CAN HIGH STRENGTH CONCRETE PAVEMENTS IMPROVE SIGHT CONDITIONS IN ROAD TUNNELS?

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ABSTRACT: Wear and tear on road pavements costs enormous sums of money in maintenance each year. Road dust is unpleasant and if found in larger quantities can cause health problems. Road tunnels are particularly prone to discomforts caused by the presence of dust. Reduction in visibility is one of the problems. Dust is chiefly caused by the continuous mechanical breaking down of the road pavements, combined with soot from vehicles. In winter the wear and tear from studded tyres will give markedly worse visibility than in the summer. The amount of dust generated and the distribution of particles will bear direct relation to the quality of the road surface. In road tunnels the road pavement lightness strongly influence the operational costs of the tunnel lighting.

To enjoy safe and comfortable driving, drivers need to be able to perceive clearly relevant visual information. They must be able to drive without fear that they are lacking this necessary visual information and be able to see a sufficient distance ahead. This distance will vary with driving speed, braking performance of the vehicle, and so forth.

1 VISIBILITY-CONTAMINATING PARTICLES IN TUNNELS

Visibility in road tunnels is reduced by the attenuation of light caused by small suspended particles. These particles absorb and scatter light, reducing the amount reaching a driver's eye and lessing the apparent contrast of any obstacle.

The visibility-contaminating particles in road tunnels can be divided into two groups:

- particle escape from petrol and diesel vehicles
- products of wear and tear

Exhaust-gas from petrol and diesel propelled vehicles consists of an unknown number of dissimilar gases and particles. Important for visibility conditions in road tunnels are escape of soot (black smoke), condensed fuel (white smoke), and small oil drops (blue smoke). Because diesel motors always work with surplus air, these tend to dominate in the escape of particled contaminants.

Soot and exhaust-gas particles have at the outset a particle size varying between 0.01 and 2 micron (1 micron = 1/1000 mm), but through agglomeration in the exit-gas system particles with a diameter up to about 10 micron can be formed. An uncertain question is as to whether additional agglomeration of exhaust-gas particles in the tunnel atmosphere occurs. The escape of soot and particles with motor vehicles' exhaust-gases will decrease as new regulations on catalyst equipment for new cars, and planned and probable requirements for exhaust-gas are brought into operation.

The products of wear and tear principally comprise mineral dust from the continuous, mechanical breaking down of the road surface. In addition are found the particles caused by wear and tear by vehicle tyres and possibly studs and chains.

Tests of dust at the road-side (ground deposit) in Trondheim, spring 1994, showed that wear and tear particles from asphalt and concrete road surfaces had in the main a diameter less than 2,5 mm.

