NUMERICAL TREATMENT OF MOVING LOADS AFFECTING THE STABILITY OF NSLS II LIGHT SOURCE ACCELERATOR*

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Abstract

Cultural noise generated within or in the proximity of a light source facility aiming to achieve stability levels of a few nanometers in the electron beam and extremely small photon beams in special experimental lines could be a limiting factor towards achieving the performance goals. While operating systems within the facility are more readily identifiable as sources of vibration and cause of instabilities, and they tend to be of deterministic nature so appropriate action can be taken to minimize their impact, moving-type loads such as traffic in the general vicinity or within the bounds of the accelerator facility are more of a stochastic nature and require a different approach in assessing their impact on the synchrotron facility. In this study the effect of such loads, which contain both stochastic elements and a complex spectrum, on the stability performance goals of the NSLS II synchrotron and its vibration-sensitive experimental lines is addressed. This is achieved through the synergy of a comprehensive numerical model and an array of recorded field data.

INTRODUCTION

The ground motion at any site hosting light source facilities extremely sensitive to vibration is the result of natural and cultural (man-made) activities that arrive at the site through wave propagation. Dominant part of the cultural vibration is the traffic-borne vibration from near-by highways or even roads near or within the facility. While the way traffic-borne vibration is generated is similar in all sites, it is the propagation path which is influenced by the substrate and attenuation characteristics at each particular site that make quantitative difference. Experience from numerous studies at different sites around the world it has been assessed that traffic-borne vibration dominates the ground motion spectra between 10-30 Hz. Fig. 1 depicts power spectra of ground motion recorded at different sites by comparing surface vibration with that at depth. The records indicate that vibration at the surface, and in particular over the frequency range associated with traffic, attenuates significantly with depth. Fig.2 compares ground motion frequency spectra at three light source sites (NSLS II, APS and Spring-8). The spectra at the APS and NSLS II sites are very similar while for the Spring-8 site the traffic-induced ground vibration is completely absent. This is one of the reasons why the rms ground displacement at Spring-8 is of the order of 2 nm at the surface and between 2-100 Hz. Point of interest in Fig.2 is the spectral peak ~ 9Hz which is attributed to the "wave-guide" role of the top soil layer at the NSLS II site.

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With the NSLS II, a 3rd generation light source requiring extreme stability both for the lattice and the experimental lines, cultural noise induced by unavoidable moving loads within the accelerator facility or in the vicinity is being addressed. The objective is to understand the impact of these loads, even temporarily, on the stability of the machine and its experiments and implement design features, if necessary, that will minimize the effect.

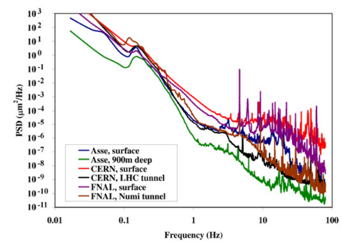

Figure 1: PSD at selected sites and depth effects [1].

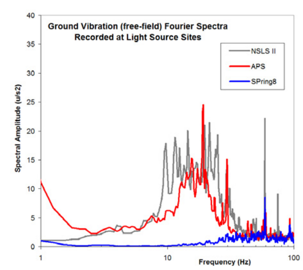

Figure 2: Ground motion spectra at light source sites.

The study focused on three types of moving loads that are common to all light source facilities namely large vehicles moving in access ways/roads around the perimeter of the facility, similar vehicles traveling over the pavement of the access tunnel which allows access to the inner-ring area and lastly service vehicles traveling on the access corridor situated at the outer edge of the experimental floor. To quantify the potential effects large scale numerical models reflecting the design features of the facility were generated. These were subjected to transient loads representing "conservative" scenarios in terms of speed, vehicle un-sprung mass, and road roughness.

Extensive previous work by the author (proprietary) associated with train passage in the vicinity of vibration-sensitive facilities has shown that large-scale numerical simulations can indeed lead to assessment of vibration that is in close agreement with actual measurements of passing loads both in terms of amplitude and spectral characteristics.

NSLS II TRAFFIC-BORNE VIBRATION

To assess the effect of moving loads either within or in the vicinity of NSLS II large-scale numerical models that captured the governing design features were employed. The numerical models were solved for the transient loads representing passing vehicles by utilizing the LS-DYNA solver. In addressing the effect sensitivity studies were performed to qualitatively assess the impact of structural design features that will impede the propagation of traffic-borne vibration.

