

THE USE OF LARGE GLASS BEADS IN LINEMARKING

NIGHT PERFORMANCE (RETROREFLECTIVITY)

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A. INTRODUCTION

1. This report summarises the results of several linemarking field trials carried out in NSW between August 1994 and March 1999. The work primarily concerned the night performance of waterborne paints with large glass beads, investigated because of the proposed use of these materials for improving the wet night visibility of linemarking. However, some information on the performance of thermoplastic and two-pack linemarking materials, as well as several types of glass beads is included for comparison.

2. The materials used in the field trials were those commercially available at the time, and they were applied using accepted application rates and methods. The results reported here therefore indicate the performance of these materials alone. Since materials and application practices are under continual development, it is possible that improved performance, above that reported here, may occur as new materials and improved practices are adopted. Details of application rates and methods to optimise performance should be obtained from material suppliers.

3. The following field conditions may also significantly affect the performance of linemarking materials.

- a. Pavement type
- b. Pavement condition
- c. Pavement alignment
- d. Line type
- e. Weather conditions during application
- g. Rainfall and other environmental conditions existing during the life of the marking
- h. Traffic volumes

The field trials do not cover all of the possible variations in the above factors. The information provided in this report is therefore a guide only, as significant changes in performance may occur in other situations where the above conditions differ from those prevailing during the trials.

B. GENERAL PERFORMANCE FACTORS

The overall performance of linemarkings containing large (class B) glass beads is greatly influenced by the following factors.

1. **The quality of the glass beads used.** That is, the percentage of rounds, the clarity of the beads, the colour and refractive index of the glass used. High performance beads will tend to give high initial retroreflectivity and lead to longer life of the painted line.

2. **The bead application rate.** A minimum 400 g/m² of beads retained is generally required to give high initial retroreflectivity. If the application rate is too high (greater than about 600g/m²) performance may be adversely affected.

3. **Paint film thickness.**

(a) Waterborne paints. A minimum of 300 µm dry film thickness is required to hold the beads and to create efficient retroreflectivity. If the thickness is too great (above about 450 µm dry film thickness) the beads will be retained, but will not reflect light efficiently. In such a case the initial retroreflectivity reading may be low, but will tend to decrease only slowly. It should be noted that the thicker the paint film, the longer it will take to dry.

(b) Thermoplastic. Since thermoplastic materials are applied at a film thickness of at least 1.5 mm, large beads may sink into the molten material if its temperature is too high. This can result in unacceptably low dry and wet retroreflectivity. If the temperature is too low, beads may not sink deeply enough and thus be quickly lost.

4. **Coarse pavement surfaces** (eg relatively new seal pavement). This type of pavement affects performance in the following ways.

(a) If the pavement is new, the aggregate may still be covered with precoat, causing loss of adhesion of the paint and rapid decrease in retroreflectivity.

(b) The surface area of the pavement may be increased by as much as 40% due to its coarse texture. To achieve the recommended application rates higher outputs of both paint and beads may be necessary.

(c) The paint thickness will be least on the tops of the stones, resulting in rapid bead loss from this part of the surface.

(d) Beads may be unevenly distributed over the surface, with many beads accumulating on one side of a stone and/or in the 'valleys' between the stones.

All of the above, (a) to (d), can affect the overall performance of lines applied to a coarse spray seal surface, but the effects would be reduced at each repainting of the line.

5. **Curing rate of paint.** The effects of weather conditions on the curing rate of waterborne paints are outlined in RTA Technical Direction 98/7: [*The Use of Waterborne Paints with Large Glass Beads*](#). If applied materials are not protected from traffic before they are sufficiently hardened, rapid bead loss is likely to occur, causing the retroreflectivity to decrease to an unacceptably low level after only a few hours of traffic exposure. This is especially relevant if the materials are applied at night, under conditions of high humidity, or when there is little or no air movement.

C. RATE OF LOSS OF RETROREFLECTIVITY

Several field trials have been carried out in NSW since 1994. The results to date of these trials are collated here to

