RAPID: Confirmation of Structural Dynamics Concepts for Urban Structures Subjected to Adjacent Construction Blasting; PI Charles H Dowding, Department of Civil & Environmental Engineering, Northwestern University

This grant from the GGGE Program of the CMMI Division provided supplementary instrumentation to advance the state-of-the-art of construction blast vibration control with the objective of reducing the cost of constructing urban buildings and facilities. The potential economic benefit is large. In New York City alone in the 20teens over $17 billion is being spent on transit projects that involve some construction blasting for excavations and tunneling in rock.

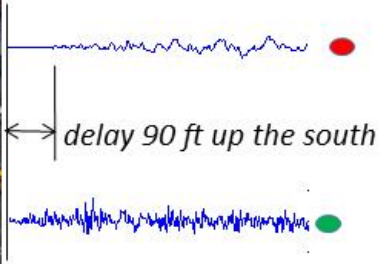
Measurements enabled by this deployment of supplemental instruments tested the hypothesis that because of high frequency excitation, urban structures are not perturbed as greatly as typically assumed, and thus vibration controls may be safely reduced and or changed. Time correlation of these measurements along a structure also allows increased accuracy in the calculation of building strains that are responsible for cosmetic cracking, the object of control by regulation. Additional instrumentation leveraged ongoing measurements of full scale building response to high frequency, blast induced excitation at a construction site in New York City. They were used to time correlate excitation and response motions, and to measure additional responses not required by construction regulations.

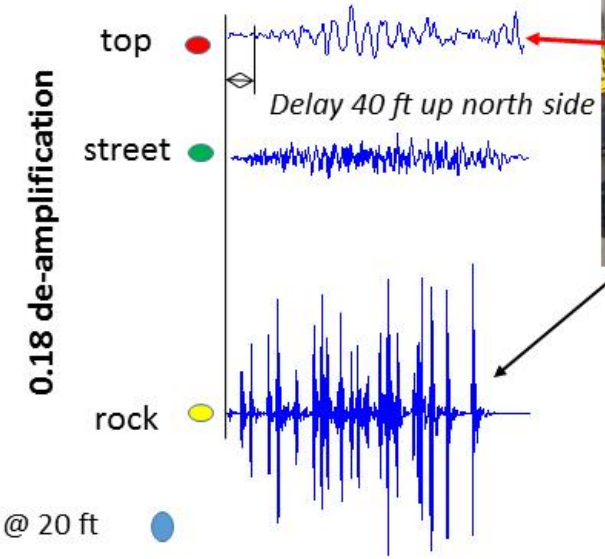
Excitation frequency and strain based analytical techniques developed in Earthquake Engineering, Blast Protective Design, and Structural Dynamics should also be applicable to these urban situations; however, validation by measurement had not occurred because of the difficulty of finding full-scale, urban test structures. Current regulations and understanding are based upon measurements of the response of residential, 1 to 2 story single family structures when subjected to excitation frequencies lower than typical of urban blasting. Extension of observations on urban by response spectrum analysis to taller structures when excited by higher frequency ground motions needs to be validated.

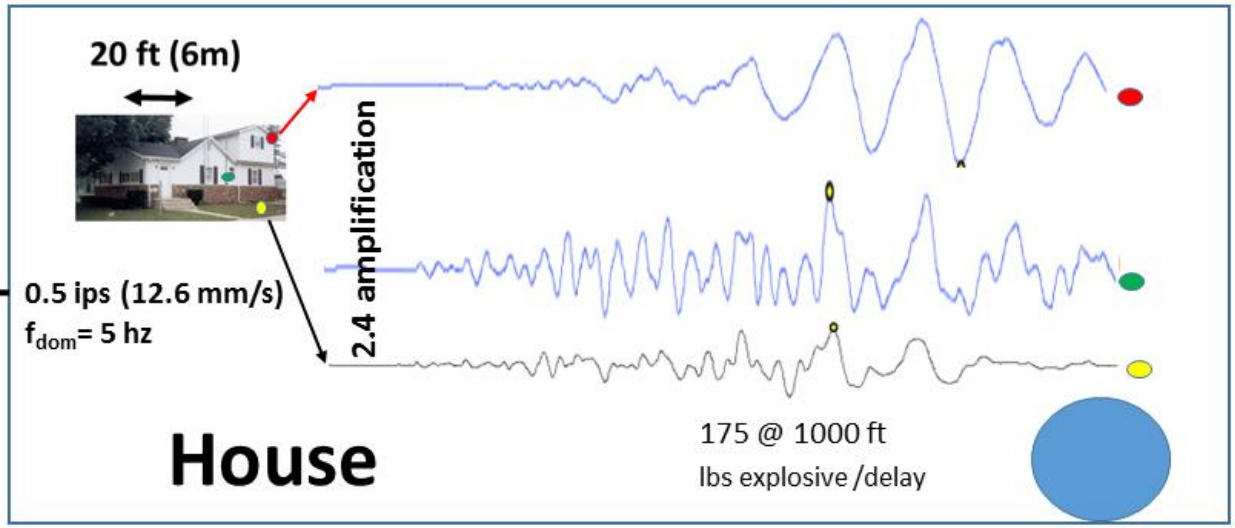
Major findings are summarized in the accompanying single figure by scaled comparison of response of urban structures to high frequency excitation with that of houses to lower frequency excitation. Scaled photographs of both structures underscores the relatively massive nature of urban structures– by weight and size. All information regarding the smaller “house” example is enclosed in its own box. Blue circles at the bottom compare the amount of explosives detonated in any instant and the distance between blast and structure. Resulting excitation, measured at each structure at the yellow dots, is shown by the adjacent time histories; urban to the left and house to the right. Response at the red dots shows that despite urban excitation amplitudes twice those at the house, urban response was de-amplified to only 20% of the excitation, while house response was amplified to 2.4 times that of the excitation. This difference is in part the result of higher frequency (333 cycles per second, cps or Hz) urban excitation compared to the lower, 5 cps, house excitation. Urban de-amplification also results from the non-homogenous response compared to the house. Arrival times of the motions differ greatly for the urban structure as shown by the difference in arrival times of the motions at yellow, green and red dots. For the house the peaks of the yellow, green and red coincide. The difference in arrival and response times for urban structures demonstrates that the energy of the urban high frequency excitation is insufficient to produce whole body response of the massive urban structure.

Time histories of measurements made possible by this grant, a report and a prepublication version of a published article are archived and made available at http://iti.northwestern.edu/acm by pressing the “High Frequency Excitation” button. All of this progress was accomplished with a grant of only $24,000 by leveraging ongoing measurements of full-scale structures by Aimone-Martin Associates, cooperation of the NY City Fire Department and a fortuitous confluence of a Fulbright fellowship.

Urban Structures Unresponsive Compared to Houses even when excited by larger blasting vibrations because of their mass and the ultra high frequency excitation pulses







Timing, frequency and amplitudes of motions at various locations around **urban** structure show low, de-amplified response compared to the amplified response of small residential (**house**) structures even though urban excitation amplitude is 2.15 times greater than house excitation