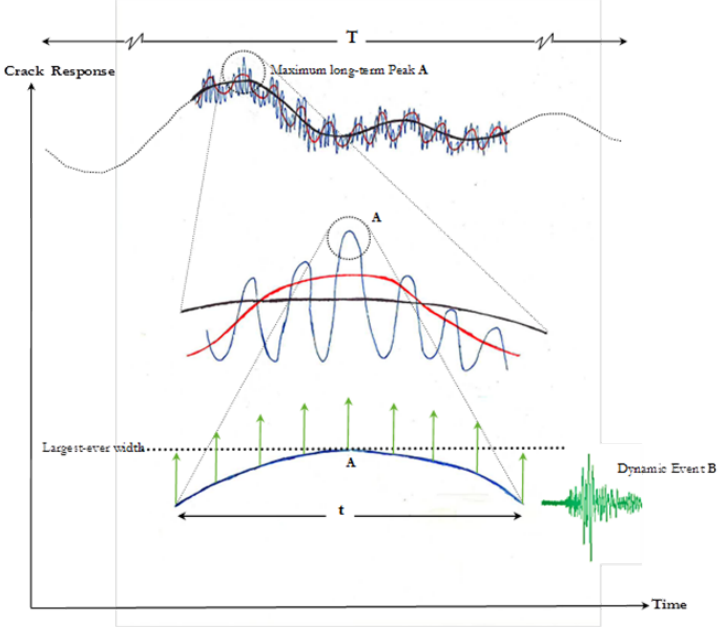
Newsletter #29
Inclusion of Amplitude in Calculation of the Probability of Occurrence of a Dynamic Event during the Single, Yearly Period of Vulnerability



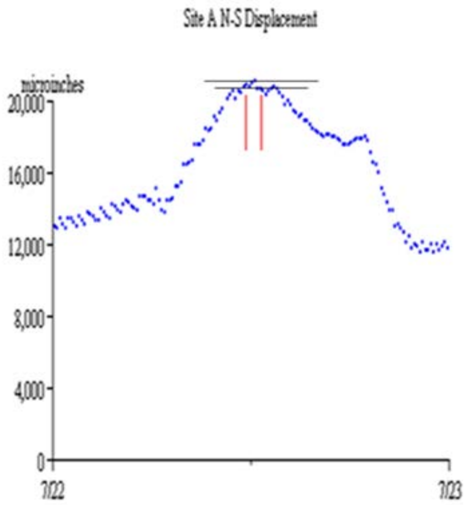


Figure 1 (left): Crack response at the once a year time of vulnerability (blue A arc in the bottom, middle and top), and a dynamic event (green B in the bottom right). If event B with the time of exposure, t, were to occur during the period of vulnerability, A, it would add to the long term crack response to exceed the maximum. (Meissner, 2010)
Figure 2 (right): Specific example of the exposure time (between the red lines) for a ground motion that produced a 10 micro meter (400 micro inch) crack response. This critical exposure time is that during which that dynamic response might induce the crack response to exceed its yearly maximum if the event were to occur during the once a year period of vulnerability.

This newsletter describes the development of a simple means of calculating the probability of a dynamic event adding to weather induced crack response so as to exceed the maximum yearly crack response, defined in the previous newsletter (#28). It is the third in the series on the importance of occupant induced and naturally occurring crack responses. Based on this procedure the fourth and final newsletter will compare probabilities of occupant and blast induced events leading to the exceedance of the maximum naturally occurring crack response.

Crack response is highly cyclic and is the sum of reoccurring similar but not equal components as illustrated in Figure 1. This illustration is an idealized version of long term crack response time history shown in Figure 1 of Newsletter 28. The 24 hour cycle of the raw crack response data is produced by daily swings in temperature (and to lesser extent humidity). The lower frequency of the 24-hour rolling average of the raw data, shown in red, highlights passages of high and low pressure fronts and associated wide swings in humidity that occur every week or so. Finally the yet lower frequency of the 25-day rolling average highlights longer trends that ultimately define the seasonal response. As shown and illustrated in Figure 1 in this and Newsletters 27, during each year, T, there is only one long term peak labeled A in this newsletter.

If a dynamic disturbance, either occupant or construction induced, is to crack a wall or extend a crack, it must occur during the single, long term maximum crack response period of vulnerability, A in blue in Figure 1. If a dynamic event were to occur then, its intensity can be accounted for by determining an exposure time, t in green at the bottom right of Figure 1.

Exposure time, “t”, is defined as the time during which the zero to peak amplitude (µm) of the dynamic crack response “could” be added to the long term peak response (peaking portion of blue line A) or period of vulnerability to exceed the peak or maximum long term response. If the zero to peak dynamic crack response occurred during the period of vulnerability, it could widen the crack more than it had ever been that year. This increase is shown at the bottom of Figure 1 as the addition of the green to the blue crack response surrounding the blue peak. The larger the amplitude of the green dynamic response, the longer will be the exposure time, “t”. The exposure time is not linearly related to the amplitude because of the parabolic shape of the peaking long term response,

The procedure for determination of “t” is shown in Figure 2. This is an enlargement of the daily N-S crack response of the Naples house shown in Figure 2 in Newsletter #27 as the blue line labeled 4407 µ-in [110 µm]. Consider an event that produces 10 micrometer (400 micro inch) zero to peak crack response intensity. The relative amplitude of this dynamic contribution is shown by the two horizontal black lines in Figure 2 at the peak. Limits of the intersection of the lower horizontal black line with the blue daily response time history are shown by the vertical red lines. The time between these red lines shows that the exposure time for a 10 micro meter (400 micro inch) event would be some 80 minutes.

This procedure for translation of crack response intensity or amplitude to exposure time, “t”, was employed equally for both occupant and blast induced dynamic events in the study summarized in these four newsletters. For a given period of vulnerability, A, exposure time, “t”, is proportional to the measured µm crack response amplitude of the dynamic event, no matter its origin. Thus the greater the vibratory crack response, the longer the exposure time, t.

If both the single period of vulnerability and the dynamic events are randomly and evenly distributed in time over a year, the probability of a dynamic event occurring during the period of vulnerability can be calculated. Consider a crack at its period of vulnerability. Occurrence of dynamic events during this time is similar to drawing balls out of a bag full of a year’s worth of balls. Each ball represents one minute of time, since exposure times, “t”, the time based index of the amplitude of crack response, is measured in minutes. For a dynamic event with a “t” of 30 minutes, there would be 30 balls out of a year’s worth of balls, some 525,600 (365 x 24 x 60) minutes or balls. If there were two such events per year there would be 60 balls. Thus the probability of either of these two events of this magnitude occurring during the period of vulnerability would be (2 * 30)/525,600 or in general

$$(n^* t)/T$$

where n = the number of events of a given intensity, t = time the vulnerable crack is exposed to the event with this given intensity, and T is the time period under consideration. Intensity is the zero to peak amplitude of the crack response to the event (Dowding et al, 2019). The following Newsletter # 30 will compare probabilities of occupant and construction induced dynamic events.

References

Dowding, C., Meissner, J., and Chou, K. (2019) Estimating Probabilities of Cosmetic Cracking from Vibratory Events by Field Measurement. Draft article. Available upon request.

Meissner, J. (2010): The Straw that Broke the Camel’s Back, Internal Reports, Infrastructure Technology Institute, Northwestern University, Evanston, IL. Available on request.