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Environmental Considerations for Highway Tunnels

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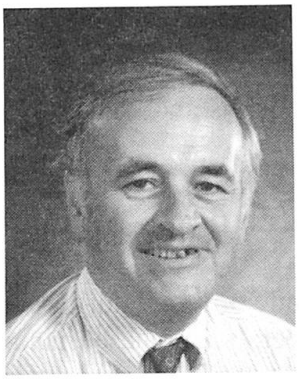

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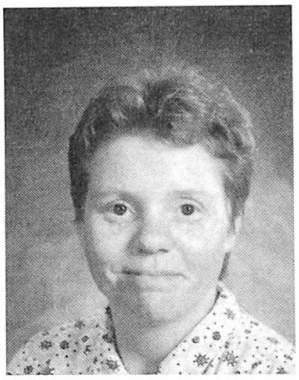

Summary

Road tunnels may be constructed in order to control environmental problems that an open road would otherwise produce. Nevertheless, there are many environmental effects generated by the construction, use and decommissioning of highway tunnels, and not all of these are beneficial. Major impacts are identified and discussed briefly. Where appropriate, predictive methods are outlined.

1. Introduction

Tunnels are increasingly perceived as a means of reducing adverse environmental impacts of roads, in both urban and rural situations. Although tunnels do have major beneficial effects when compared to open roads, there are also environmental problems specific to tunnels. Possible environmental consequences of constructing, operating and, ultimately, decommissioning tunnels are discussed.

One major problem is that almost anything can be considered as "environment", and it is difficult to know where to "draw the line". Objectors to road schemes are becoming ever more diligent, so that it is best to consider more environmental impacts rather than less in an Environmental Statement (ES) in order to anticipate as many objections as possible. In any case, it is good practice to identify all potentially significant environmental problems. The ES for any tunnel scheme will need to address the local situation. Thus, environmental considerations will be significantly different for an urban tunnel than for a tunnel in a rural location. **It must be emphasised that tunnels may be built solely for environmental reasons, so by no means all impacts are adverse**.

The purpose of this paper is to draw attention to possible environmental issues surrounding the construction, operation and decommissioning of highway tunnels. It is not intended to provide a complete list of all possible environmental impacts due to tunnels, but rather to provide a

starting point for environmental assessment exercises. Some environmental effects have been the subject of recent research, and are well understood, in particular tunnel construction induced ground movements and vibration and the consequent effects on nearby buildings. There is some understanding of noise in the vicinity of the portals of operational tunnels, but the prediction methods require further development and validation. Much the same is true of the dispersion of airborne pollution. Assessment of the effects on the general community, on natural habitats and the flora and fauna, are less amenable to general civil engineering expertise, and will require specialised knowledge. It is suggested that for major tunnel projects, consideration should be given to appointing an independent environmental assessor who will continuously monitor all environmental effects during construction.

A fuller version of this paper may be found in Andrews and Cloke (1998).

2. Environmental considerations during the life of a tunnel

The environmental effects of a tunnel are significantly different during the major parts of the life of the tunnel, namely the construction phase, the operational phase (including maintenance), and the final decommissioning, or abandonment, of the tunnel, but some effects will be common to more than one era.

2.1 Construction

Many tunnel construction activities are common to any major surface construction; for example plant operation and heavy goods vehicle movements. This paper identifies activities peculiar to tunnel construction. Construction techniques for cut and cover tunnels are not dissimilar to those for retained cuttings, but nevertheless, cut and cover tunnels do have environmental impacts distinct from bored tunnels.

The following impacts might arise during tunnel construction.

a) Vibrations from subterranean construction activities, including tunnel boring machine or roadheader operations, installation of dowels and rock bolts, and blasting may cause nuisance or damage to nearby structures, including buildings and other infrastructure. In cases where vibration is thought likely to be a problem, careful selection of construction methods and the plant used might be sufficient to reduce the effects to acceptable levels. Where use of explosives is likely, trial measurements of site specific vibration transmission characteristics will provide data which can be used to determine explosion sequences and weights so that vibration levels do not exceed required limits.

b) Work inside tunnels normally requires forced ventilation and airborne pollution generated by plant and other operations may require careful treatment, as it will be released only at particular locations on the construction site. In exceptional circumstances, contaminated air will require cleaning before release. Some construction techniques release large quantities of dust or similar contaminants, notably sprayed concrete which has rebounded during New Austrian Tunnelling Method (NATM) construction.

