Hire a Consultant – and Go Wrong with Confidence?

***Eric E. Ungar**, Contributing Editor*

Let's take a look at a problem that has many of the characteristics often encountered by consultants who work in the field of building vibrations. A 10-story building with two levels of below-ground parking is to be constructed on an empty lot located near a busy urban street. Near-complete design drawings for the building are available, and plans call for sensitive instruments, such as magnetic resonance scanners, to be installed on the third floor. The vibration criteria for these instruments are well defined, and we need to determine whether these instruments will be subject to excessive vibration due to the street traffic – and if so, what can be done about it.

Addressing this problem in the time-honored way by progressing from the source to the receiver, we may want to start by characterizing the vibrations at the site due to the traffic. This probably is best done on the basis of measurements. It is obviously sensible to obtain data over an extended period at enough points to cover the footprint of the building, ideally measuring the vibrations at each point in three orthogonal directions. However, should we measure at the surface or in bore holes or in pits at the depth of the building's foundation? To what extent will the vibration measured on the bottom of a bore hole replicate those expected at the building's foundation? Removing a considerable amount of soil to accommodate the lower levels of the building is likely to have an effect – and surely the mass of the building (and also its resonance characteristics) will result in changing the vibration at our measurement points from those we observe in the absence of the building.

In addition to the question of where to measure, there is the question of when to measure. The temperature and moisture of the soil may be expected to affect its dynamic properties and how well it transmits vibrations from the street to the building site. How well do data we obtain in summer represent conditions encountered in winter? Do we need to take account of the weather, which is likely to affect not only the soil's transmission characteristics, but also the traffic speed and street surface conditions (puddles, potholes, and mounds of snow and ice, for example)?

Suppose that we can answer these questions satisfactorily and that we have made extensive recordings of the vibration data. Now, what shall we do with the data? Assuming that we have a sufficiently good model of the building, we could undertake the formidable task of "playing" the recorded time-series data into a model of the building, taking proper account of all the phase differences and time delays between the measurement locations. Or should we use upper bounds of the spectra computed from the data to carry out some sort of modified steady-state analysis to obtain estimates of the greatest expected vibrations at the locations of vibration sensitive equipment?

And how can we accomplish adequate dynamic modeling of the building with (at least) all of the heavy items (scanners, building service equipment, pipes) in place? A finite-element model that could yield reliable results at the frequencies of interest, which typically are very considerably above the building's fundamental, would need to be composed of an extraordinarily large number of elements.

These elements also would need to represent structural details and equipment, which are never fully defined before the building is actually in place. Even if we had a supercomputer that could enable us to deal with a very large number of elements, the computed results would not represent reality. Although statistical energy analysis could provide estimates of the average vibrations, these estimates depend crucially on the damping of the structures, which is never well known beforehand.

So what can a consultant do beyond carrying out analyses based on all sorts of worst-case assumptions? The answer is: bring to bear experience and extrapolation of data obtained in situations that have some similarity to the problem at hand. It is the responsibility of a good consultant to bring technical insight, intuition, and real-world experience to the table, enabling the design team to avoid going wrong with confidence. S&V

The author can be reached at: eungar@acentech.com.