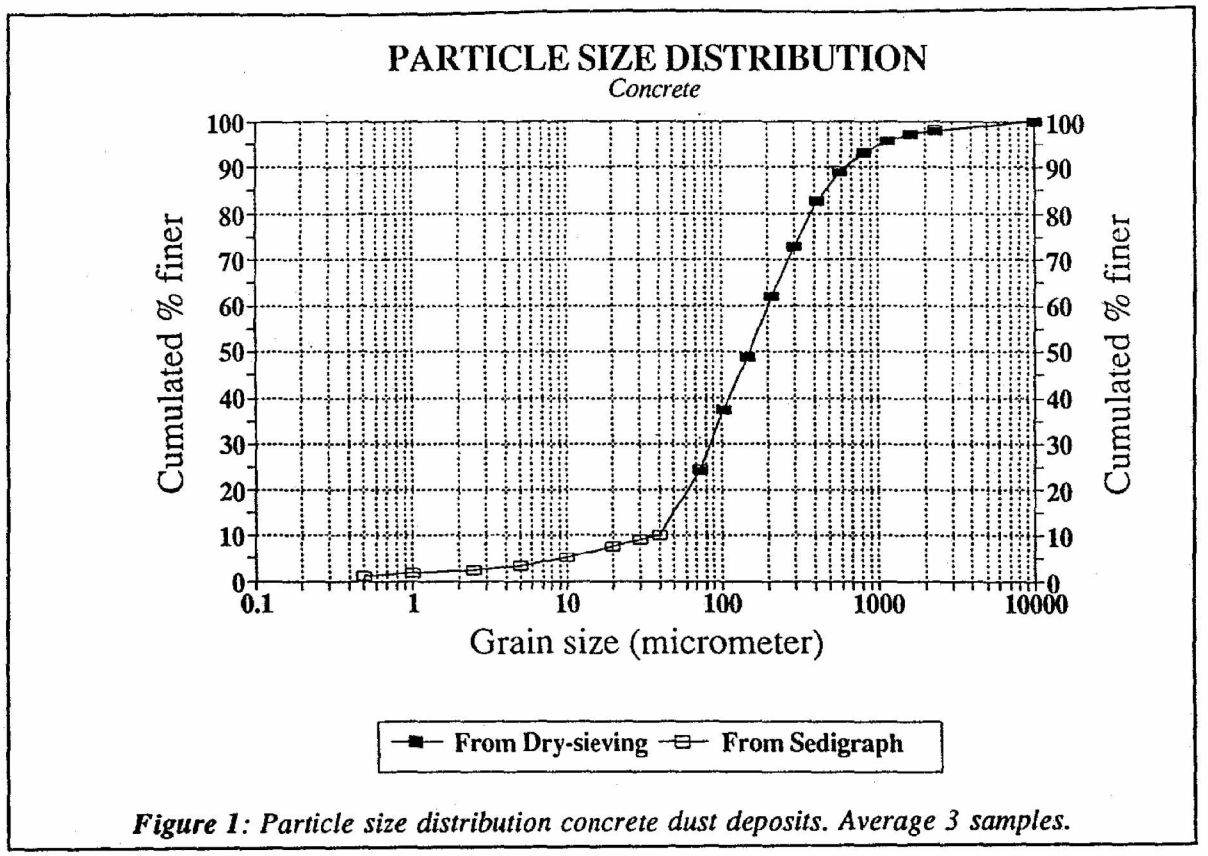

***Figure 1**: Particle size distribution concrete dust deposits. Average 3 samples.*

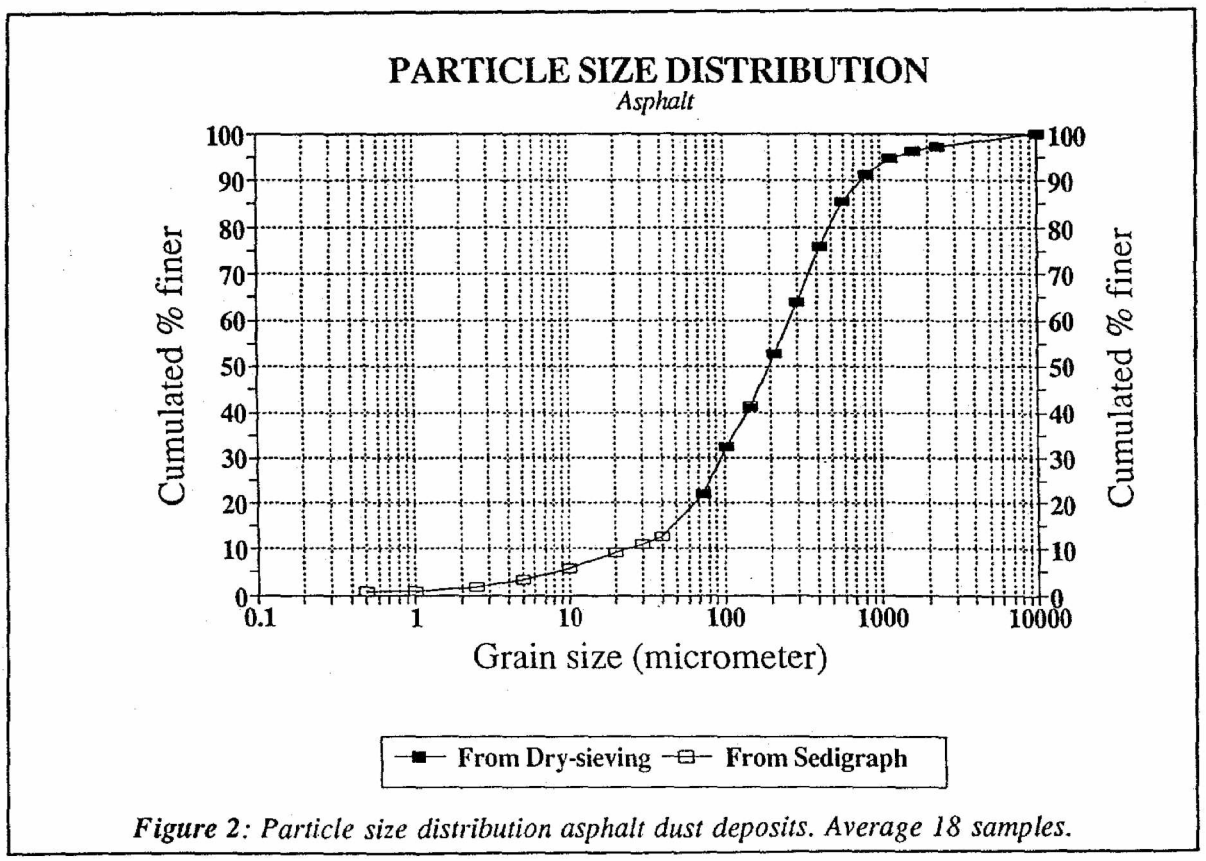

***Figure 2**: Particle size distribution asphalt dust deposits. Average 18 samples.*

About 32% weight of the asphalt particles was less than 100 microns in diameter. Approximately 38% weight of the concrete particles was less than 100 microns. Concrete dust deposits have a higher share of particles less than 5 microns.

Because of turbulence from traffic and possibly natural and mechanical ventilation, road-side dust particles whirl up and become airborne. In