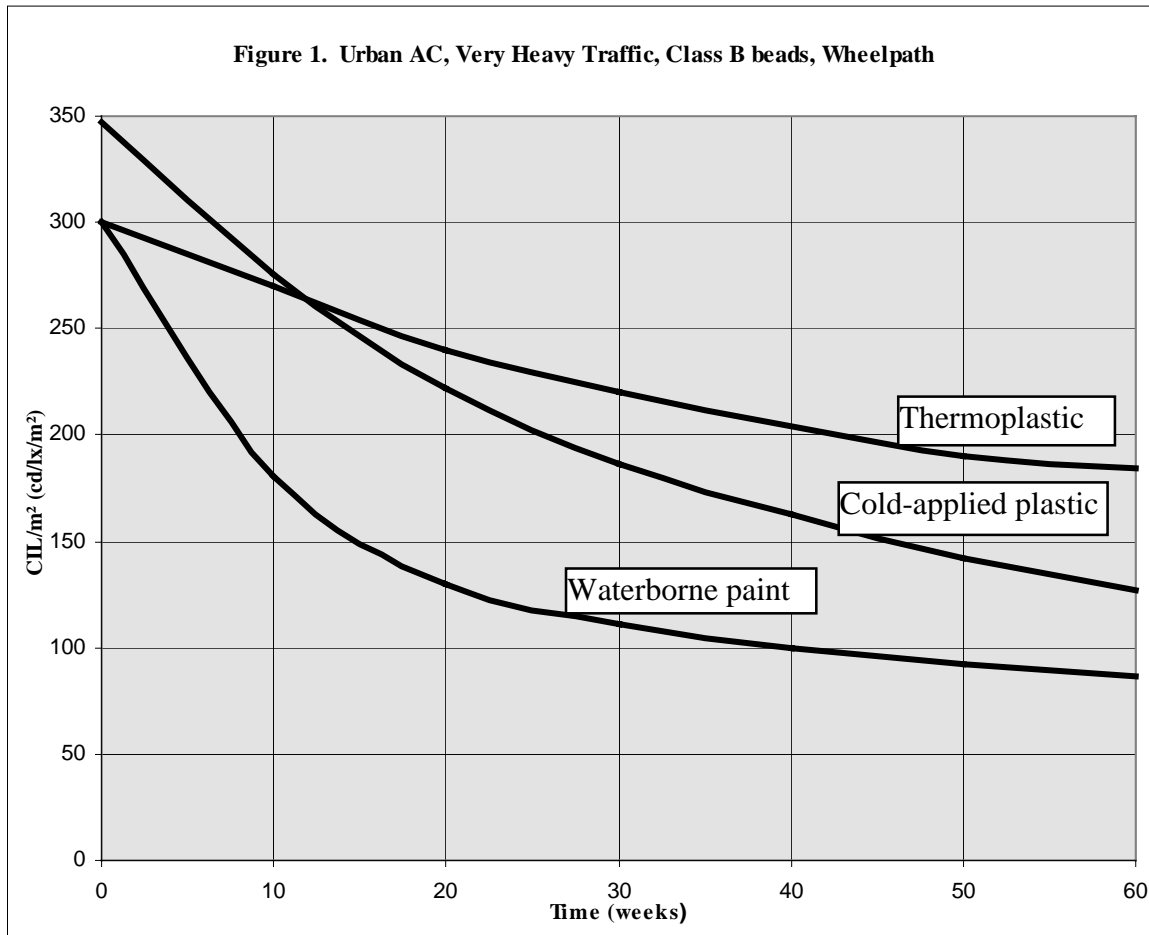
- provide some indication of the rate at which painted lines deteriorate under different traffic conditions,
- compare the performance of small (class A) with large (class B) beads under both dry and wet conditions,
- compare the performance of waterborne paints with that of extruded thermoplastic and of two pack materials.
- compare the performance of beads from different manufacturers.

1. Effect of different traffic conditions.

The results summarised here were collected from trials where the waterborne paint film thicknesses were within the recommended range. However, some bead application rates to waterborne paints were low (partly due to the coarse texture of the pavement surface) and some were higher than recommended. As a result initial retroreflectivity readings varied considerably (260 mcd/lx/m² to 500 mcd/lx/m²). Results indicate that under any given traffic conditions the *rate* of loss of retroreflectivity is very close to the same for different application rates of the one type of bead. For this reason it was considered justified to convert the relevant charts such that all start with an initial retroreflectivity of 300 mcd/lx/m² (see Figures 1 to 5). If paint and beads are applied in such a way as to achieve higher initial retroreflectivities it is highly likely that the values will level off at much higher values than those indicated. For the two part cold applied plastic lines the initial values are higher because the recommended application rates are higher.

(a) The urban situation. This is shown in Figures 1 and 2. Waterborne paints, thermoplastic (extruded) and two-part cold-applied plastic (sprayed) with large glass beads were applied as transverse lines to an asphaltic concrete pavement with very high traffic flow (6 lane, 14,500 vehicles per lane per day). The materials were applied at night.

