Utilization of a Noise Attenuation Calibration Model for Concrete Pile Driving in Florida

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Introduction

There is concern that underwater noise during pile driving may be loud enough to harm marine organisms. Thresholds for organism death, impairment, and behavioral changes are well understood. It is important to ascertain both if these thresholds are breeched and the distance from a pile drive where they are exceeded. To predict this radius of influence (ROI), transmission loss (TL; i.e., sound attenuation as a function of distance) must be determined. TL is often estimated a priori by a well-known logarithmic decay:

$$\mathrm{TL} = L_s - L_r = F\log_{10}\left(\frac{r}{r_0}\right) \qquad (1)$$

- F = TL coefficient
- r = ROI
- r_0 = reference range (usually 1 m)
- L_s, L_r = sound-levels at r_0 and r respectively

Data have shown that *F* may vary. A conservative generalization that is mirrored by federal guidelines is that *F* = 15.

Further analysis has shown that the equation above oversimplifies the problem to some extent. More broadly:

$$\mathrm{TL} = b - a\log_{10}\left(\frac{r}{r_0}\right) \qquad (2)$$

In this equation, *a* is analogous to *F* while *b* represents attenuation due to "other" factors like geotechnical conditions, attenuation through the water column, strike energy, pile penetration, and receiver angle. Others (see Martin & Barclay 2019, for example) have calibrated *b* as a function of drive parameters, but practically implementing this calibration requires field measurements at several locations during pile driving, and this may be impractical.

Methodology

In Florida, most transportation-related construction is in relatively small/shallow coastal creeks and rivers (i.e., less than 1 mile wide with water depths of 30 ft or less) using square precast concrete piles with dimensions between 18 inches and 36 inches in similar geotechnical conditions. The *F* = 15 assumption recommended by federal guidelines is based upon data from mostly steel piles and not concrete piles like those used in Florida.

From 2018-2023, investigators in Florida gathered pile driving noise data from 84 pile drives on transportation-related construction projects (i.e., bridge construction) using a unique buoy-mounted hydrophone system that simultaneously measured noise at five distances from each drive. Sound statistics were analyzed using single-strike methods outlined by federal guidelines and international standards [Fig. 1].

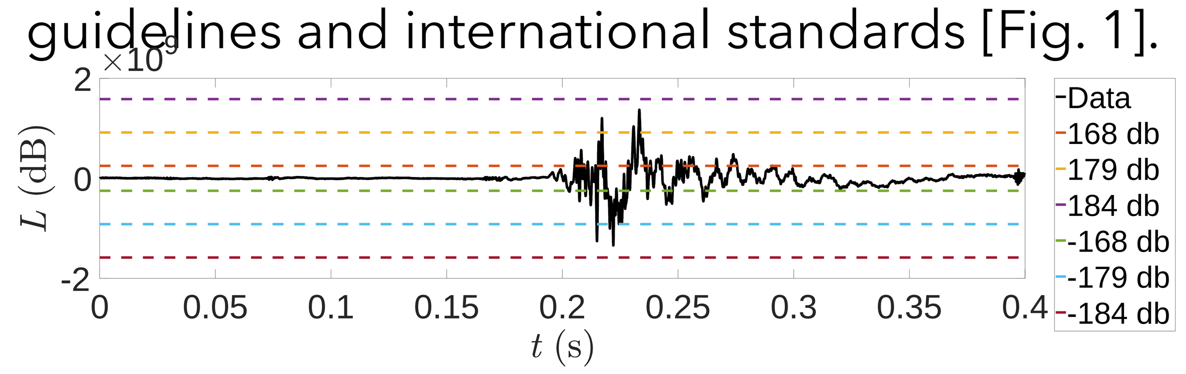

Figure 1: Typical hammer blow during a pile drive; data from Howard Frankland Bridge between St. Petersburg & Tampa, FL

These statistics included the following:

- RMS. Root-mean-squared sound-level, which is analogous to the average sound-level.
- SEL. Sound exposure level, which is analogous to cumulative sound.
- PEAK. Peak sound-level, which is the highest sound-level per drive.