tunnel atmosphere these blend together with exhaust-gas particles from motor vehicles. Investigations in several road tunnels show that the size of the airborne particles in the tunnel air varied from 0.01 up to 300 microns. Between 80% and 99% of the particles are smaller than 10 microns. Particles less than 2-3 microns in size are dominated by soot, but particles larger than this are dominated by mineral dust.

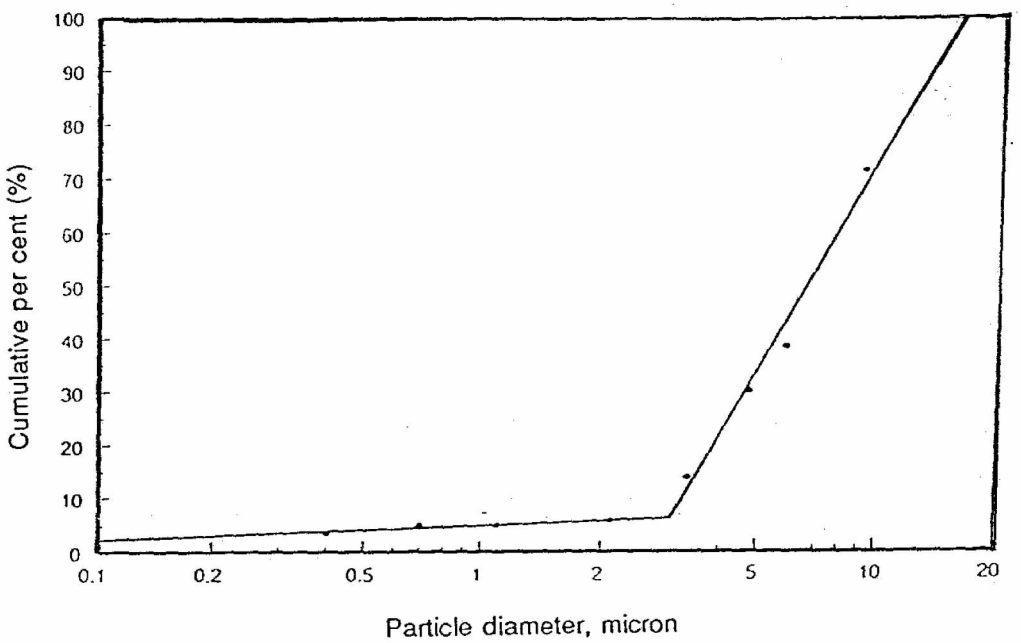

Figure 3: Example of particle distribution of airborne dust in a road tunnel with asphalt pavements and high traffic load in october/november 1992 /Lindgaard, I 1992/.

