

and the construction inspections could be neglected, which is not a viable alternative, or (b) some of the work could be done by contract.

For a number of years now the department has been contracting 25 to 30 percent of its maintenance needs, and we are going to have to continue at that level or higher. Also, agreements are being drawn up with consulting engineers to do construction inspections. Other tasks that could be done by contract include material testing, plant inspection, grading inspection, surveying, and it is possible that we will hire a consultant to look after an entire construction project.

I had hoped to report a complete reclassification

and merging of the highway maintenance worker and construction technician grades into a new position description combining the knowledge, skill, and ability required for both job assignments. Although this is being done, it has not been completed. As previously indicated, work assignments frequently cross between maintenance and construction, and I am sure that all of the employees understand this to be our goal.

The area organization, with its reduction in middle management supervision, is functioning better than I anticipated and appears to be enjoying good acceptance.

A Maintenance Management System for Road Markings

PER SIMONSEN

The Danish Road Directorate has recently issued provisional specifications for marking traffic lanes of main roads beginning in 1984. Simultaneously recommendations on materials for, and maintenance of, marking were issued. Specifications and maintenance strategy are based exclusively on the functional requirements of the markings. It is to be expected that the introduction of the recommendations will result in a higher standard of marking and thus contribute to increased road safety.

GENERAL SPECIFICATIONS FOR MATERIALS AND EXECUTION

Marking performed by contractors is required to meet a number of conditions [referred to in Denmark as the AAB (1,2)] before delivery and before the expiration of the guarantee period. These fall into three general categories: (a) optical properties, (b) skid resistance, and (c) durability. The required minimum values are stated in Table 1.

Optical Properties

A recently developed reflectoscope (i.e., a small box with white opal glass plates) is used for measuring optical properties (see Figure 1). The measurement is made by comparing the road line with a number of filters placed in front of the opal glass plate.

For unlighted roads, the reflection of the road marking in the dark, which is indicated by the spe-

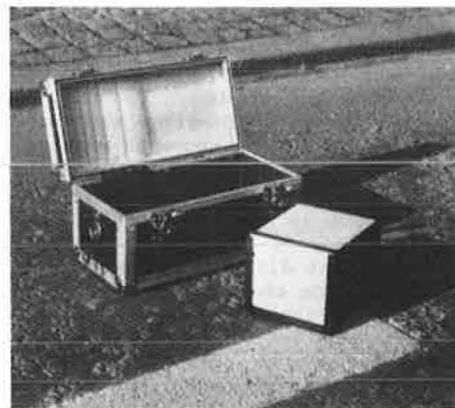


FIGURE 1 Reflectoscope with storage box and filters.

cific luminance (SL), is determined in the light of the main beams of the headlights of an automobile. The reflectoscope is placed behind the road marking with the measuring face turned toward the spot of observation, which is chosen to be about 50 m in front of the reflectoscope at a height of 1.2 to 1.5 m above the carriageway (see Figure 2). The reflection is determined by comparing the road marking with the different reference surfaces.

For lighted roads and in daylight the reflection properties of the carriageway markings are deter-

TABLE 1 Functional Requirements for Road Markings

Time	Mean Luminance Coefficient, Q_0 ($\text{cd}/\text{m}^2/\text{lx}$)	Specific Luminance, SL ($\text{cd}/\text{m}^2/\text{lx}$)	Skid Resistance (srt)	Maximum Wearing (% of area)
At delivery	0.16	0.16	55	0
Expiration of guarantee period	0.13	0.13	55	30

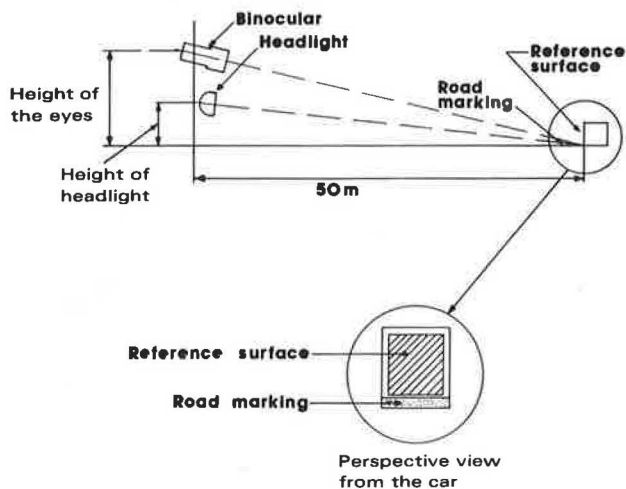


FIGURE 2 Geometrical conditions for observation of reference surfaces of a reflectoscope.

mined in terms of the mean luminance coefficient (Q_0). This parameter is measured by the other face of the reflectoscope. A quantity of light emitted via a mirror corresponds to the light intensity by which the line is lighted from the surroundings (see Figure 3); and by assessing which filter corresponds

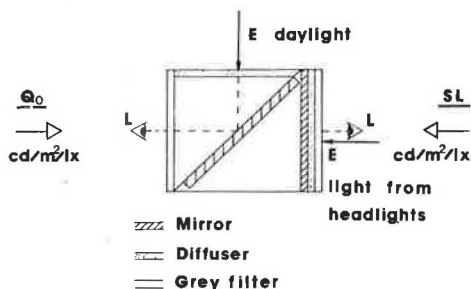


FIGURE 3 Reflectoscope for determining the mean luminance coefficient (Q_0) and the specific luminance (SL). Different grey filter densities give different values of Q_0 and SL.

to the line, the Q_0 -value is determined. The use of the reflectoscope is illustrated in Figure 4. It was developed by a working party set up by the Danish Road Directorate along with the firm of Hansen & Henneberg as consultants in the field of reflection. It is manufactured by Brüel and Kjaer and costs less than U.S. \$500.