One of the areas of interest in light sources, including NSLS II, is the potential for experiment disruption due to vibration from heavy service vehicles riding on the pavement of the access tunnel beneath the ring and the experimental floor (Fig. 3)

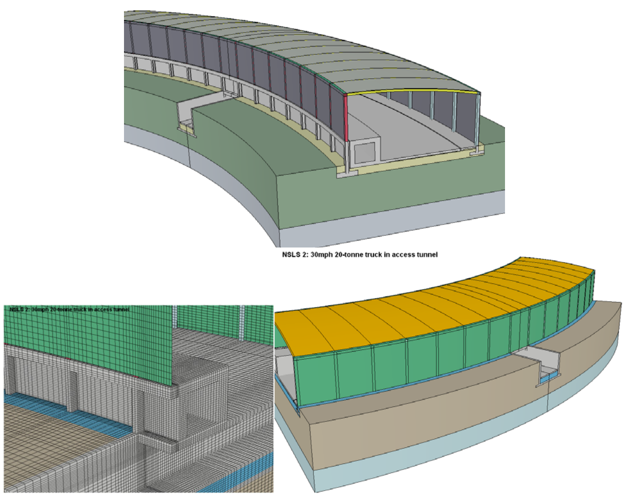

Figure 3: Modeling of NSLS II access tunnel.

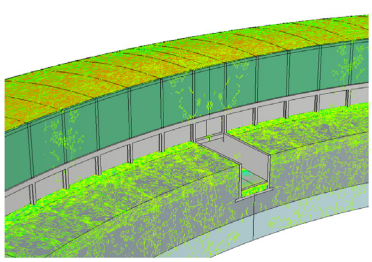

Figure 4: Vibration field generated by a 20-tonne, 20 MPH vehicle traversing the NSLS II access tunnel.

To help minimize the impact, the road pavement is decoupled from the structure (floating on engineered sand). A 20-tonne two-axle vehicle was simulated to traverse the pavement at 20 MPH. The transients were constructed around the un-sprung mass of the vehicle, the bouncing frequency of the sprung mass, the tyre treads and the road roughness (pavement seams) which were captured with a loading factor. Fig. 4 depicts acceleration fringes around the tunnel structure. The attenuation of spectra from the pavement to the ring is shown in Fig. 5.

Common to all light sources is the vibration generated by forklift vehicles traveling on the access corridor. The presence of an access tunnel raises more concerns for potentially increasing the vibration amplitudes further. In this study a forklift vehicle was simulated and analyzed (Fig. 6). Of interest, other than assessing potential amplification when traveling over the tunnel, was to evaluate the beneficial role of the isolation joint separating the edge of the experimental floor from the access corridor.

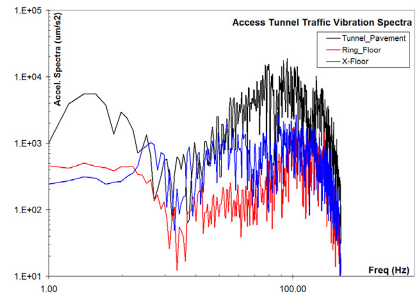

Figure 5: Comparison of acceleration spectra.

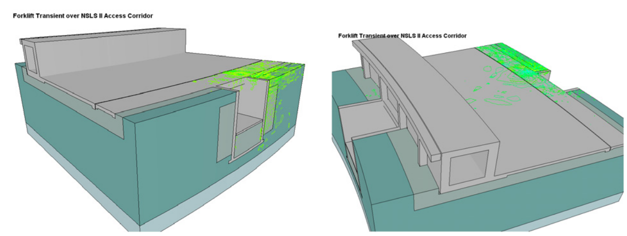

Figure 6: Numerical simulation of a loaded forklift vehicle traveling on the NSLS II access corridor.

Figures 7 and 8 depict the positive role of the design features such as the isolation joint in disrupting forklift-induced vibration and causing significant attenuation.

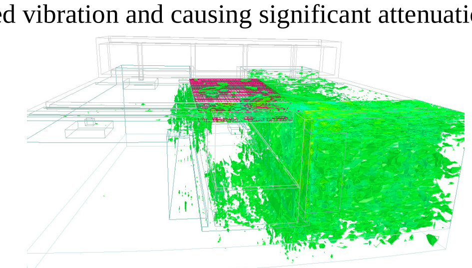

Figure 7: Interaction of forklift-induced ground vibration with the NSLS II access corridor structural features.

Traffic in the vicinity of a vibration-sensitive facility is a continuous concern especially for light sources seeking extreme stability. To assess the impact on NSLS II a model incorporating the ring/experimental floor structure with a near-by road (Fig. 9) was generated. Traffic was simulated on the pavement for a 20-tonne vehicle traveling at 30 MPH. The transient assumed for the two axles also shown in Fig. 9.

