# Investigation Of Wave Induced Motion Of A Breakwater Structure Using Automated Monitoring

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## 1.0 INTRODUCTION

Over recent years, a crack has been forming in a breakwater structure on the Lake Ontario shoreline. An investigative study was undertaken to determine if there is significant motion of the breakwater structure, and if so, whether this motion is wave-induced. Two automated seismographic monitors were fixed to the breakwater, one at each of the east and west ends of the structure, on either side of the crack (Figure 1), for a period of three months during the winter storm season. Motion was recorded in terms of peak particle velocity and was post-processed to compute peak displacement. Various important characteristics about the motion of the structure were evident.

## 2.0 MEASUREMENT INSTRUMENTATION AND METHOD

The two automatic seismograph monitors were used for this project equipped with external, triaxial geophones, to measure instantaneous velocity at a point (typically termed "peak particle velocity" or PPV, in units of mm/s), in the three principal directions: X, Y and Z. Because it was expected that the monitors would be inaccessible during the measurement period (due to ice build-up) each monitor was connected to a modem and phone line for remote data retrieval and reconfiguration.

Two different modes of data acquisition were employed during successive measurement periods, in order to gain different types of information. For the first two weeks, the monitors were configured in *interval* mode, during which the motion was monitored continuously and the maximum PPV occurring in each 15 minute interval was logged by the monitor, respectively in each of the three principal directions. This mode of operation allowed a manageable amount of information about the measured motion to be recorded continuously, with no gaps in the data. During the second measurement period, the monitors were configured in *threshold trigger* mode. In this configuration, the monitors captured detailed information for a preset segment of time (e.g., 10 s) once the measured instantaneous motion exceeded a programmed threshold value. Although the monitoring is not continuous in trigger mode, this configuration allowed the unit to store a snapshot of the measured motion waveform, for post analysis. After two weeks of measuring in trigger mode, the monitors were configured back to interval mode to record data continuously for the remaining two months of the study period.

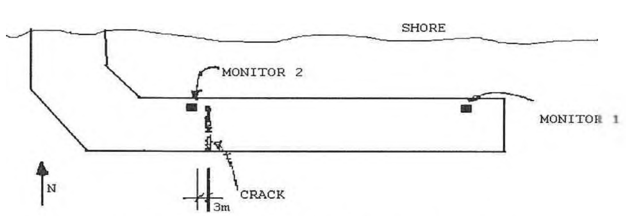


Figure 1: Shematic Plan of Monitor Locations

The data was post-processed in a variety of ways to highlight salient aspects of the measurement results. The post processing included integration of the measured velocity data [mm/s] into peak displacement [mm], correlation of motion of the breakwater to wind speed and direction, correlation of motion at Monitor 1 to motion at Monitor 2, and a general consideration of the motion measured in the three principal directions.

## 3.0 SUMMARY OF MEASURED RESULTS

A primary issue of concern during the initial monitoring period was the degree to which the motion on the breakwater structure could be correlated to wind speed and direction. Since the wave motion of the water will, in general, vary with wind speed, and the direction that the waves strike the breakwater will vary with wind direction, a correlation would indicate that the motion observed on the breakwater could be attributed to wave motion. Figure 2a shows hourly wind speed measured at Toronto Island Airport, obtained from Environment Canada. Figure 2b and Figure 2c show the motion measured at Monitor 1 and Monitor 2. Judging visually by the similarity in shape between the graphs of wind speed and measured breakwater motion, there is general correlation between high winds and pronounced motion. Figure 3 shows the result of an exponential regression calculation for each of the sets of monitored results against wind speed. From the trigger-recorded waveforms, it was evident that the true motion of the breakwater fell within the frequency range of about 2 to 8 Hz, while data falling outside this range was found to be noise (primarily spikes and hum on the A/C lines). The complete set of the data was separated into useful data and noise, during post-processing, based on the frequency range described above.

Figure 4 shows the correlation between the motion measured at Monitor 1 and Monitor 2. The slope of the best fit straight line shown in Figure 4 indicates that, on average, the motion