2 ASPHALT VERSUS CONCRETE PAVEMENTS IN ROAD TUNNELS

It is important for visibility conditions in road tunnels to reduce the amount of particles in the tunnel atmosphere which foul light sources and fittings as well as the tunnels' reflective surfaces, and lead to deterioration in the tunnel airs optical qualities. Dissimilar road pavements/pavement qualities with the same incidence of wear and tear produce dissimilar amounts of particles with dissimilar particle-size distribution. On account of varying composition of relevant materials and varying traffic conditions from tunnel to tunnel, the total optical effect of the particle contamination also varies. An inspection in two austrian road tunnels, one with concrete and the other with asphalt road surfaces, showed that optical visibility-reduction (m^{-1}) with the same gravimetrical concentration was significantly less in the tunnel with the concrete road pavement than in the one with asphalt, without further explanation being given / Pischinger & Puchvein, 1976 /.

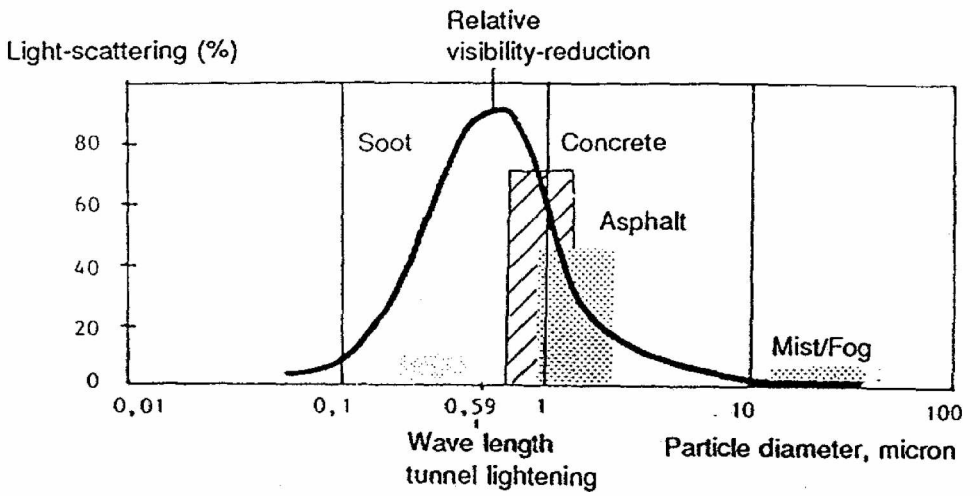

Figure 4: Light scattering due to particles of dust, soot and mist. /Myran. 1989/.