Other Requirements

Skid resistance is measured by a pendulum roughness indicator, and wearing is assessed visually. The guarantee period depends on the type and material of the marking and is given in Table 2.

TABLE 2 Guarantee Period (years) for Carriageway Marking

	Linear and Arrow Markings	Transverse and Other Markings
Thermoplast	4	2
Paint and foil	1	0.5

Painting

Lines are often painted by the road authority itself and demands of elasticity, durability, and ability for storage of the paint are determined by current testing methods.

MAINTENANCE STRATEGY

The objectives of a maintenance strategy for road lines are to reduce costs of construction as well as operation at a given standard level.

Functional Criteria

The standard level is determined by the criteria of remarking as given in Table 3. The general specifications for remarking are also based on functional requirements. The main roads are classified in two groups: groups A and B. Group B has the greatest need for optical guidance for road safety reasons and therefore places higher demands on the optical properties of the lines. The classification is



FIGURE 4 Measuring the mean luminance coefficient (Q_0).

TABLE 3 Criteria of Remarking

Group	Mean Luminance Coefficient, Qo (cd/m ² /lx)	Specific Luminance, SL (cd/m ² /lx)	Maximum Wearing (% of area)
A	0.10	0.06	50
B	0.13	0.10	50

based on information on road alignments, which is stored in the road data bank of the Danish Road Directorate.

Annual Marking Costs

As in the Danish road standards for pavements, annual costs, which are calculated from the capital recovery factor, are used as a basis for choosing marking materials (i.e., when deciding whether to use thermoplast or paint in a given case). At the present time the rate of interest used in the capital recovery factor is 7 percent.

The maintenance strategy is summarized below. Then two examples are given for determining which marking material is the most economical.

- General: On unlighted roads, beads are applied; on lighted roads, beads are not applied.
- New Marking: Thermoplastic material is applied on new wearing courses; marking is carried out by contractors, and the AAB applies.
- Remarking: An assessment of wearing is made in both the daylight and dark. Different remarking criteria apply for roads in group A and group B. The average annual maintenance costs are calculated, and the material is chosen. The AAB applies.

Example 1

Ten thousand square meters are to be remarked; the initial price of thermoplastic material and line painting is D.kr. 65 per m² and 15 per m², respectively. It is assumed that the interest (r) is 7 percent a year.

In the first case the renewed marking with thermoplastic material lasted 4 years. It is expected that line painting will last 1 year, and it is assumed that the remaining life of the pavement will be at least 4 years. A calculation x) of the average annual costs (G) gives:

G for thermoplastic material = D.kr. 191,750 and
G for line paint = D.kr. 160,500.

In this case it would be better from a purely economic view to renew the marking by line painting. x) G is determined as the product of the initial price of the marking renewal and the capital recovery factor a(n):

$$a(n) = [r(1+r)^n] / [(1+r)^n - 1]$$

where n is the expected life of the renewed marking, which is assessed on the basis of the experience derived from the marking renewal on the section in question, and r is the interest.

A table of a(n) is shown below for n between 1 and 10 years and for r equal to 7 percent and 9 percent per annum.

r = 7 percent		r = 9 percent	
n(year)	a(n)	n(year)	a(n)
1	1.070	1	1.090
1.5	0.725	1.5	0.742
2	0.553	2	0.568
3	0.381	3	0.395
4	0.295	4	0.309
5	0.244	5	0.257
6	0.210	6	0.223
7	0.186	7	0.199
8	0.167	8	0.181
9	0.153	9	0.167
10	0.142	10	0.156

Example 2

The conditions are similar to those given in example 1, except that the renewed marking has lasted 5 years and the pavement is expected to have a remaining life of 9 years. Because surface renewal of the road is to be made within the coming year it is expected that the remarking with thermoplastic material will last 10 years, whereas marking with line paint is assumed to last 1.5 years. In this example

G for thermoplastic material = D.kr. 99,450 and
G for line paint = D.kr. 108,750.

Therefore it would be better to renew the marking with thermoplastic material.

CLOSING REMARKS

It is the intention of the Danish Road Directorate to obtain an improved and more uniform standard of the carriageway marking on the main roads by issuing new provisional recommendations. Increased road safety is the expected result. Copies of the recommendations are available from the Danish Road Directorate on request.

REFERENCES

1. Afmærkning paa kørebanen, Almindelig arbejdsbeskrivelse for materialer og udførelse (Carriageway Marking, General Specifications for Materials and Execution). Vejdirektoratet, København, Jan. 1983.
2. Afmærkning paa kørebanen materialevalg, trafikale behov og vedligeholdelse (Carriageway Marking, Choice of Materials, Traffic Requirements and Maintenance). Vejdirektoratet, København, Jan. 1983.