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Bridge Foundation Pile Driving Vibration Monitoring

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Seventh International Conference on Case Histories in Geotechnical Engineering
April 29 - May 4, 2013 CHICAGO
and Symposium in Honor of Clyde Baker

BRIDGE FOUNDATION PILE DRIVING VIBRATION MONITORING

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ABSTRACT

In southern California a big bridge was under construction in urban area. Based on the size and depth of the steel and concrete piles some of the residential buildings within the 200ft distance from the center of the different footings (there were six footings sitting on steel pipe piles) were selected and vibration monitoring devices installed in their back yard. Some of the owners complained during the excavation process for a big channel behind their back yard before starting any pile driving operations. Three of those residential owners informed the authorities during the bottom of that big channel compaction operation their bad vibration experience. Five different buildings selected within 200ft from the bridge footings for each footing pile driving operations, set sensors and device in their back yards and collected velocity data from the start of the first pile to the last pile driving. The maximum velocity (in/sec) for each operation was compared with the maximum required limit (0.3 in/sec) to make sure if the pile driving operation caused any crack or damage to any building structures.

In this paper besides considering the vibration monitoring devices, installation procedure the velocity reduction diagram from the pile to the sensors and the velocity limitations for preventing residential structural damage, the location and the method that were used for this bridge construction will be presented .

INTRODUCTION

Vibration monitoring is a specialized procedure for recording, analyzing, and quantifying vibrations resulting from construction operations. Pre- and post-construction building condition surveys include photographic and videotape documentation of the interior and exterior condition of the building(s), and the extent and location of existing signs of building distress such as cracks, spalling, signs of settlement, flooding, leaking, etc. Vibration monitoring plan which includes, but is not limited to, the limits of vibration monitoring work, location of all structures to be monitored, location of any underground utilities, maximum allowable Peak Particle Velocities (PPV) as indicated in the contract documents, location of seismograph placement(s), and details for anchoring geophone(s). Vibration monitoring provides real time printouts of PPV's and frequencies of construction vibrations and expedites the on-site decision making process.

VIBRATION LIMITS

The peak particle velocity (PPV) is generally accepted as the single most important characterization parameter of discrete shocks, when developing vibration criteria to assess the risk of potential damage. Other factors to be accounted for include the frequency content of the vibration and the type and condition of the facility of concern.
Construction vibrations consist of a composite or "spectrum" of many frequencies and are generally classified as broadband or random vibrations. The normal frequency range of most ground-borne vibration that can be felt generally starts from a low frequency of less than 1 Hz to a high of about 200 Hz. Vibration levels are usually expressed as single-number measure of vibration magnitude, in terms of velocity or acceleration, which describes the severity of the vibration without the frequency variable.

Table 1. Pile driving vibration effects on human and building

PPV(in/sec)	Effect on Human	Effect on Building
<0.005	Unnoticeable	
0.005 to 0.015	Hardly noticeable	No
0.02 to 0.05	Begin to irritate	
0.1 to 0.5	Unacceptable	Begin to damage
0.5 to 1	Inconvenient	Plaster damage
1 to 2	Unpleasant	Most limits
>3	Unpleasant	Minor structural damage

For this project, the specifications limit the levels of vibration to 0.3 inches per second (in/sec).

VIBRATION MONITORING DURING PILE DRIVING

A four-span, cast-in-place, post-tensioned concrete box girder bridge approximately 9.0-feet deep with a 6-foot deep haunch at Bent 2, and 42-feet wide and supported by concrete and steel pipe piles all constructed in one stage.
According to project specifications, monitoring equipment were stationed within 3 ft of the exterior of the buildings that were within 200 ft from the footing pile driving. Number of buildings that were within the 200ft from the footing pile driving area is shown in Fig. 1.

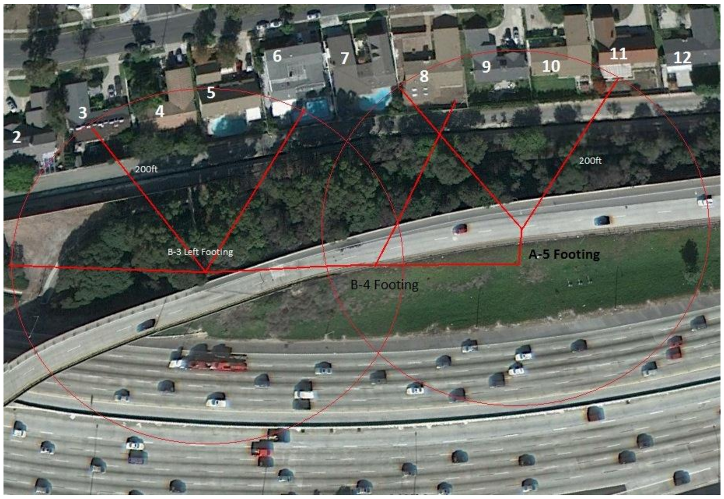

Fig. 1. Buildings within the 200ft of the pile driving

Just three footing of this bridge was in the limit of 200 ft from the residential buildings. The project for which this study was performed included driving 35 ft long, 14 inches rectangular concrete piles, and 57 ft long 16inches diameter steel pipe piles. An APE D36 open ended single acting diesel hammer was used for driving the piles. Total of 37 fourteen inches concrete piles and 91 sixteen inches steel pipe piles were driven within 200ft limit from the residential buildings.
There was a continues V-ditch along the backyards between the pile driving locations and the buildings. The site cross section is shown in Fig.2.