Figure 2a: Wind Data Jan 13-19 2001

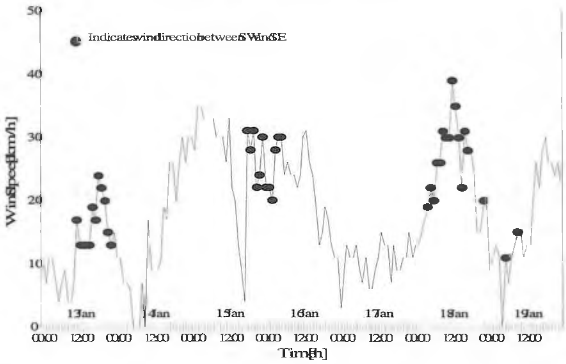



Figure 2b: Monitor 1 Jan 13-19, 2001

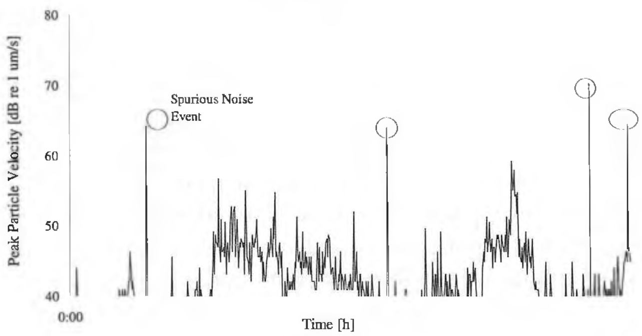



Figure 2c: Monitor 2 - Jan 13-19, 2001

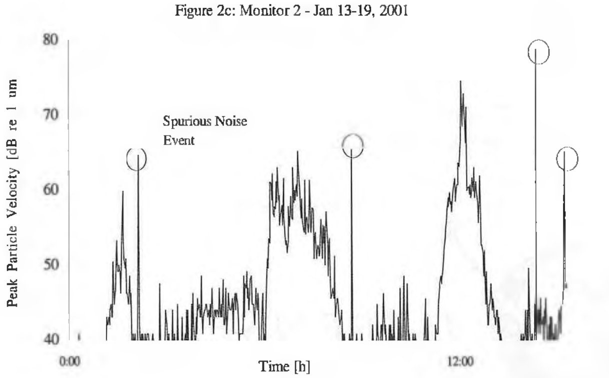



Figure 3: Wind Speed vs. Lateral PPV - Jan 13-19 2001

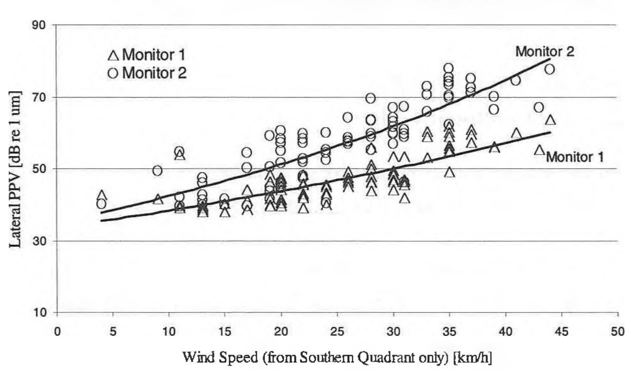
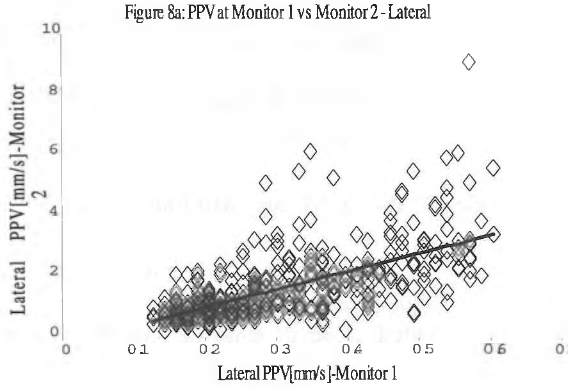



Figure 8a: PPV at Monitor 1 vs Monitor 2 - Lateral




at Monitor 2 is a factor of 3 to 5 times greater than that at Monitor 1. Given that the driving force the two locations is effectively equal (wave impacts), this suggests that the mobility of the structure at Monitor 2 is significantly greater than that at Monitor 1. This observation and the relatively poor correlation (significant scatter in Figure 4) suggest that the two halves of the structure move essentially independently of one another. From a review of all the useful monitored data, the north-south motion at Monitor 2 was greater than that in the vertical or east-west direction, while at Monitor 1 the motion was no greater in north-south direction than in the other two principle directions. This suggests bulk motion is occurring at the west end of structure in the north-south direction. Also, since the wave impacts upon the breakwater occur primarily from the south (given its orientation), the motion in east-west and vertical directions is most likely a result of deformation (i.e. relative motion) rather then bulk motion of the structure as a whole.

## 4.0 CONCLUSION

The motion at the east and west ends of the breakwater was essentially non-correlated, suggesting that the two halves of the structure (on either side of the crack) move independently of each other. The west end of the structure was found to have displacement 3 to 5 times greater than that at the east end. The recorded data about the motion of the structure appears to indicate the possibility of both bulk motion and elastic deflection of the structure.