station. Instrumented columns supported both the below street level train shed and office buildings along Park Avenue above the train shed.

Concern for structural safety of GCT and Park Ave. structures was high. In addition there were concerns for passenger safety and operation of the Metro North Railroad (MNRR), which provides some 700,000 passenger trips per day in and out of NYC through GCT. Construction had to proceed while the MNRR operated at full capacity. Buildings above the train shed included iconic structures such as the former Pan Am (now Met Life) and Helmsley buildings, and the Roosevelt and Waldorf Astoria hotels. These buildings are some of the most expensive real estate in NYC.

Use of strain as an alternative criteria on this project led to the recording of strains reported in this set of four Newsletters. The strain criteria were developed from a number of projects in NYC that are described in Dowding, Meissner, and Weller (2020), available on request. Blast induced strain response time histories of more than 12 columns surrounding ventilation shaft # 5 excavation (shown by red arrow in Figure 1) demonstrate their low magnitude compared to that produced by passing trains (Newsletter # 40) and a high rate of attenuation with distance (Newsletter #41). Measurement of particle velocity response time histories at the top and the rock-founded bottoms of the columns shown in the middle top inset in Figure 1 show deamplification and a lack of coherent structure response. In addition, these measurements (time coordinated to 1000'th of a sec) allowed calculation of strain time histories from velocity time histories to compare with those measured with foil strain gauges shown in the upper right inset in Figure 1 (Newsletter #42).

Blast fragmentation was conservatively designed. First as shown in the upper left insert in Figure 1 rock was chemically fractured down to a depth of 5 m (16ft), which increased the vector distance from the base of the nearest column to the top of the nearest blast hole from the horizontal 2m to a slant distance of 5+ m (17 ft). The shaft perimeter was perforated with unloaded, 62 mm (2.5 in.) line drilled holes on ~ 200 mm (8 in.) centers. The first one-sixth lift shot was designed as a sinking round. Blast holes were detonated as a spiral around three, 150 mm (6 in.) empty burn holes with delays lengthened to accommodate movement of the preceding delay's fragmented rock.

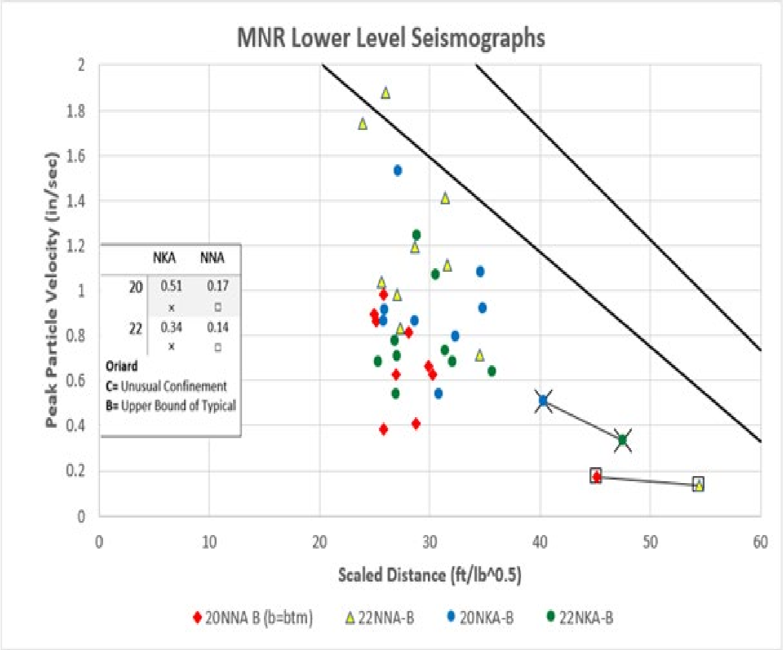

Figure 2 – Scaled distance plot of peak particle velocity (PPV) of the tabulated data in Table 1 describe the attenuation of the excitation with distance.