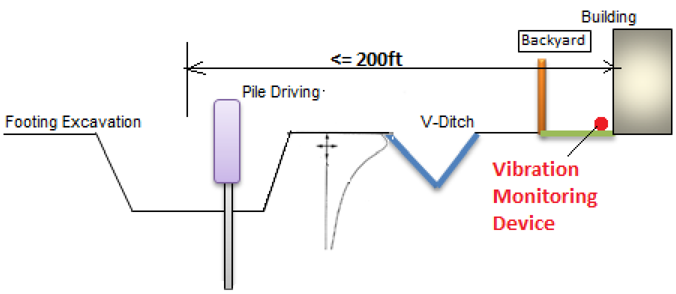

Fig. 2. Typical site cross section through the 200ft

Monitors were installed within 3 ft of the building if the homeowners allowed entry to their backyards. Otherwise they were installed within 3 ft of the southern fence of the property facing the pile driving location.

Fig. 3. Monitor installations in the backyard of a building

At first 37 piles were driven from the northern row and working towards the south side of the footing. Vibration results summary for one day at each monitoring location with maximum PPVs for each one hour interval is shown in Table 2.

Table 2. Summary of recorded vibrations

I.D. No.	Location	Time	Maximum Peak Particle Velocity (IN/SEC)	Frequency
A	Building a	7 – 8	0.040	11
		8 – 9	0.040	12
		9 – 10	0.045	11
		10 – 11	0.035	11
		11 – 12	0.035	10
		12 – 13	0.060	7.9
		13 – 14	0.050	7.4
		14 – 15	0.045	8.4
		15 – 16	0.010	>100
B	Building b	7 – 8	0.070	N/A
		8 – 9	0.045	24
		9 – 10	0.045	26
		10 – 11	0.040	24
		11 – 12	0.035	11
		12 – 13	0.060	20
		13 – 14	0.045	7.8
		14 – 15	0.040	8
		15 – 16	0.005	>100
C	Building c	7 – 8	0.070	23
		8 – 9	0.100	<1.0
		9 – 10	0.070	17
		10 – 11	0.060	18
		11 – 12	0.030	18
		12 – 13	0.070	18
		13 – 14	0.025	4.9
		14 – 15	0.025	9.5

Raw data showing the PPVs recorded in Longitudinal, Transverse, and Vertical direction and their corresponding frequencies for each two minute interval are provided for each footing and Fig. 4 is showing one of them.

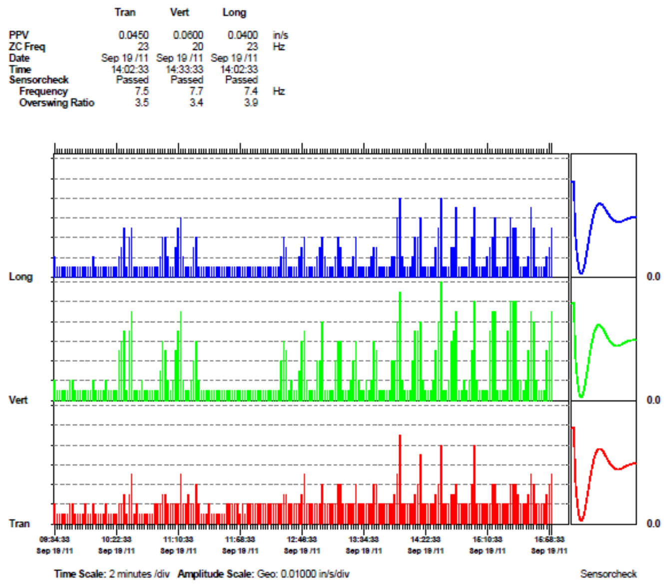

Fig. 4. Longitudinal, vertical, and transverse velocity histogram

CONCLUSION

Surface ground movements were measured in three directions (longitudinal, transverse, and vertical), and the vertical velocity was the maximum.

Effect of the V-ditch close to the backyard wall was reduced the soil movement by surface separation, and rays traveled longer distances to get to the sensors. So, V-ditch existence had a reduction effect on the ground motion.
The highest level of vibration recorded during a week of pile driving for different footings close to the residential buildings was 0.100 in/sec that was one third of the limit.
No damages were filled after pile driving operations.
Based on this study, if even there was no V-ditch the highest vibration level could not reach to the limit (0.30 in/sec).

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