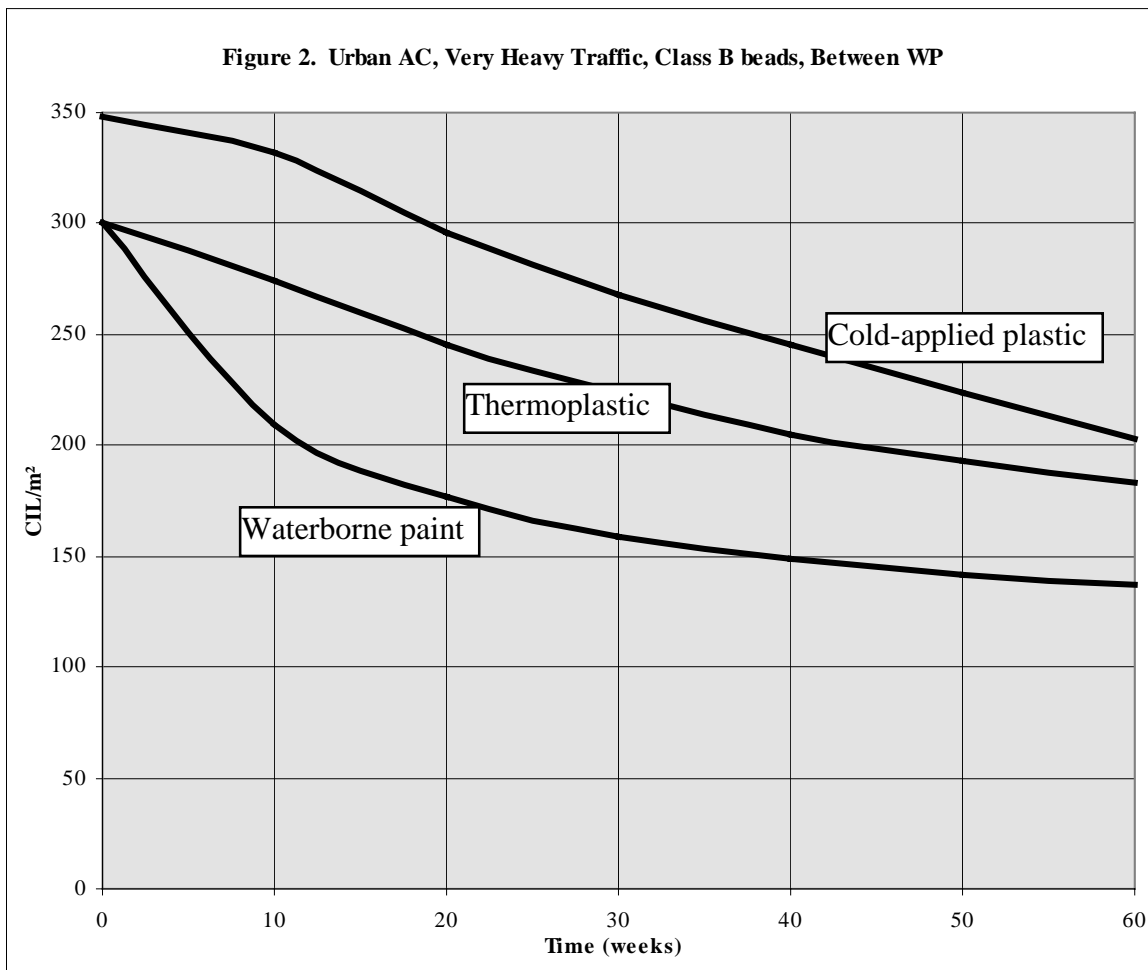
(i) Wheelpaths



It can be seen that the materials with large beads lose retroreflectivity rapidly in the wheelpaths.

The wheelpath results indicate that large glass beads are unsuitable for use in transverse lines.

(ii) Between Wheelpaths



The between wheelpath results suggest that both extruded thermoplastic and sprayed two-pack materials are suitable to be used with large glass beads for urban *longitudinal* lines.

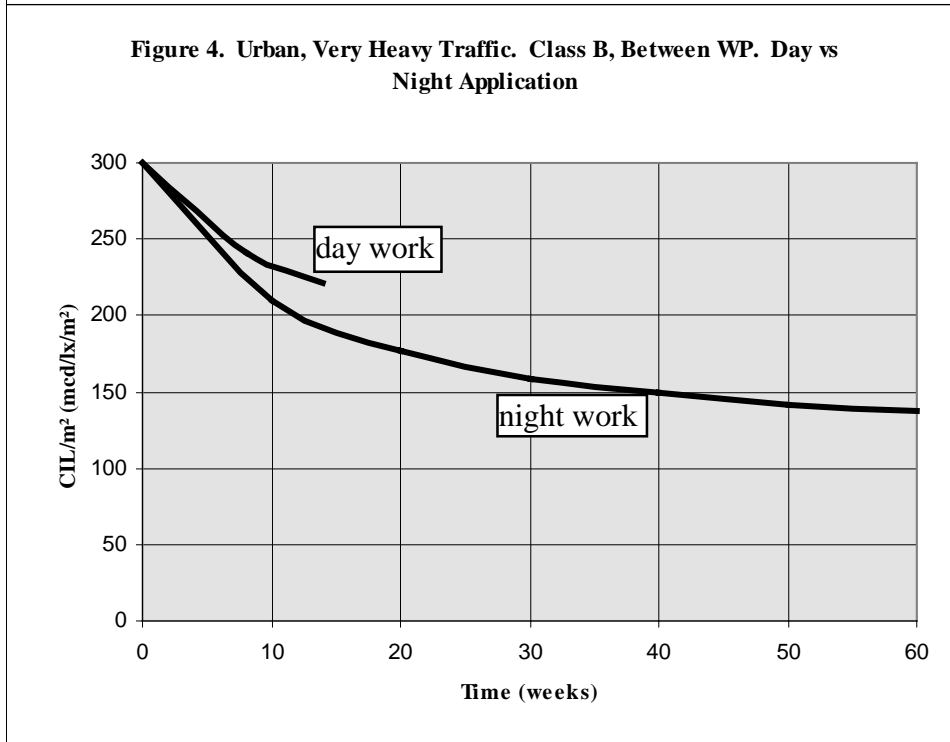
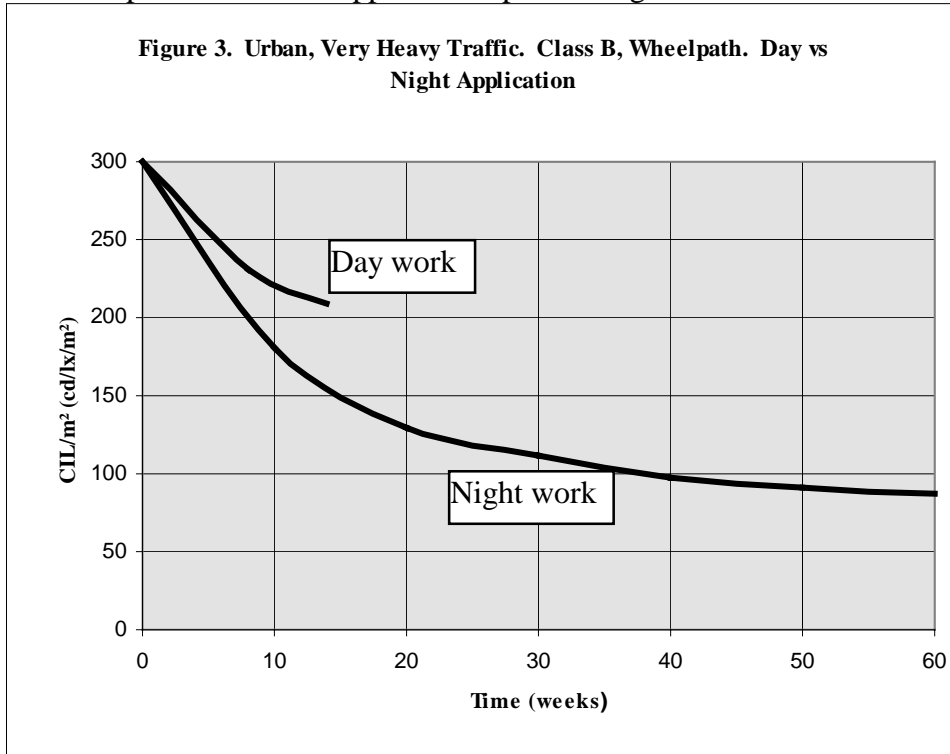
It was found that with extruded thermoplastic the retroreflectivity levelled off to a value between 150 mcd/lx/m² and 200 mcd/lx/m² regardless of the initial value. This residual retroreflectivity results from the intermix beads which continue to reflect after the upper surface of the material together with virtually all of the surface-applied beads have worn off.

