

## Road tunnel linings: Design for safety, comfort and aesthetics

*There is a growing concern as to the feeling of confidence and comfort while driving in tunnels. Another problem is the difficulty in evaluating the effect of tunnel design on driver behaviour and traffic safety. The Norwegian Public Roads Administration recently focussed these problems in an international symposium.*

In Norway, more than 800 road tunnels have been built to overcome communication problems in regions with mountains and fjords, as well as in urban areas. A large number of the tunnels are situated on roads with light traffic, and experience shows that it is possible to combine austerity in design with a high safety level in relation to surface roads.

Much effort has been made to develop simple and cost-efficient linings for water and frost protection of the tunnels. A

project "Road tunnel linings" has been established to provide a basis for codes, quality control, contracting and further development. One of the subprojects deals with lining design in relation to traffic safety, comfort and aesthetics.

However, there is growing concern in society regarding the feeling of confidence and comfort while driving in tunnels. This fact is especially true for recent projects including very long tunnels, and subsea tunnels with long slopes. Internationally, it is often difficult to "sell" the tunnel concept when planning road projects. To counteract this trend, architects, psychologists, artists and lighting consultants have been consulted to make tunnel designs more attractive.

Although there are many types of design for making tunnels more attractive, no common design principles or guidelines have so far been agreed upon. Another problem is the difficulty in evaluating the

effect the designs have on driver behaviour and traffic safety. As a consequence, the Norwegian Public Roads Administration decided to invite workers in this field to an international symposium to discuss the state of the art and a future approach to achieve improved and more commonly accepted guidelines.

### International symposium

A symposium was held in Oslo on 9-10 October with international experts from Japan, Spain, Sweden, the USA and Norway, who presented the latest ideas and research results. Participants from Denmark, Sweden and Norway, working specifically with installation design also attended, making a total of 35 participants.

Artists, architects, engineers and consultants on lighting presented ideas and design proposals in relation both to road tunnel projects and general artistic impressions from tunnels. Some of the presenta-



PHOTO: B&B ENRGE

*Short tunnel on the E18 near Kristiansand, demonstrating good visual control.*

tions were based on video recordings from simulators showing how drivers respond to the different designs. The two-day symposium closed with a panel discussion, where problems of pollution, cleaning and maintenance were also taken up.

### Road tunnel linings: Elements to be considered

The behaviour of drivers seems to be dependent on traffic volume, tunnel standard, and in particular, driving experience. Less than 5 percent of drivers avoid tunnels because of anxiety and claustrophobia. Most drivers slow down and move away from the tunnel wall towards the middle of the road when entering the tunnel. Once inside the tunnel, they increase speed and drive closer to the tunnel wall. The distance they keep is dependent on the level of lighting and the optical guidance indicated, for instance, by "cats' eyes". However, some nervous drivers slow down, while half the drivers (in Norway) drive faster than the speed limit. Attention to these findings is essential when designing tunnels with a view to safety and confidence.

The contributors were agreed on the general image problems of road tunnels. The psychological factors involved in driv-

ing through long tunnels were stated to be the sense of confinement, claustrophobia and fear of being trapped. A monotonous visual environment promotes a lack of concentration, orientation and connection with the surface. To counteract this image, the key points for the design of road tunnel linings were found to be:

- Signing
  - Lighting
  - Colours
  - Emergency equipment
  - Lining materials
  - Ornamentation/patterns.
- The main subjects discussed in relation to tunnel linings were lighting, colour, ornamentation and patterns.

### Lining/colours

It was pointed out that a sense of confinement occurs when the height of the ceiling is reduced. Since light colours promote a feeling of spaciousness, a light coloured ceiling should encourage a sense of well-being and confidence. Taking this argument further, light coloured walls should also provide a feeling of space. The greater the light inside, the higher will be the level of visual control. On the other hand, the Norwegian designs mainly have dark ceilings, the argument being that drivers

should be encouraged to direct their attention to the road, and a light ceiling would introduce a disturbing element.