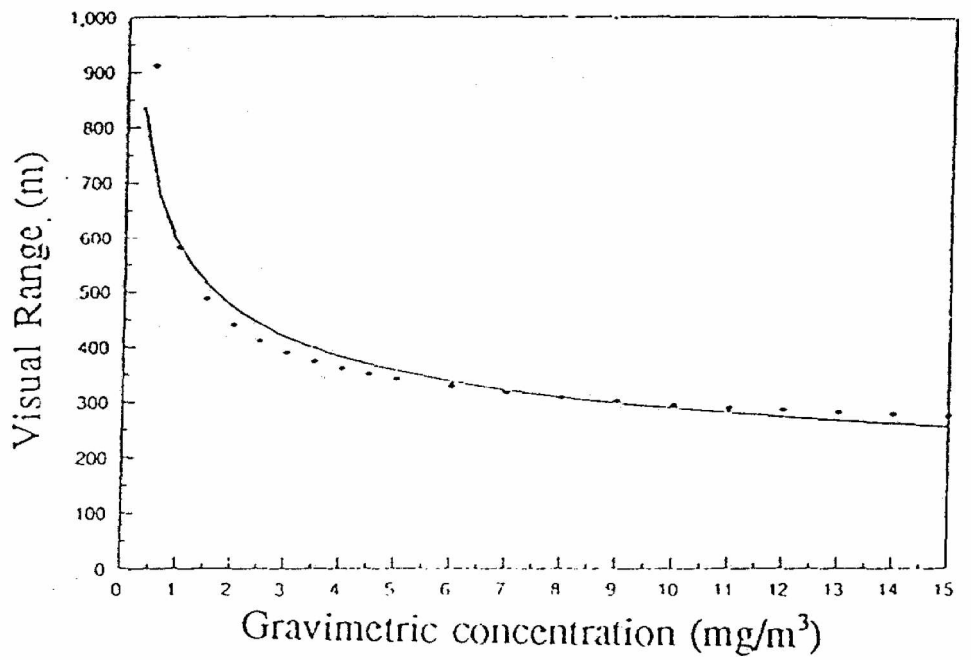

Figure 5: Visual range (m) vs. gravimetric particle concentration (mg/m³), Holmestrand tunnel, concrete pavement (C40). /Hedalen, T. 1992/

The difference in visibility-lengths in asphalt and concrete paved tunnels with the same gravimetrical particle concentration and traffic conditions can principally be explained, it is believed, through the differences in asphalt and concrete particles' optical qualities. The dark asphalt particles absorb more light than their concrete-related equivalents.

Measured partial wear and tear (wear and tear pr rotation, 10^{-4} mm/rotation) in dry and wet testing of the same road surface qualities are shown in the table below. Results from testings in "Veislitern" suggest that concrete surfacing with greatest pressure-resistance, heavy-duty concrete with 10% silica, gives the least contamination of visibility in road tunnels.

Table 1: Partial wear and tear (wear and tear pr rotation, 10^{-4} mm/rotation) in dry and wet testing /Myran, T 1986/.

Type of pavements	Pressure-resistance (MPa)		Partial wear and tear (10^{-4} mm/rotation)	
	28 days and nights	90 days and nights	Dry	Wet
Concrete C40	58	(68)	0.77	1.92
Heavy-duty concrete with 10% silica	89	99	0.38	1.18
Heavy-duty concrete without silica	58	77	1.20	2.59

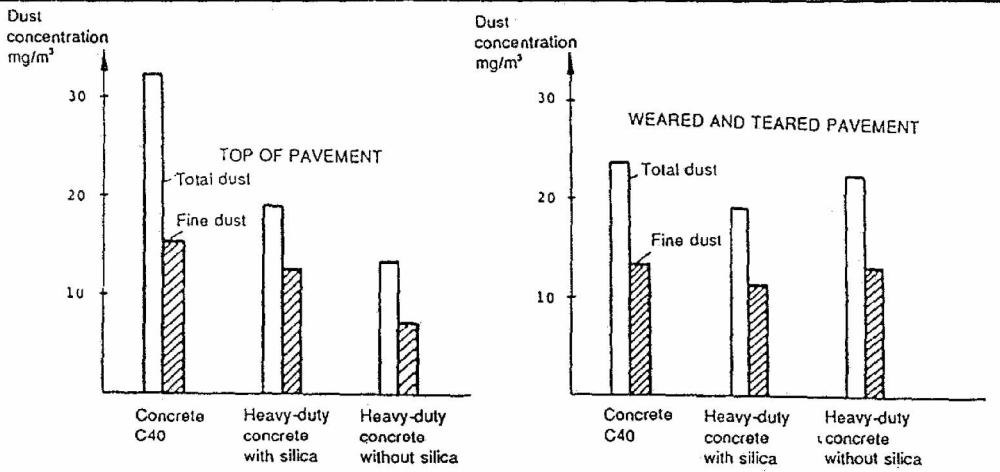

Figure 6: Average concentration (mg/m³) of total dust and fine dust (particles < 5 micron) from wear and tear on concrete pavements /Myran, T 1986/.