Isopleths associated with detrimental effects to marine organisms are based upon these statistics.

Results

Results showed an interesting trend in the sense that data suggested that *a* and *b* were always correlated in Florida [Fig. 2]. As such, investigators were able to develop a model of the form:

$$b = a_1 a + a_2 \qquad (3)$$

where a_1 and a_2 represent best-fit coefficients. These coefficients were calibrated for the steel impact drives, steel vibrational drives, and concrete impact drives observed during this study. Of these three drive-types, the model is most suitable for concrete impact drives. However, it is interesting to note that the model's predicted attenuation coefficient was usually close to *F* = 15 when used with steel drives.

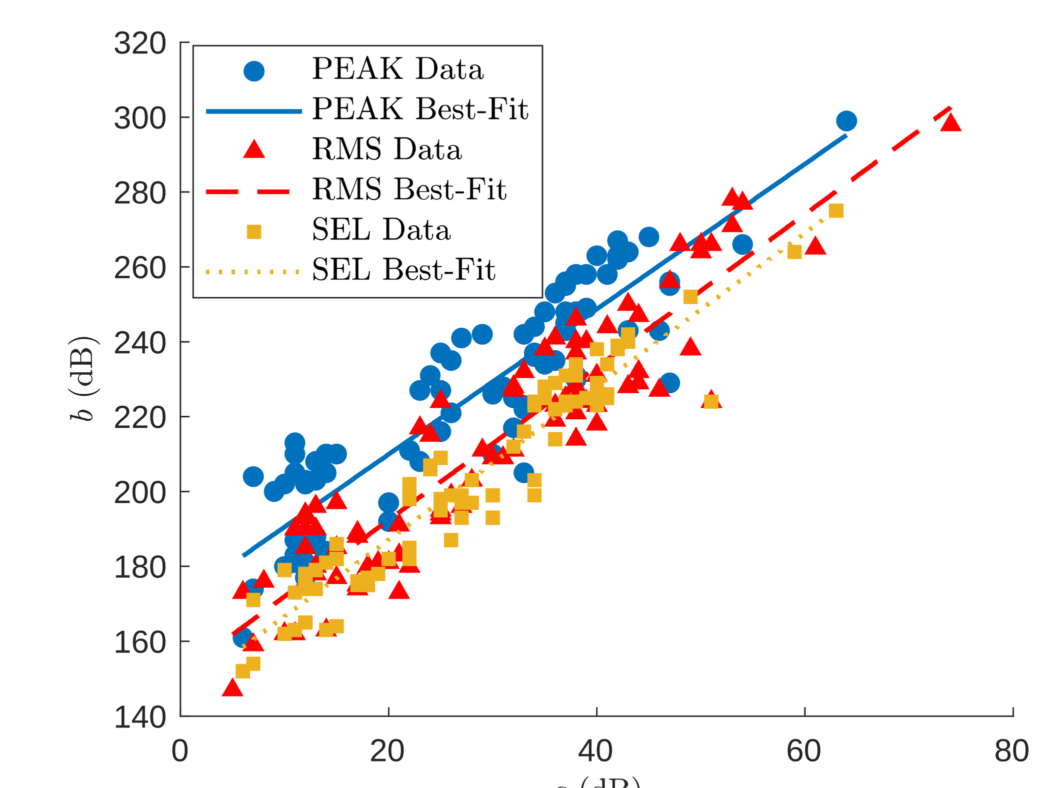

Figure 2: Apparent correlation between a and b from pile driving data in Florida

Implementation

To implement the new model, a calculator was developed that is calibrated based upon the drive-type. If pile driving noise data is known at one location during driving, Eq. 2 and Eq. 3 may be used together to return total predicted TL at that location. The new calculator computes isopleths automatically.

Verification

The model was validated using two methods. First, a "blind prediction" test was conducted whereby one pile drive was excluded from the model and the remaining drives were used to predict the excluded drive's *a*-value [Fig. 3(a)]. Next reported attenuation coefficients from out-of-state were predicted using the model [Fig. 3(b)]. Results showed very close agreement between measured and predicted data.

