High speed lines on soft ground: dynamic soil-track interaction and ground borne vibrations

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The seminar was organised by the Swedish Rail Administration (Banverket), and the chosen venue was not far away from the site where strong dynamic effects and intensive ground vibrations from high-speed trains had been first observed in 1997-98 (for details see the article by the present author Ground vibration boom from high-speed trains prediction and reality, Acoustics Bulletin, 23 (4), 15-22 (1998)). The aim of the seminar, which has attracted about 50 participants from 10 European countries, USA and Japan, was to discuss new problems in the field of railway-generated vibrations occurring when train speeds approach and exceed certain critical velocities of track and ground. For railways built on soft soil these critical velocities may be especially low (40-50 m/s). Therefore, the associated dynamic effects can be observed for train speeds of only 160-180 km/h.

The culmination of the seminar was the visit of all the participants to the site where strong track and ground vibrations had first been observed (Ledsrgard, 25 km south of Gothenburg). A temporary speed limit of 140 km/h has been recently imposed on this part of the line to avoid undesirable speed-related dynamic effects. This has been done following the series of recent investigations conducted by the Banverket in collaboration with several Scandinavian Institutions (Chalmers University of Technology, Royal Institute of Technology, Swedish and Norwegian Geotechnical Institutes). However, in spite of this speed limitation, two test runs of the Swedish high-speed train X2000 at a speed of 200 km/h were specially arranged by the Banverket to demonstrate the phenomenon to all the participants of the seminar. Since conventional commuter trains continued to travel on this part of the line at speed of 140 km/h it was possible for everyone to make a direct comparison of ground vibrations from the 'low speed' commuter trains, which were just about normal, with those associated with high-speed train X2000 running at a speed of 200 km/h, ie satisfying the condition of ground vibration boom.

When the first run of the train X2000 took place in the direction to the South of Gothenburg, most of the participants were standing near the embankment. During the train passage, very strong ground vibrations could be felt through the legs. Apart from this, one could see high amplitude bending vibrations of the masts carrying electric wires above the tracks. Such very strong electric mast vibrations may result in the interruption of electric power supply to the electric engines of a locomotive. This is why they represent one of the major concerns for railway companies. Another major problem is very large rail deflections which may cause premature wear of the rails and even train derailment.

During the second run of the high-speed train, which was performed by the same train returning to Gothenburg, some of the participants, including the author of these notes, were standing on the open flat field covered by grass at distances 15-20 m from the track. A very strong sensation of ground vibrations was present there as well. Moreover, it was even possible to see the Rayleigh surface waves in the grass-covered ground. As expected, the waves were propagating at a certain speed-dependent angle relative to the train. This was certainly an unforgettable and unique experience!

According to the members of Swedish and Norwegian research teams, who had these propagating Rayleigh surface waves video-recorded, the displacement amplitudes of the associated ground vibrations at ground vibration boom are very large – around 20 mm, with particle velocity of 80 mm/s. Comparison of these values with the level of 10 mm/s, considered in many vibration related standards as the level causing structural damage, demonstrates that no building could withstand vibrations like these for a long time. Fortunately, the nearest buildings in Ledsrgard are at distances of about 200-300 m from the track, so that ground vibrations might reach them very attenuated.

Among the presentations given in the seminar a significant part was dedicated to studying the particular case of Ledsrgard ground vibrations which represents the worst case from the point of view of hazardous dynamic
Several presentations gave an insight into the theory of the phenomena which is now fast progressing. This included the role of surface Rayleigh wave velocity in the ground, contributions of bending waves propagating along the track, speed resonance effects and amplification of vibrations, effect of layered geological structure of the ground, etc.

The rest of the talks described the results of measurements undertaken outside Scandinavia. In particular, the effects identical to those observed in Sweden were reported from Holland, Switzerland and Japan. All these clearly indicate that, with the general trend of increase in operating train speeds, the problems discussed in the seminar will appear sooner or later in many countries in Europe, Asia and North America. It has been recognised that international co-ordination of efforts is needed to tackle the problem.

The first example of such co-operation is now under way between the Scandinavian countries Sweden, Norway and Finland. The next step apparently will be European co-operation in the framework of one of the EC programmes.

Victor V Krylov FIOA

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