Vibration control in a tunnel under an office rehabilitation project

Marc Asselineau[1], Stéphane Mercier[1]
[1] *Peutz & Associés, F-75010 Paris, France, Email: peutz@club-internet.fr*

Introduction

During the preparatory work for the Universal 1900 exposition, the line between the Paris railway stations of Austerlitz and Orsay was rerouted into a tunnel under the administrative building of the station (actually two single track tunnels under the building). In those days nobody really cared for vibrations transmitted from the tunnel to the structure of the nearby buildings, and due to the time factor the loading gauge and the radius of the curves were kept to the minimum allowing the third rail vehicles of that time to run through.

Over the years the line was modernized, with overhead replacing the third rail and more modern rolling stock taking over. However it was not possible to increase the loading gauge or to broaden the curves (Figure 1). With the opening of the rail connection between Orsay and Invalides this former branchline was eventually turned into a major part of the Paris express rail network, with a train running every 2 mn on each track at peak hour.

Figure 1: The tunnel before rehabilitation; note the reduced loading gauge and the structural connections of the track to the tunnel walls.

A century latter, the former administrative building is being turned into a high class office rental project, and the structure borne noise from trains has turned from synonym of wealth to nuisance. Due to the fact that part of the building is preserved it was not deemed possible to implement vibration control measures on the building. Therefore vibration control had to be implemented under the track. This led to some interesting testing in the tunnel, especially as the safe access was restricted in time (typically from 02:00 to 04:00) and more to the point there was not much available space to store and secure any apparatus in such cramped spaces.

Preliminary diagnosis

Prior to the design of the project vibration measurements were taken on the floors and walls of the existing building structure, together with noise measurements in the offices; in addition vibration measurements were also taken on the structure of the tunnel. It turned out that on a 15 s time span (corresponding to the run through of a train) the velocity levels could reach an average 87 dB in the building and even a stunning 99 dB on the ground floor right above the tunnel, with 62 dB(A) in an average office above the tunnel; meanwhile the velocity levels could reach 120 dB in the tunnel.

Figure 2: Entrance to the tunnel under the building; note the concrete structure in the background.

Right out of the tunnel by the administrative building the track was rigidly laid on a concrete structure structurally connected to the tunnel (Figure 2). It was found out that vibratory energy was transmitted from this zone too.

Close examination of the building lead to the discovery that the ground floor over the tunnel was rather thin. More to the point close examination of the track work showed that the ballast was rather thin; it was explained this was because of the requested height clearance for the overhead. In addition it was found out that quite a number of sleepers were abnormally long and rigidly connected to the wall structure of the tunnel, with all sleepers being broader and thicker than usual; it was explained by the track gang that due to the restricted loading gauge all those sleepers were of the type normally used under point work. More to the point the western lower tip of those sleepers was grinded away in order to accommodate the irregular ground (Figure 3). As for the rigid connections to the structure it was found out that due to the restricted clearance the track was not mechanically laid and in order to extend its operational life structural connections were added. More to the point, it was also found out that one of the track had been treated to a resilient mat in older times, however it had been ripped to shreds by an earlier mechanical tampering of the trackwork. At any rate no trace of mat between the ballast in the tunnel and the concrete structure outside was found.

Figure 3: Cross section of the trackwork showing the larger than usual ties thinned on one side.

Noise and vibration control measures

The restricted loading gauge in this old tunnel prevented the use of a floating slab due to the excessive height of such a construction scheme. In addition the very peculiar geometry of the tunnel, with its ground being lower on one side than the other, called for custom tailored vibration control measures.

Basically, the vibration control measures called for a resilient mat under and on each side of the ballast, with careful consideration being given to the overall thickness as it could eventually foul the loading gauge. In addition, the ground floor of the building over the tunnel was rebuilt using a thick concrete slab.

Advantage was taken of a summer break in the operation of the line due to heavy track renewal further down the line. Over two shifts of two weeks, one for each track, the old track and ballast were removed, and then the ground was carefully scrapped so as to erode any protrusion. Resilient mats by Angst+Pfister (Sylomer 25B) were then glued in position (Figure 4), with particular care to ensure that the junctions between mats were tight enough to prevent the intrusion of ballast material. A first layer of ballast was then spread over the mats in order help stabilize it, and the top of the mat was then glued and protected using a metal inverted L profile. The track was then laid ; this time no rigid connections to the walls of the tunnel were allowed but in order to help stabilize the trackwork a steel paddle was added at the tip of some of the sleepers. Prior to adding more ballast, the clearance between the bottom of the paddle and the mat was carefully checked. After completion of the ballast a careful examination was performed in order to spot any zone were ballast might have been spread over the top of the mats, with any excess carefully removed. The ballast was then manually compacted.

Figure 4: The resilient mat by Sylomer glued to the floor and lower walls of the tunnel.

Meanwhile the original rail fasteners on the concrete portion out of the tunnel were removed and replaced by resilient fasteners by Pandrol. Care had of course been taken to ensure that the ballast mat from the tunnel was laid along the edge of the concrete structure so as to prevent vibration transmissions at this end.

Commissioning measurements

After completion of the project measurements were taken on the floors and walls of the building structure, together with noise measurements in the offices; in addition vibration measurements were also taken on the structure of the tunnel. It turned out that on a 15 s time span (corresponding to the run through of a train) the velocity levels would not exceed an average 75 dB in the building and 81 dB on the ground floor right above the tunnel, with 40 dB(A) in an average office above the tunnel; meanwhile the velocity levels did not exceed 105 dB in the tunnel.

Conclusions

Numerous constraints (historical classification of the building façades, available time span to perform the civil engineering and track work, as well as structural considerations) prevented the usual somewhat heavy approach of decoupling the structure of the building from its foundations, or even to use a floating slab under the track. In addition the measurements were rather complicated to perform due to the heavy traffic on the line and the busy environment.

All considered this turned out to be a rather interesting project with regards to the custom tailored solutions that were needed. Without reaching the hoped for levels, results were nevertheless rather satisfactory. This proves that a very vigilant supervision must be exercised at every step of the project to ensure the optimal result.