Sprayed two-pack materials generally have higher initial retroreflectivity due to higher application rates. However, they lose retroreflectivity steadily. The rate of loss is about the same for both class A and class B beads (see page 8).

(iii) Day and Night Application of Waterborne Paint

Preliminary results shown in Figures 3 & 4 indicate that the main problem with the use of waterborne paints in the urban situation is that work must generally be done at night. Because of the high humidity usually experienced at night, it appears that the paint seldom dries fully even after several hours, resulting in a rapid initial loss of beads.

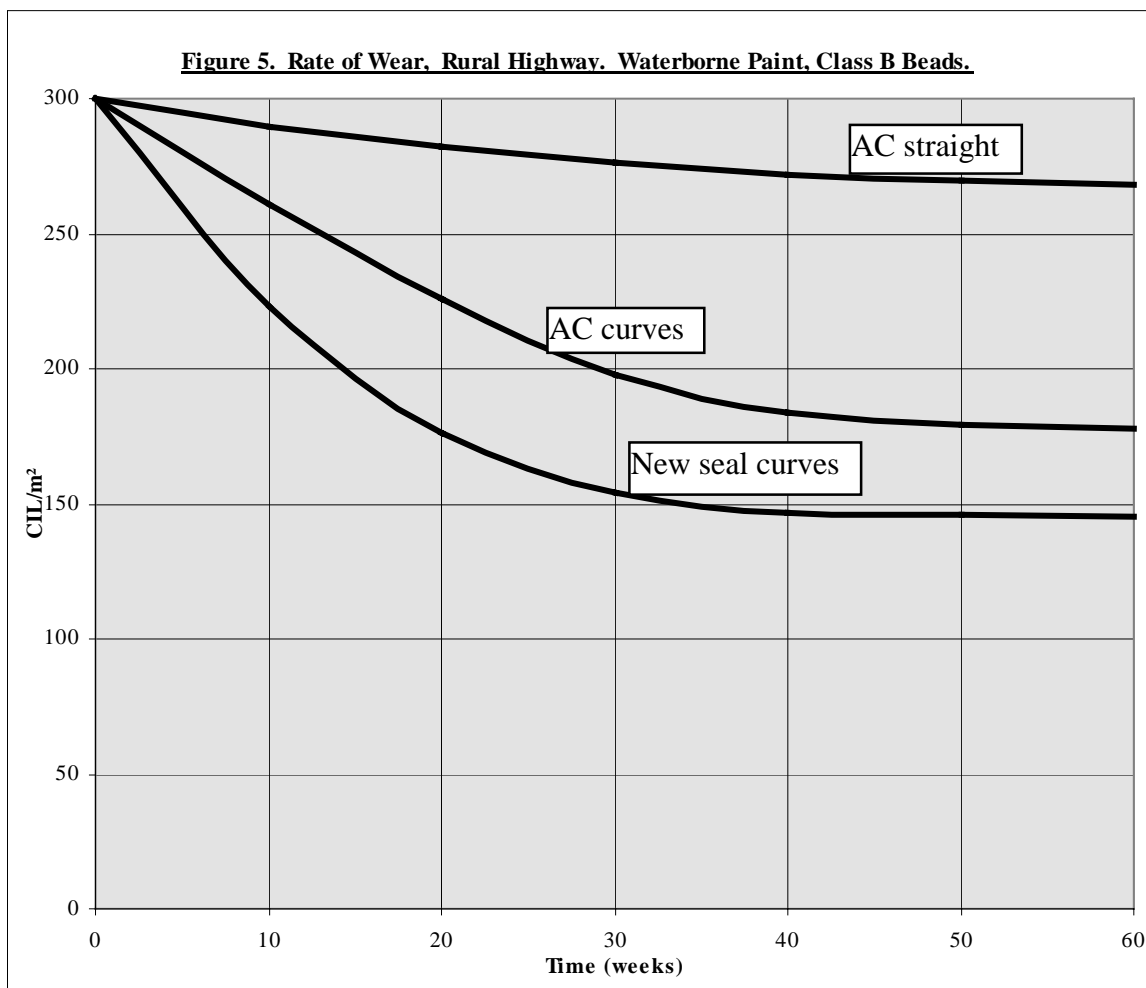
Paints which were applied as transverse lines during the day and given sufficient time to fully dry before exposure to traffic appear to be performing much better than those applied at night.



(b) The rural situation. This is shown in Figure 5. Edgelines were applied on major highways (two lane, 4000 - 5000 vehicles per lane per day), using waterborne paints and large glass beads. The lines were applied to asphaltic concrete both on curves and on straight sections; and to a new spray seal pavement on curves.