c) Ground settlement may cause damage to nearby structures, buildings and services if not controlled. In the worst cases buildings may require demolition. In less extreme cases, they may need to be temporarily evacuated in order to effect repairs or to remove occupants from

potential danger, and this could result in considerable costs, particularly if they are business premises. There exist well established, empirically based methods for predicting settlement induced by tunnel construction, especially in soft ground. Methods appropriate to individual structures, which may include nearby buildings and buried services, can then be used to predict damage levels. Ground movement problems can be reduced, or eliminated totally, by, for example, careful routing of the tunnels (including lowering them), employing construction techniques which minimise ground loss, or by the use of compensation grouting.

d) Lowering of groundwater levels may occur either because tunnel excavation opens up new drainage routes or because of dewatering activities during tunnel construction. This could have an indirect impact on surface water features and groundwater abstractions. Ecological effects could be permanent, particularly if the groundwater level remains low for a long period of time.

e) Contamination of surface waters and aquifers might occur due to the spillage of construction materials or wastes either within or outside the tunnel. This could have an indirect impact on aquatic ecology and water abstractions. A particular concern arises from the use of shotcrete in NATM tunnels because some concrete accelerators are very alkaline.

f) Compressed air working may force in-tunnel contaminants into the surrounding ground and aquifers. A particular concern occurs where a bentonite shield method is employed for spoil removal purposes. There is opportunity for contamination from both above ground and below ground activities. Air leaking from the tunnel may also disturb the bed of any overlying water feature, potentially leading to contamination of the aquatic environment. There have been unattributable reports of linoleum floor covering being disturbed in an old dwelling above a compressed air working.

g) Health and safety impacts of working in and below, potentially contaminated land must be considered. National and local legislation will determine precise details which must be observed.

h) There will be legal implications for the re-use of clean excavated material and the disposal requirements for potentially contaminated spoil. Again, national and local legislation must be observed.

i) The effects of temporary loss of land and habitat to provide work sites and access, including cut and cover construction, and immersed tube fabrication yards will require assessment. On completion of construction, there may be opportunities to return work sites to their original condition, or to develop or otherwise improve them. A good example is the immersed tube fabrication yard at Conwy in North Wales, which was used as the basis for an attractive new estuarine marina.

j) A beneficial impact of the scheme may be the (temporary) exposure of the geological resource of the area providing an opportunity for study or exploitation.

k) Abnormal occurrences, such as fire or explosion during construction could affect areas outside the tunnel. For example, toxic smoke could be released at portals and invade the neighbourhood. A major collapse during construction (eg Heathrow, Münich) could expose nearby environmental entities to risk.

2.2 Operation

During the operation of a road tunnel the following impacts may become environmentally significant.

a) Elevated air pollutant concentrations will be found within the tunnel and near the portals due to vehicle emissions within the tunnel. Acceptable in-tunnel levels will generally be governed by short term exposure limits, determined by consideration of occupational health standards (and should include the effects on vulnerable members of the community), or other more subjective criteria. Ventilation is the main tool for controlling these levels. Outside the tunnel, limits set by national or local air quality standards regulations will apply. Various methods are available for predicting dispersion of vitiated air from tunnels, including simple Gaussian models, computational fluid dynamics models and wind tunnel scale models. All have some limitations. Recirculation between adjacent tunnel bores, or ventilation stacks and tunnel portals should be avoided, for this will raise pollution concentrations both within the tunnel and at the final exhaust point. In addition, there is a trend towards limits being placed on pollutant emissions from portals and exhaust stacks.

b) Noise and vibration will be generated by vehicle movements within the tunnel and at the portals. There is anecdotal evidence to suggest that noise and vibration from tunnel fan operation may also give rise to nuisance above shallow tunnels. The sudden increase in noise levels as vehicles emerge from the tunnel may heighten noise nuisance (impulsivity).

c) An assessment of the visual impact of above ground features such as portals, ventilation shafts/towers, and control buildings must be made.

d) Long-term settlement may continue at a reduced rate through the operation stage with impacts on nearby buildings and structures.

e) Groundwater flows may be disrupted or enhanced, which could have an indirect impact on water abstractions, surface water features and aquatic/wetland ecology. There exist commonly used methods for predicting underground water movements.

f) Contaminated water collected in tunnel sumps may contain pollutants and require treatment before release.

g) A road in tunnel may require less landtake, thus reducing the visual impact of a road scheme and reducing the loss of habitat and other amenities.

h) Existing community severance may be reduced or removed by routing a busy urban road in a tunnel.