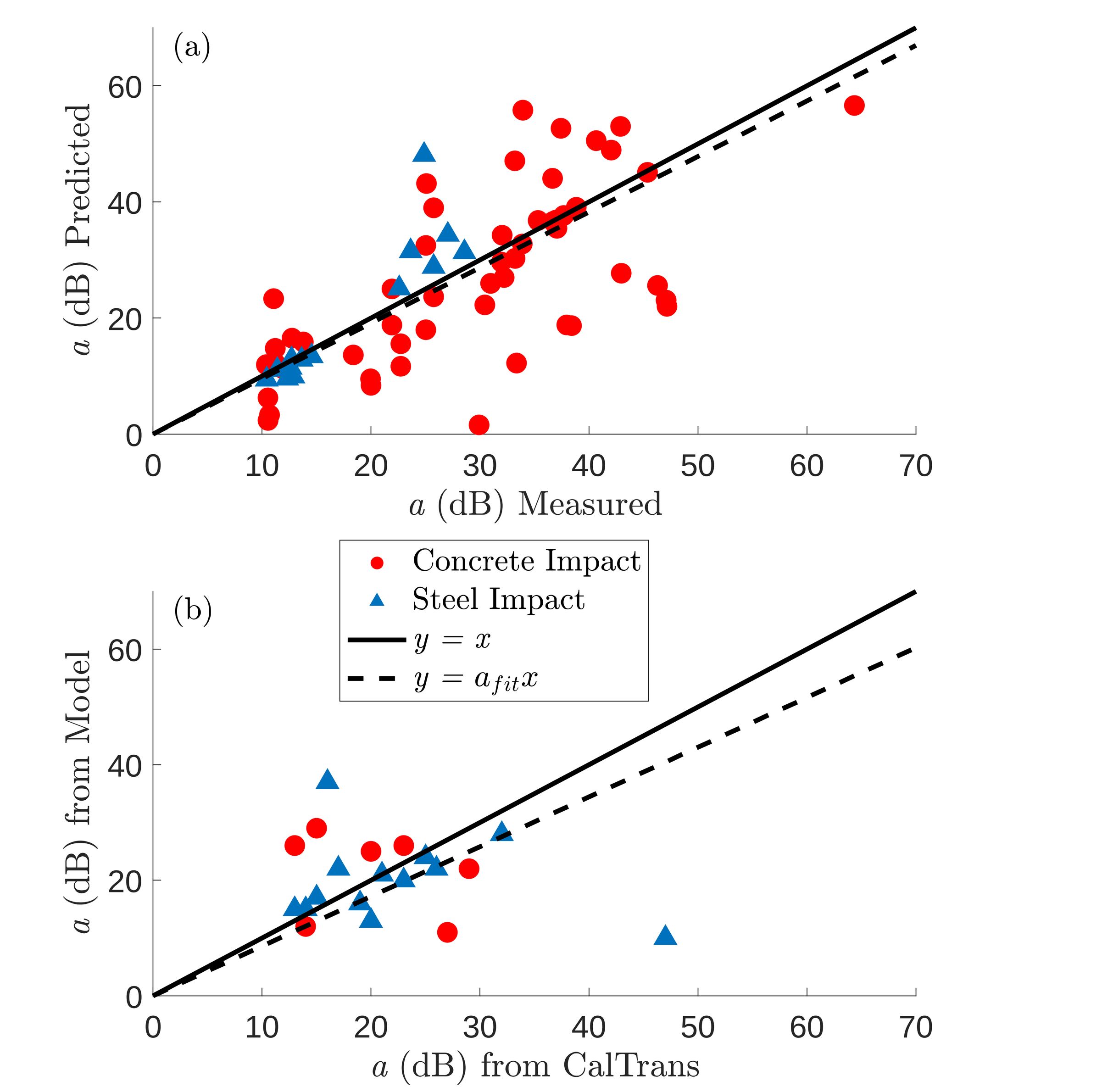

Figure 3: Verification results showing (a) blind prediction results; and (b) modeled results as a function of data from CalTrans. Only RMS data are shown here due to space constraints, but SEL and PEAK data were similarly close.

Acknowledgements & Disclaimer

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