

Assessment of Construction Vibration Impacts on Historic Structures

Chetlur G. Balachandran*

Parsons Brinckerhoff Inc. One Penn Plaza, New York 10119, U.S.A.

Abstract: This paper presents the results of preliminary assessment to determine potential construction vibration impacts to historic structures in the project area where three options are being considered for improvements to an existing roadway. The potentially affected historic structures were identified by Cultural Resource Specialists. The historic structures are more likely to be affected by temporary construction-related ground vibration impacts than by traffic-generated operational vibration impacts. The roadway alternative that would cause the least vibration impact was selected. Where required mitigation was considered.

INTRODUCTION

It is not common that the choice of a roadway alternative is strongly influenced by effects of construction ground-vibration on nearby fragile historic structures. This study addresses the potential construction vibration impacts to historic properties in the area of three alternative currently being considered for improvements to an existing roadway. The study utilizes the available conceptual designs and construction-related information. Once an alternative is selected and engineering plans and other in-depth studies are prepared, a more detailed vibration study would be conducted if it appears that the preferred alternative could have vibration impacts to historic properties. This future study also could recommend specific measures to minimize or avoid vibration impacts. The four historic structures which were identified within the project's area of potential impacts are 1) a Historic Fort, 2) a Legislature Building, 3) an Electrical Substation, and 4) an Auxiliary Building (in the Legislature Complex).

CONSTRUCTION VIBRATION

In the present study, identified historic structures in the project area are more likely to be affected by temporary construction-related ground vibration impacts than by traffic-generated operational vibration impacts. Traffic-generated vibration impacts are not a factor because the historic buildings that are in close proximity to an existing road are already experiencing moderate levels of ground vibration from cars and heavy trucks traveling on that road, and the levels are expected to remain at the same levels following construction. Therefore, the present study focuses on construction-period vibration impacts on the sensitive historic structures in the project area. The particular concern is to comply with ground-vibration criteria to safeguard fragile historic structures within the project area against construction-induced ground vibrations. The potential for annoyance from ground vibration to occupants of these buildings are also briefly discussed.

SOURCES OF CONSTRUCTION VIBRATION

There are three types of vibrations from roadway construction equipment 1) transient or impact vibration; 2) steady-state or continuous vibration; and 3) pseudo-steady-state vibrations.

Examples of transient or impact vibrations include those that occur from blasting with explosives, impact pile driving, demolition, and wrecking balls.

Steady-state or continuous vibrations include those generated by vibratory pile drivers, by large pumps that are used in jacking underground pipes, and by compressors.

Pseudo-steady-state vibrations are of a random nature or consist of series of impact vibrations at short enough intervals to approach essentially a steady state condition. Examples of these include jackhammers, pavement breakers, trucks, bulldozers, cranes, and scrapers.

GROUND-VIBRATION CRITERIA FOR POTENTIAL COSMETIC AND STRUCTURAL DAMAGE TO HISTORIC STRUCTURES

Potential vibration effects caused by heavy construction equipment that could be used during construction of all three roadway options include annoyance to people working in these areas or visiting these areas and minor damage to historic structures. Below is a discussion of criteria that were used to measure vibration impacts.

ANNOYANCE CRITERIA:

Annoyance to people from construction vibration would depend on the magnitude of vibration as well on the type of human activity involved. Vibration produced during construction operations become of concern when it can be felt. The criteria use in determining annoyance depend on the building use as well as time of day. Conservative design criteria that can be used for assessing human sensitivity during construction are those that have been developed by the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI). Based on these criteria a constant value of peak particle velocity in a limited range of low frequency vibrations can be used to describe the annoyance caused by ground vibration in buildings. Based on these considerations, the construction -vibration annoyance criteria applicable to the historic fort which is frequented by visitors during the daytime is a maximum peak vibration velocity of 0.25 mm/sec and that for the legislature building is a peak vibration velocity of 0.5 mm/sec.

DAMAGE RISK CRITERIA:

Extensive studies by the U.S.Bureau of mines suggest that a peak vibration velocity of 50 mm/sec should not be exceeded if major structural damage is to be prevented. The U.S.Bureau of Mine criterion for minor damage to non-historic and residential and office buildings is a peak vibration velocity of 5 mm/sec or less. This criterion is far below the threshold of risk of major structural damage, but it makes allowance for buildings of all types and for the triggering effect of vibration on stress concentrations that may already be present in nearby affected buildings. Adoption of more stringent vibration damage risk criteria is appropriate for fragile historic buildings.

CONSTRUCTION VIBRATION CRITERION:

For this project, a peak particle velocity of 3 mm/sec, based on the Swiss Standard (SN 640312) was recommended as a minor damage criterion. This level is intended to prevent minor architectural damage as well as structural damage. Though this level is somewhat conservative, it was recommended as the design criterion because ground vibrations are highly dependent on operational and site specific parameters.

VIBRATION IMPACT ASSESSMENT:

The approach used for the preliminary vibration assessment was to screen typical construction equipment and construction activity and to identify that equipment or activity that would likely equal or exceed impact criteria levels at each of the four historic structures, for both annoyance and minor damage. The minor damage assessment took precedence over the annoyance assessment in terms of assessing the overall impact for each option and in determining which option would have the least impact on the historic structures. The construction vibration impacts for each option was determined in greater detail. Based on the preliminary analysis, one of the three alternatives was selected. This option proposed construction of a four-lane roadway on harbor fill around the edge of the peninsula and construction of two new lanes on fill along the existing road. Under this alternative, the only structure that would be affected under the minor damage criteria is the auxiliary building in the Legislature Building Complex. Annoyance is not a consideration at the Auxiliary Building because it is an unoccupied service building.

MITIGATION

The following general mitigation measures were recommended: 1) preconstruction survey and structural integrity inspection at the potentially affected historic buildings, 2) mitigation of vibration from sheet piling operations by employing jetting water ahead of the sheet piles and construction vibration monitoring at the sensitive buildings, 3) inclusion of construction vibration specifications as part of the construction contract documents: e.g. "The contractor shall not exceed the construction vibration criterion of 3 mm/sec peak ground-vibration velocity, at the historic structures, within the established critical distance for each construction activity. If at any time the ground vibration level exceeds the specified criterion of 3 mm/sec due to any construction activity, then the construction operation shall stop. Construction shall not recommence until the source of vibration is determined and replaced by an alternative construction technique or equipment".