The straight sections of asphaltic concrete are representative of relatively favourable conditions.

The sections of new spray seal on curves are representative of some of the least favourable conditions found in the rural situation - where the lines are constantly subject to the scrubbing action of cars and trucks. Cones were used to protect the work from traffic until the paint was dry.



It can be seen that the life of linemarking is highly dependent on both

- the nature of the pavement surface and
- the road alignment.

On a smooth pavement where the alignment is good, it is likely that waterborne paint with class B beads will last for several years. On a coarse-textured pavement where the alignment is poor, it may only last for one year.

2. Effect of different types of beads

(a) The urban situation

A field trial was conducted where transverse lines were applied across the kerbside lane of a very heavily trafficked Sydney trunk road. Waterborne paint, extruded thermoplastic and sprayed two-pack material were applied at recommended thicknesses using the following surface-applied beads. Materials were applied at night.

<u>Surface-applied Beads</u>	<u>Nominal Bead size</u> <u>(mm)</u>
Class A	0.15 - 0.85
Class B	0.85 - 1.4
Class MA*	0.6 - 0.8
Class MB*	0.6 - 1.3

*Note: *Imported beads. The code MA designates a bead of similar size to class A, but with quite different size distribution. The code MB designates a bead of similar size to class B, but with quite different size distribution.*

(i) Class A (small) and Class B (large) Beads Compared

Figures 6 to 8 draw a comparison between the performance of Class A and Class B beads only, with waterborne paints, extruded thermoplastic and sprayed two-pack material.

With the **waterborne paints** there is a clear-cut preference for class A beads in this situation. However, it should be noted that the materials were applied at night. It is likely that the resultant slow drying of the paint contributed to the rapid initial loss of retroreflectivity, especially where the class B beads are concerned.

With the **extruded thermoplastic** there appears to be no clear-cut difference between class A and Class B beads, probably because most of the surface-applied beads are relatively quickly worn off under very heavy traffic, following which the retroreflectivity is largely determined by the intermix beads which are thus exposed. In conditions of very heavy traffic it is therefore possible that the wet retroreflectivity will decrease fairly rapidly. It is also likely that the temperature of application of the thermoplastic will affect the degree of embedment of class B beads and, in turn, both the dry and wet retroreflectivity. These possibilities have not been investigated.

With the **two-part sprayed material**, the class A and class B beads perform similarly between the wheelpaths, while in the wheelpaths the performance of class B is clearly poorer.

Figure 6. Urban AC. Waterborne Paint, Class A and B beads. Transverse Lines.