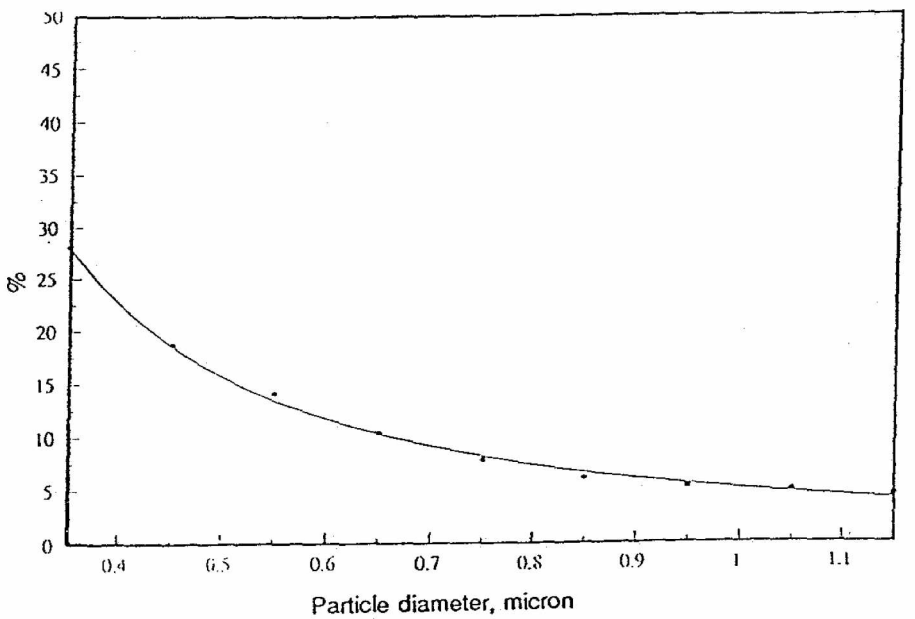

Figure 7: Average share of dust particles within the wavelength of tunnel lighting related to the number of fine particles (< 5 microns) for the different tested concrete pavements in Figure 4 /Myran, T 1986/.

Equivalent test results (Table 1, Figure 6 + 7) are not available for the dissimilar asphalt qualities. Experience shows, however, that wear and tear on asphalt road surfaces exceeds, and partically much exceeds that found in the case of concrete. Normally asphalt surfaces have a higher share of coarse particles in the wear and tear dust deposits than is the case with concrete surfaces, Figures 1 and 2.

3 TUNNEL LIGHTING COSTS AND ROAD PAVEMENTS

Luminance in road tunnels can only be provided by artificial lighting installations. The luminance depends on the lighting facilities installed, but are strongly influenced by the light being reflected from the tunnel walls, tunnel roof, road pavement and particles suspended in the tunnel air.

In road tunnels the road pavement lightness strongly influence the reflecting of light. 60-65% of the light reflected in road tunnels can be refereed to road surface lightness, 20-25% to the tunnel walls and 15% to the tunnel roof lightness /Byfors J, 1992/.

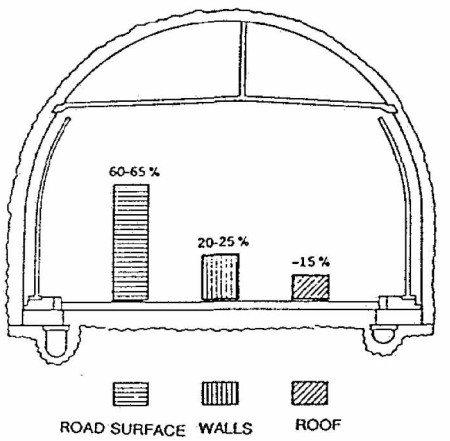

Figure 9: Relative importance of lightness of road surface, walls and roof on reflected light in road tunnels.

Concrete surfaces reflect about twice as much light as bituminous pavements.

Due to this difference in degree of lightness, road pavements significantly affects operational costs of tunnel lighting. A comparative study of operational strip lighting in the St. Gotthard Road Tunnel (bituminous road pavement) and the Seelisberg Road Tunnel (concrete road pavement) on the Swiss National Highway N2, show costs savings for tunnel lighting brought about by the concrete pavement at approximately Fr. 5 300,-/km year.

An additional difference of interest for road tunnel lighting between concrete pavements and bituminous pavements is that when the average illuminance of the tunnel increases (more tunnel lighting are installed) the driving comfort and the visual range in concrete road pavement tunnels increases. In bituminous pavement road tunnels an increase in illuminance above an optimum value will reduce sight distance, and thereby driving comfort, due to glare from the road surface.

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