Figure 2 displays the measured PPV and design scaled distance at the base of columns near the four corners of shaft #5. It is also tabulated in Table 1 on the next page. Blast 2 was detonated at the corner furthest from the 22xx columns and closest to the 20xx columns. Special identification of PPVs at 20 and 22 in Figure 2 for blast 2 shows attenuation (reduction in PPV) with distance of 20 to 30 % in a distance of only 3 to 6 m (10-20 ft). This large attenuation in such a short distance is a result of the short wave lengths (some 10 m long) associated with rock to rock excitation pulse well above 100 Hz to be discussed in the next Newsletter, #40.

Table 1 data from test blasts 1 to 10 comparing shot designs, peak particle velocities and strains at column bases

		Shot Summary Data					20NNA-B (B=btm)			20NKA-B			22NNA-B			22NKA-B			NKA-NNA Beam	
No.	Blast Type	No. Holes (No.)	No. Decks (No.)	Max. Depth (m)	Total Loaded (kg)	Max. kg/Delay	Distance (m)	PPV (mm/sec)	Strain (µin/in)	Distance (m)	PPV (mm/sec)	Strain (µin/in)	Distance (m)	PPV (mm/sec)	Strain (µin/in)	Distance (m)	PPV (mm/sec)	Strain (µin/in)	Distance (m)	PPV (mm/sec)
1	test	22	1	0.91	8.62	0.4	11.28			13.11			14.02			14.94			14.94	
2	test	24	1	1.22	9.53	0.4	12.8	4.32	3.67	11.58	12.95	12	15.54	3.56	1.71	13.41	8.64	4	14.94	5.59
3	test	32	1	1.22	22.68	0.8	11.58	10.41	8.43	14.02	27.69	15.49	12.8	28.7	21.4	14.33	16.26	8.07	15.24	6.6
4	test	50	1	1.52	49.9	1.2	12.8	9.91	9.74	15.24	13.72	11.98	11.58	44.96	28.9	13.41	18.03	9.95	15.54	9.65
5	prod 1/2 l	82	1	1.83	94.8	1.2	12.8	25.15	17.78	13.41	39.12	46.51	15.54	36.58	21.36	15.24	27.43	20.4	16.15	14.22
6	2/2 lift 5	68	1	1.83	81.65	1.2	13.72	20.83	14.73	15.85	20.32	19.9	12.8	48.51	30.31	14.33	31.75	21.9	16.76	12.95
7	1/2 lift 6	72	1	1.83	90.72	1.2	14.63	17.02	11.18	14.02	22.1	21.69	17.07	18.54	21.81	15.85	17.53	7.58	17.68	13.21
8	2/2 lift 6	140	1	1.83	186.88	1.2	14.94	16		17.07	23.62		14.02	30.99		15.54	18.8		18.29	7.37
9	1/2 lift 7	86	1	2.44	171.46	2	16.15	22.86		16.46	22.1		17.37	21.59		17.07	13.72		19.51	12.45
9A	2/2 lift 7	70	1	2.44	139.71	2	17.07	16		17.98	21.6		16.46	26.92		16.15	17.27		19.81	
10	full lift 8	142	1	2.44	312.98	2.4	17.68	22.01		17.98	23.62		18.9	25.4		18.59	19.81		21.34	11.18

Response of a beam spanning columns 20 NNA & 20NKA was also measured with a triaxial velocity transducer at the center of the span. As shown in Table 1, maximum PPVs of the beam for all 10 blasts were always less than the maximum PPV at the bottom of either of the columns. Such lack of amplification is consistent with other observations of the response of large massive structures to close-in blasting where a 2 in/s PPV control limit is employed in previous newsletters. As will be discussed below the peaks of the excitation pulses in this project occur at frequencies well above 100 Hz, as was observed at other close-in blasting cases.

References

Dowding, C.H., Weller, L., and Meissner, J. (2020) Vibratory and Strain Response of Columns to Adjacent Blasts within a Large Urban Structure. Unpublished paper. Available upon request.

The above article and thoughts and figures in these four Newsletters (#'s 39-42) are based upon the following references

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