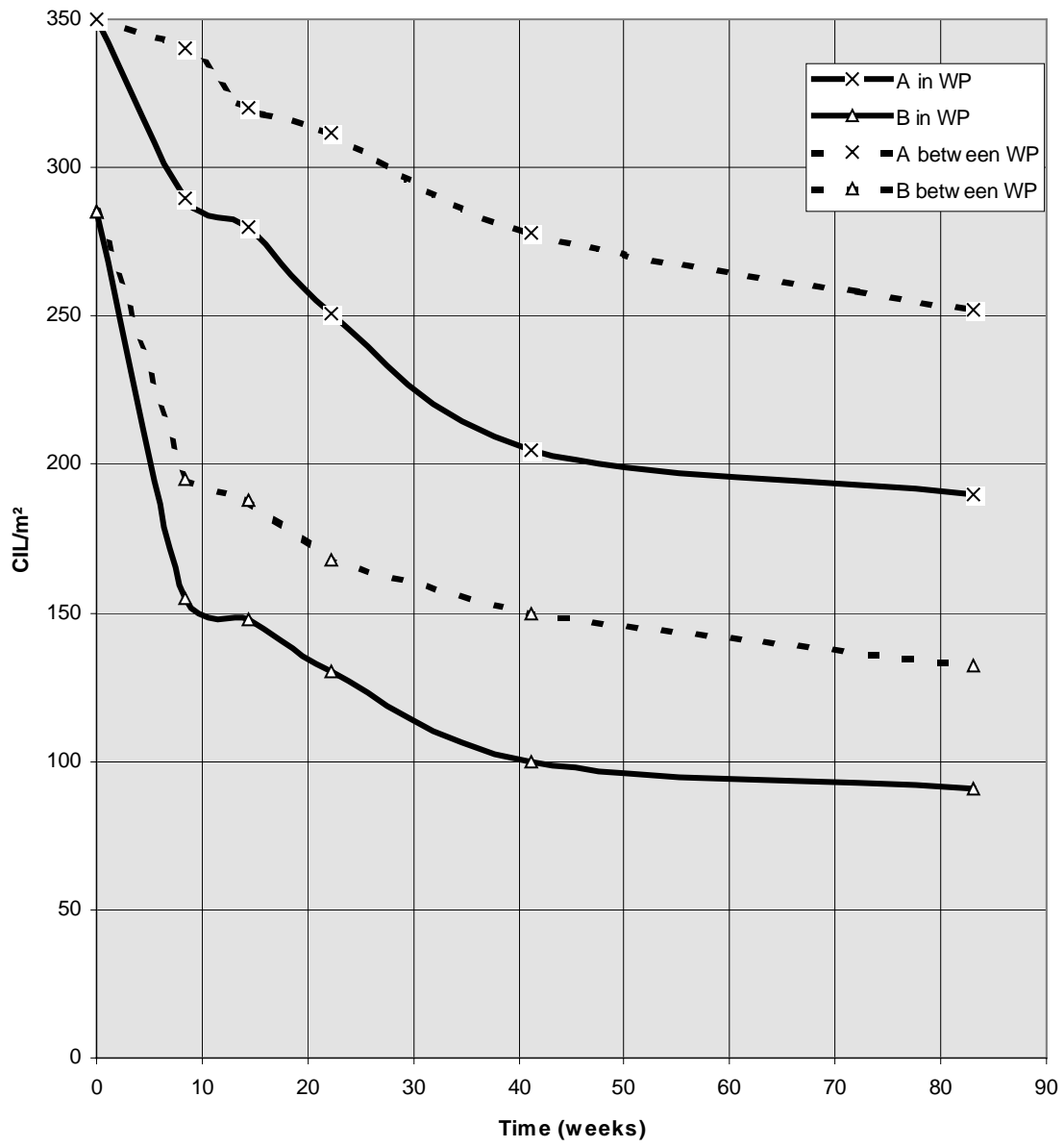


Figure 7. Urban AC. Extruded Thermoplastic, Class A and B beads. Transverse

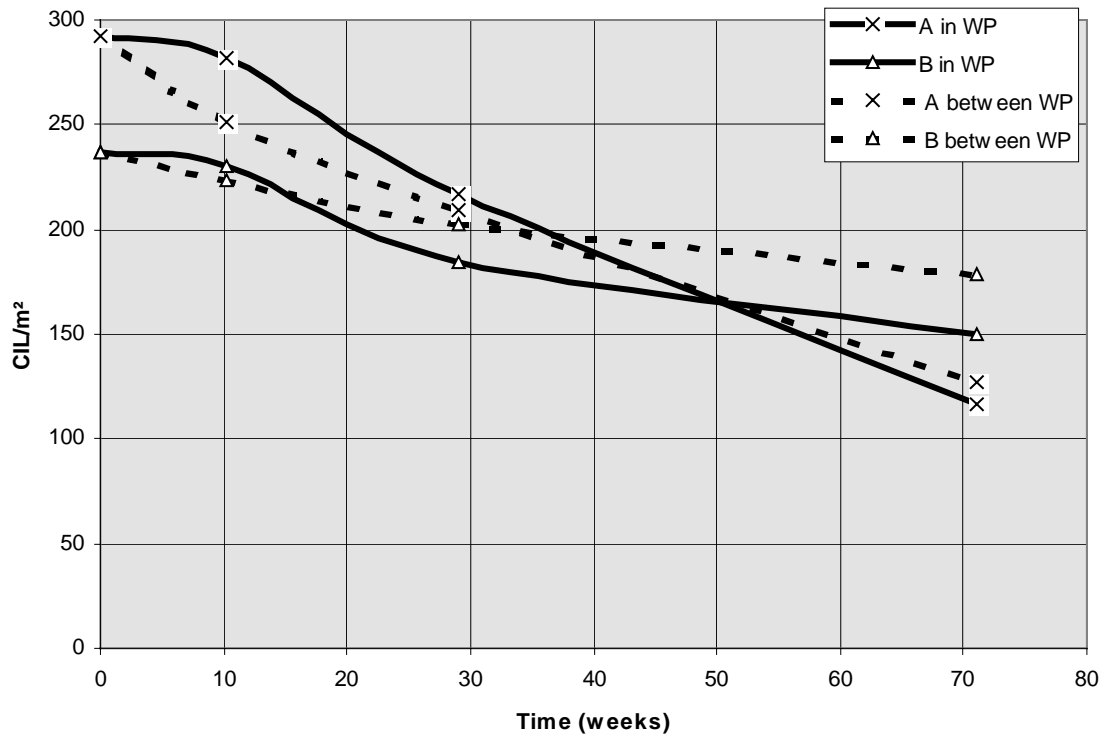
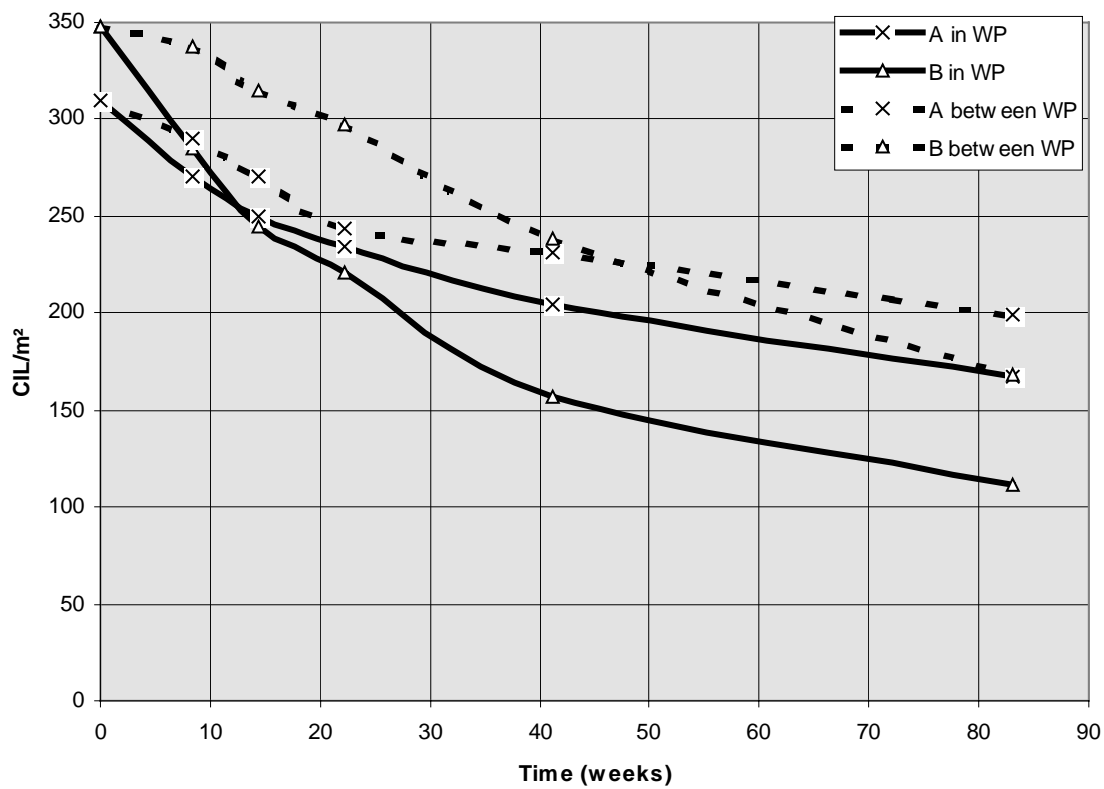