i) Abnormal occurrences, such as fire, explosion or hazardous spill could affect areas outside the tunnel. For example, an accidental toxic gas release within the tunnel could lead to a toxic cloud emerging from a portal and invading the neighbourhood. On the other hand, accident rates are generally lower in highway tunnels than on the open road.

j) Maintenance, repair and remedial activities following commissioning of a tunnel may have environmental consequences similar to some of those associated with the construction phase, in particular noise from maintenance plant operating during a night time closure could

disturb the sleep of nearby inhabitants. It is not unknown for a collapse to occur during major maintenance activities.

k) Improved traffic flows in the road network arising from the use of tunnels, including small car-only tunnels at busy junctions, which is effectively grade separation, could lead to air quality improvements around the connecting road system.

2.3 Decommissioning

The environmental consequences of any activities required to close a tunnel will need to be assessed. Permanent tunnel closure is a rare event and there is little or no information available. The environmental assessment will necessarily be made on an ad hoc basis.

Once out of use, a tunnel may still have an environmental impact. If it collapses, then there could be damage to overlying structures. Water seeping into the tunnel will need to be removed, possibly by continuous pumping, to prevent flooding or contamination of groundwater. Parts of the tunnel could be invaded by vermin. On the other hand, it could be colonised by protected species, such as bats. If the tunnel is not secured, then rubbish might be dumped in or close to the tunnel giving rise to health and fire hazards. Thus a decommissioned tunnel will still require occasional inspection, and possibly ongoing maintenance for environmental reasons.

Alternatively, consideration may be given to backfilling the tunnel, a technique which has been adopted for disused mine workings. If the backfill material is inert, then the environmental impacts will be similar to those encountered during construction. However waste that is putrescible or hazardous will require special precautions and more detailed assessment.

3. Palliative measures

Good construction site practice, tunnel design and tunnel operation may be able to alleviate some of the environmental disbenefits. Reinstatement may be viable in some cases (eg Bell Common Tunnel), and re-development of the land above cut and cover tunnels in others (eg Hatfield Tunnel, Holmesdale Tunnel and Blackwall Tunnel at Greenwich in East London, above which the proposed Millennium Experience Dome will be constructed).

4. Discussion

a) It must be emphasised that locating roads in tunnels provides significant major environmental benefits, and these must be balanced against any adverse effects. Benefits include removing noise and airborne pollution from the areas through which the road passes, reducing severance, releasing land which would otherwise be lost to the road for development, amenity or natural habitats, improving traffic flows through the connecting highway network (with benefits of reduced pollution), reduction or elimination of visual impact, etc.

b) The scope of any ES will reflect the particular location of the tunnel. It should include as much as is reasonably possible, because more effects are becoming matters of legitimate environmental concern.

c) Some effects, such as ground settlement and the resulting damage to structures, are predictable with confidence. Others, such as construction vibration may be predicted, provided that preliminary measurements are taken on site. In general these effects can be reduced, or even completely eliminated, by good engineering practice, including, for example, compensation grouting, careful design and routing of the tunnel, and working only at acceptable times of the day.

d) Operational effects, particularly noise and airborne pollution, are in principle predictable. However, existing methods require some enhancement and verification before they can be applied to highway tunnels and their neighbourhoods satisfactorily. Some airborne pollution dispersion models are expensive to set up and use, especially wind tunnel scale models. Also there are some conceptual difficulties in extending their results to a full annual weather regime and to diurnal and seasonal traffic variations.

e) Drainage effects are essentially engineering considerations. Where consequences are expected to be environmentally sensitive, then a high quality site investigation will be helpful. Drainage effects may include water table draw down, which might be a temporary effect, and interference with underground water movement.

f) In areas where the ecology is likely to be an issue, a careful advance survey will be necessary and this could result in changes to the tunnel design and route, and to construction methods. Access to specialised knowledge will be essential, and may be an on-going requirement after the tunnel opens.

g) Evaluation of heritage and cultural impacts generally needs specialised expertise, which might be available from within the architectural community.

h) For major projects, consideration may be given to appointing an environmental arbitrator who is independent of the main interested parties (including the scheme promoters, designers, contractors, operators and environmental pressure groups), who is able to function on a full time basis, and who is answerable to all parties having a legitimate interest. Such an approach was successfully employed during the planning and construction of the Sydney Harbour Tunnel in Australia.

5. Acknowledgements

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6. Reference

Andrews RD & Cloke J (1998) *Environmental considerations for highway tunnels*. Transport Research Laboratory Report, to be published.