

## Appendix A9.5

### **Noise and Vibration from Underground Construction**



## Introduction

- A9.5.1. Construction of new tunnels and passages for the BSCU will use a technique called sprayed concrete lining (SCL) to encase and so form a permanent structural support for excavated spaces. There will be occasions when SCL will also be required to form temporary support; this will need to be broken out before excavation can recommence, by which time the concrete will have set.
- A9.5.2. The techniques usually employed for breaking out SCL can generate vibration that, when transmitted through the ground to the surface, may be emitted as audible sound within overlying buildings. This sound, called groundborne noise (GBN), will typically be a low frequency hum or rumble. Above certain levels GBN can give rise to significant effects for people in these buildings. There are a number of options for mitigating these effects which are described here. The developer will ensure that one or a combination of these options are used on BSCU so that, wherever practicable, significant effects are avoided.

## Sprayed concrete lining

- A9.5.3. Tunnel lining techniques rely either on use of SCL or on installation of segments (made of iron or of precast concrete). BSCU opted to use SCL given the relatively small amount of tunnelling required and the consequent lower set-up and other costs of this technique compared with segmental lining. SCL also has the advantage that it results in less settlement and it is therefore preferable for use in an area beneath buildings of heritage interest.
- A9.5.4. The tunnels, cross-passages and adits on BSCU will use a triple layer system of a sprayed concrete outer lining, a sprayed waterproofing membrane, and a sprayed concrete inner lining with a steel float finish. The sprayed concrete comprises a steel fibre reinforced material and contains chemical accelerants to ensure that it sets as quickly as possible.
- A9.5.5. SCL will also be used for temporary structural support of headwalls that maintains tunnel form and prevents settlement. This will be required where excavation is temporarily halted while other works are undertaken (such as structural works to building foundations) or where a change of tunnelling direction is required. The tunnelling engineers have highlighted all of the areas where SCL will need to be removed. As well as removal of temporary headwalls, this also includes excavation of new cross passages through 'permanent' tunnel lining, and removal of foam concrete at the points the new tunnels and shafts link with the existing tunnels and shafts.
- A9.5.6. Because SCL is required to set quickly, its removal after even relatively short periods can require heavy machinery.

## **SCL breakout and GBN**

- A9.5.7. GBN effects from construction will depend on the source of vibration (essentially the SCL breakout technique to be used), the duration of works generating the vibration, the transmission medium (essentially, whether there are piles or not) and the occupancy characteristics in the overlying buildings (what are they used for and at what times).
- A9.5.8. There are no nationally recommended criteria (for example, within British Standards or industry guidance) for GBN from underground construction works.
- A9.5.9. The City of London's Noise Strategy states that noise levels within businesses during noisy periods must enable workers to carry out conversations, both face-to-face and on the telephone, and allow normal business to be conducted. It is considered that an internal noise level of 65 dBA or above is likely to cause annoyance and interference (dependent on the noise characteristics). Such noise should be restricted to hours outside the normal working day of 09.00 – 17.00. Timings of works with noise levels exceeding 65 dBA should be discussed and agreed with Environmental Health Officers prior to commencing.
- A9.5.10. For offices, criteria for operational GBN (from passing trains) have been outlined by the British Council of Offices, which sets levels of operational groundborne noise at 45 dB  $L_{ASmax}$ . However, it is considered that levels above these would be acceptable for construction given their short-lived nature. The City of London Corporation have suggested as much for airborne construction noise, where they state that levels 10 dB over operational thresholds can be acceptable.
- A9.5.11. Based on the above, 55 dB  $L_{ASmax}$  is regarded as an appropriate threshold for the BSCU. The exception to this is the 'quiet hours' defined in the City of London Corporation's Noise Strategy as 10.00-12.00 and 14.00-16.00 (Monday to Friday) where noise disturbance to businesses should be restricted. During these periods, 45 dB  $L_{ASmax}$  is regarded as an appropriate level.

## **SCL breakout techniques and associated noise levels**

- A9.5.12. The removal of the temporary tunnel face, which is sprayed on a daily basis and removed less than 24 hours after spraying, is primarily carried out using the bucket of an excavator. Other techniques include use of roadheaders, which are machines developed for the mining industry that use large rotating mill heads to scour rock faces (or in this case, concrete).
- A9.5.13. Experience on other tunnelling projects such as Crossrail shows that breakout of temporary tunnel face is unlikely to create noise levels within buildings above 45 dB  $L_{ASmax}$ .

- A9.5.14. Where the SCL is to be constructed using a pilot tunnel, which is where a smaller diameter tunnel is initially constructed and then enlarged to the full tunnel diameter, the lining of the pilot SCL requires removal as the tunnel is enlarged to its full internal diameter. In this situation, the use of a pulverizer (muncher) allows the SCL to be broken out as the main tunnel progresses. As with breakout of the temporary tunnel face, the removal of pilot SCL with a pulverizer is unlikely to create noise levels within buildings above 45 dB  $L_{ASmax}$ .
- A9.5.15. Where the SCL to be removed has hardened further, such as due to a planned stop of the tunnelling works, such as for extended breaks in construction works, or a change in tunnelling direction, the breakout requirements are more intensive. The quickest and easiest breakout technique involves percussive breakers or peckers to mechanically chip away at the concrete. However, this creates vibration, which, depending on its location, can generate GBN. Building piles especially can transmit the vibration up to overlying buildings. The same breakout requirements apply to the breakout for new structures and for foamed concrete removal.
- A9.5.16. The noise predictions carried out for SCL works indicate that generally, the use of percussive breakers is likely to create noise levels in the order of 45 dB  $L_{ASmax}$  which is 10 dB below the 55 dB for periods outside the Corporation's quiet hours, but on the threshold for these quiet periods. However, where there is connectivity between the tunnel and overlying buildings as a result of a pile interception, the noise level could be in the order of 57 dB  $L_{ASmax}$ . The buildings currently identified as having piles intercepted by the new tunnels are 6-8 Prince's Street, 8-10 Mansion House Place, New Court St Swithin's Lane and 33 King William Street. In these situations, quieter breakout techniques could be required.

### **GBN mitigation options**

- A9.5.17. Wherever SCL breakout is required and a risk of significant GBN effects is anticipated (i.e. an exceedence of the 55 dB/45 dB noise thresholds), the most appropriate solution will be defined to ensure, as far as practicable, that significant effects are avoided. In coming to this solution, the following will be considered:

- Avoidance or minimisation of SCL breakout – seek to avoid the need for SCL breakout through consideration of the tunnelling process and working programme to ensure that the number of planned stops is minimised while ensuring safe tunnel construction works.
- Careful profile control during the SCL construction to reduce the likelihood for unnecessarily thick sidewalls to be broken out for new pilot tunnels.
- Adoption of quieter alternative working methods for SCL breakout, using low vibration techniques, as described above.
- Defined working hours. Although tunnelling is generally a 24-hour operation, it may be possible to undertake SCL breakout works outside of the most sensitive hours of operation of overlying/nearby businesses (which could include Quiet Hours).

A9.5.18. Although percussive breakout may be the most efficient breakout method it is accepted that there are quieter techniques that could potentially be employed in certain circumstances should that be necessary. However, such alternatives have their own pros and cons which will need to be fully considered before they are utilised. These principally include health and safety, efficiency and cost.