Figure 8. Urban AC. Two-part Cold-applied Plastic, Class A and B beads. Transverse



(ii) All beads compared

The data illustrated in Figures 9 to 11 come from areas of the test lines which are between the wheelpaths only, to try to simulate the performance of longitudinal lines on very busy urban roads.

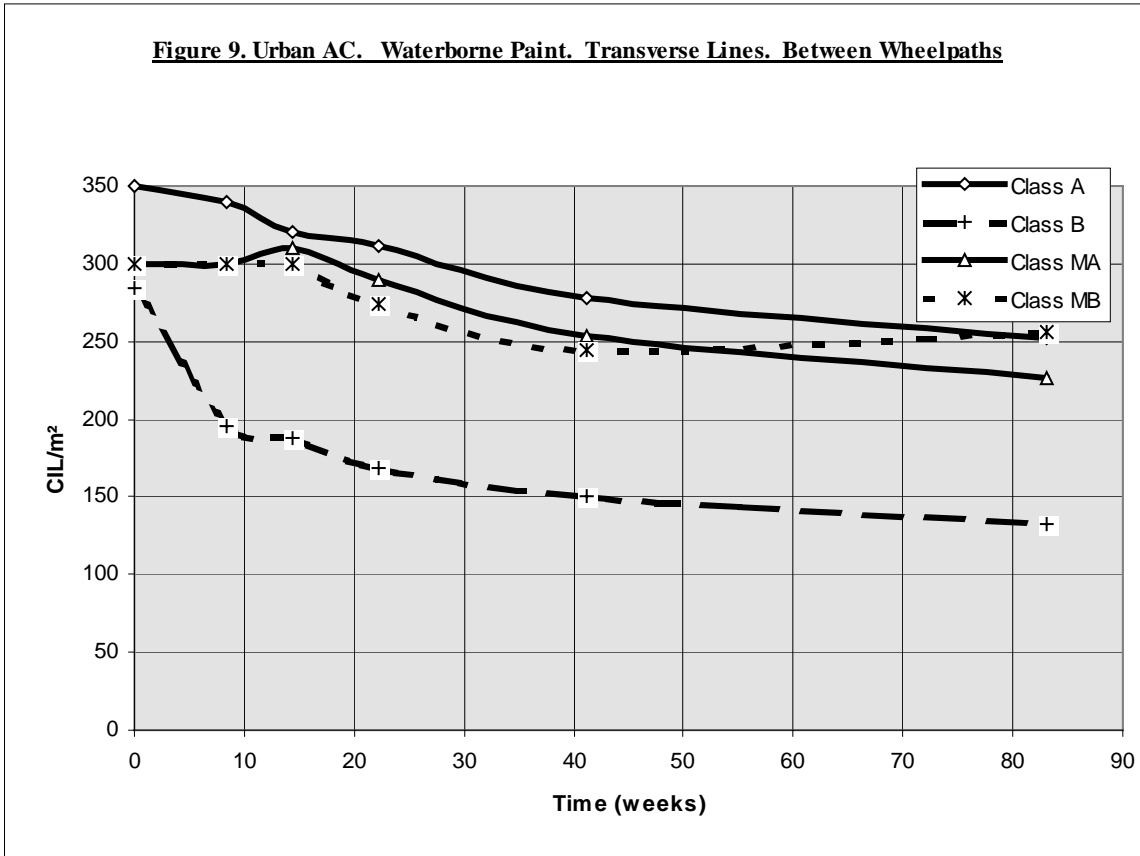


Figure 10. Urban AC. Extruded Thermoplastic. Transverse. Between Wheel Paths.