A lighting level of 7 cd/m<sup>2</sup> as in Japan and 6 cd/m<sup>2</sup> as in Norwegian tunnels with heavy traffic was discussed. The Stockholm Orbital Road design with a light ceiling combined with reflection barriers along the walls makes it possible to reduce the lighting level to 5 cd/m<sup>2</sup>. It was pointed out that the lighting level depends on the surfaces and their ability to reflect light, and a specified lighting level is not decisive in achieving the optical guidance desired. However, the effect of pollution should be considered when a tunnel is designed.

### Ornamentation/pattern

It is a common belief that surface treatment is one of the most important elements in achieving visual control. A well designed layout may assist in breaking up monotony and providing the driver with information on road geometry, speed, changes in inclination, orientation and connection with the surface. However, it should not be confused with road signing standards or act as a disturbing element. A further restriction is the reduced effect of ornamentation through ageing and spoiling.



PHOTO: KJØR A. JUKKA, BERGEN

*Austmannalia tunnel, E134 Hordaland, is situated in a steep hillside between a mountain plateau and the Røtdal valley. The tunnel slopes downwards on a curve, and visibility is very poor on bright days after driving through the snow covered plain, or when there is drifting snow. Improvement measures have been considered and a geometric pattern has been applied to the wall surfaces. This was greatly welcomed and appreciated by drivers.*



PHOTO: EIVAR HENNING

The use of patterns may also have an important impact on the driver's behaviour. Patterns with vertical elements alone, for example, provide cues regarding speed and wall curvature. Since this makes the driver more aware of speed, such vertical patterns may be used to influence the driver to reduce (or increase) speed. Patterns with horizontal elements alone appear to give visual cues regarding the change in inclination of the road, but becomes more difficult to interpret in curved tunnel sections.

#### Emergency equipment

Safety installations, such as emergency telephones, shelter areas, laybys and signposting systems, contribute to the visual control level inside the tunnel. Norwegian studies reveal that 60–70 percent of drivers listen to the radio when driving through tunnels provided with antennas. This makes it possible to transmit information on special events, and to give drivers encouragement and confidence. However, emergency telephones are used in less than 50 percent of the events that warrant their use. To improve this situation, the Norwegian representatives strongly recom-

mended changing the sign from "SOS", which is the EU standard, to "Service Telephone".

#### Simulated driving in tunnels

How is it possible to evaluate the effect of the different lining designs on driver behaviour and safety? Studies of events may be a possibility, but are not very useful since it takes a long time to achieve results. A better approach, but still too slow, may be to study driver behaviour by means of video recordings in the actual tunnel sections.

At the symposium, the usefulness of computer simulation studies was demonstrated in a convincing way. A computer simulation of an actual tunnel design can be developed, and drive-through animations can be created to develop hypothetical designs worthy of more detailed evaluation. The designs are viewed while driving at high speed in a dark and dusty environment. This method makes it possible for the designer to obtain a realistic impression of the various solutions. Furthermore, drivers' response to various proposals can be tested safely.

*The lightly coloured wall fabric with a geometric pattern to indicate curvature and downward inclination of the road at the entrance to the Austmannalia tunnel.*

#### Final remarks

The symposium was successful in bringing together many views on a subject currently in its initial phase. Much work and consideration is required to arrive at solutions that will produce the desired effects on road tunnel safety, comfort and aesthetics. Important contributions were made by, José Juncá Ubierna, John Carmody, Yoshikazu Ota, Gunnar Jensen, Guro Ranes, Kaare Skallerud, Owe Swanson and Erik Wessel.

This article was specially written for Nordic Road & Transport Research by Arne Grønhaug, Senior Geologist at NRRL.

Reference:  
José Juncá Ubierna. Lining and portal design with attention to traffic safety and aesthetics. Internal Report No. 1950.