The numerical model was analyzed for the baseline loading as well as variations of the load transient (randomization based on speed, roughness, etc) that reflect uncertainty in the actual conditions. Fig. 10 depicts fringes of ground vibration emanating from the road traversed by the 20-tonne, two axle truck. To qualitatively assess the potential benefit from a trench running parallel to the road, analyses were performed. Fig. 11 represents the numerical model used in evaluating such effect. Comparison of ground vibration at a location between the trench and NSLS II is shown in Fig. 12.

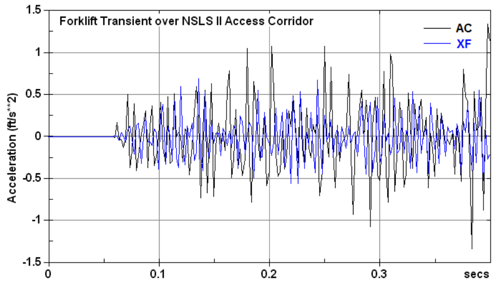

Figure 8: Effectiveness of isolation joint separating the NSLS II experimental floor from the access corridor.

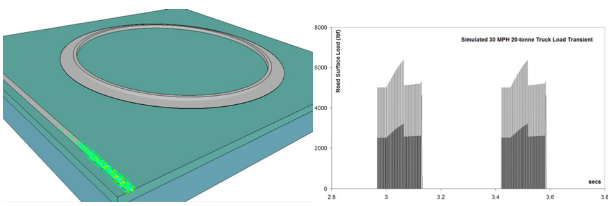

Figure 9: Numerical representation of site traffic-borne vibration at NSLS II and vehicle pavement dynamic load.

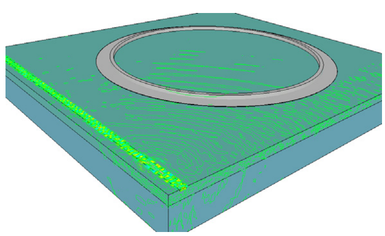

Figure 10: Traffic-borne vibration and NSLS II ring.

Field Studies on Moving Loads

In an attempt to benchmark the simulation model developed for moving loads and in particular multi-axle vehicles and adjust it to conditions representative of the NSLS II site conditions, a field test was recently conducted on the site. A series of ground acceleration measurements were made utilizing an array of ground vibration monitoring stations situated along a normal to a road pavement shown in Figs. 9. Preliminary processing of the recorded data and comparison with simulated data showed that there is general agreement between the two (Fig. 13) especially in the location of peaks in the frequency axis. Adjustment of the parameters in the simulation model that reflect the "exact" test conditions (vehicle un-sprung mass, speed, road roughness, etc.) as well as damping characteristics of the site for this type of loading is currently under way.

SUMMARY

The effect of moving loads on the stability of NSLS II light source has been studied using large-scale numerical models for transient simulation and wave propagation and explicit finite element analysis solvers. Structural features that tend to influence the resulting vibration on the experimental floor of the facility have been analyzed. In an effort to benchmark the developed models, field tests on the NSLS II site have also been performed.

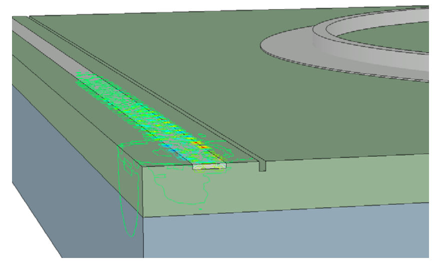

Figure 11: Simulation of traffic-borne vibration including the effect of a trench disrupting propagation.

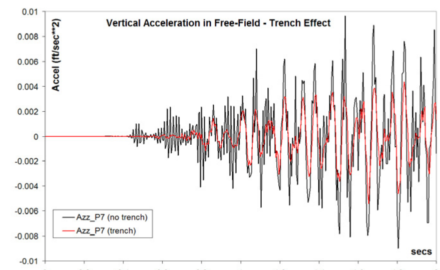

Figure 12: Simulation-based assessment of trench effect.

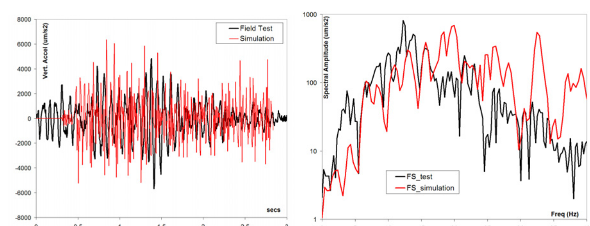

Figure 13: Field and simulated ground acceleration and spectra from a passing 20-tonne truck.

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