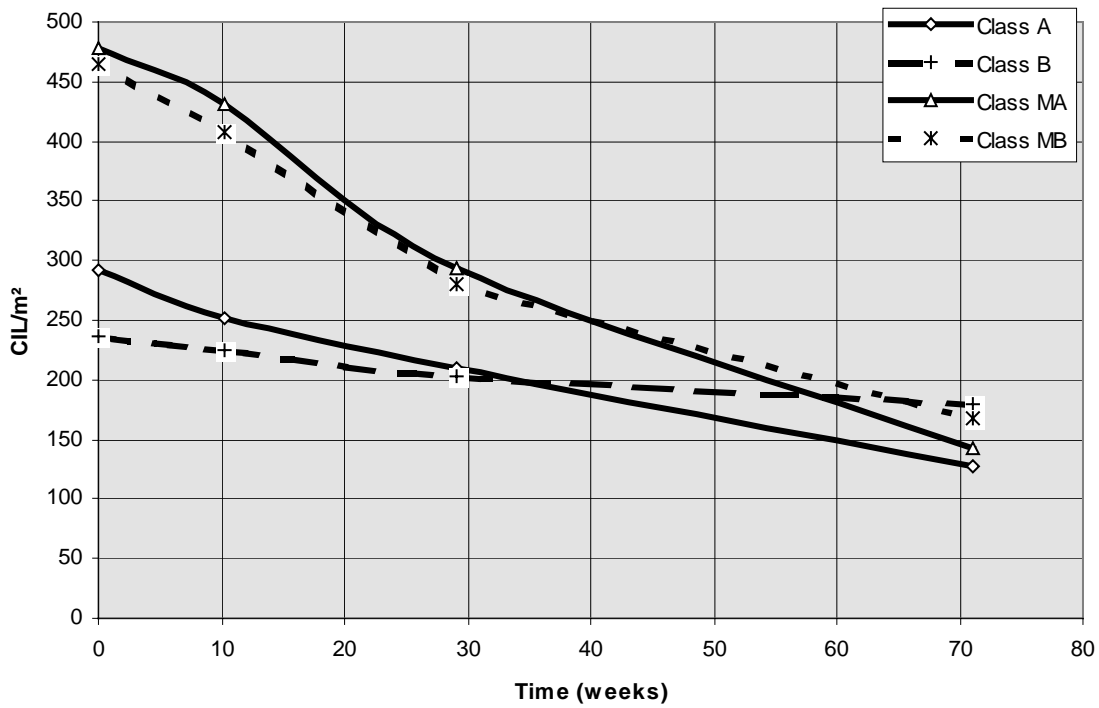
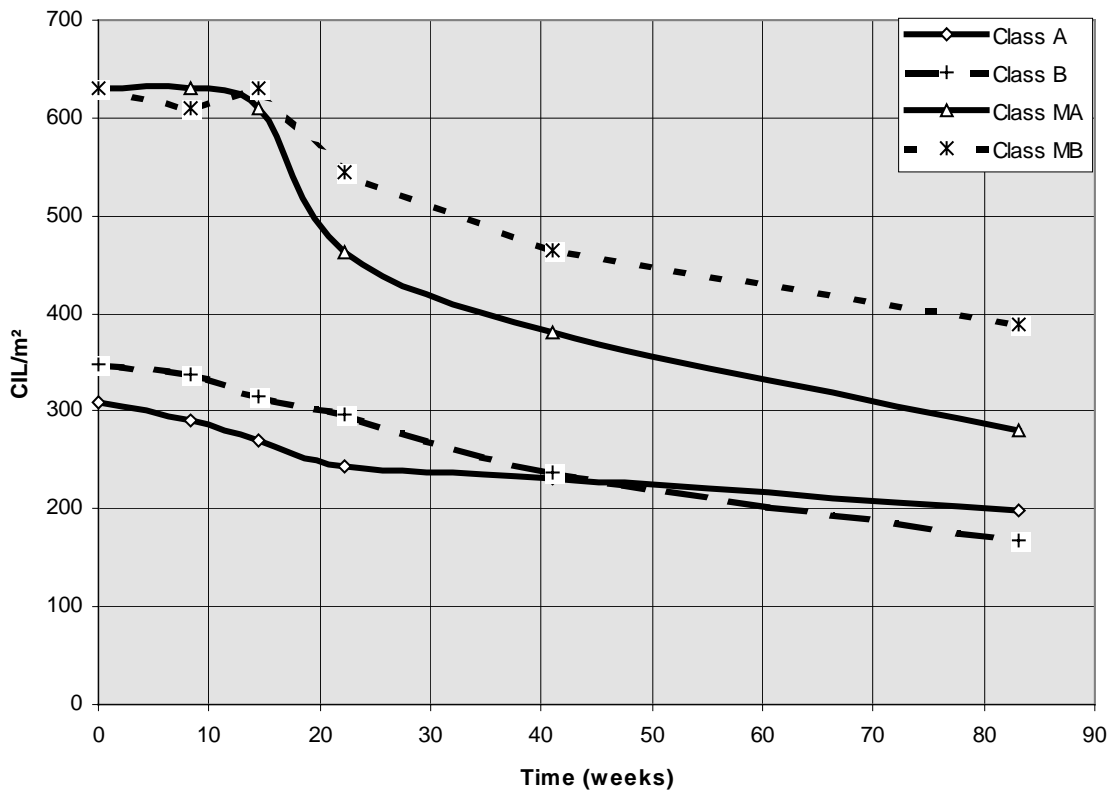


Figure 11. Urban AC. Two-Part Cold Applied Plastic. Transverse Lines. Between Wheel Paths.



Class MA and MB beads gave higher initial values than classes A or B, except in the case of waterborne paint, where class A gave higher values. These differences had a significant effect on the life of the waterborne paint and cold-applied plastic markings, but not the extruded thermoplastic. With the extruded thermoplastic most of the surface-applied beads are relatively quickly worn off under very heavy traffic, following which the retroreflectivity is largely determined by the intermix beads which are thus exposed.

(b) the rural situation.

Two trials were conducted on a major rural highway, using a number of different types of beads with waterborne paints. The trials were designed to find the effect of using different types of beads in conditions of high wear, both on new seal pavement (coarse texture) and asphaltic concrete pavement (smooth surface).

<u>Surface-applied Beads</u>	<u>Nominal Bead size</u> <u>(mm)</u>
Class A	0.15 - 0.85
Class B	0.85 - 1.4
Class B (AC07 coated)*	0.85 - 1.4
Class E20	0.425 - 1.0
Class MB*	0.6 - 1.3

*Note: *Imported beads. AC07 is a silicone coating designed to improve adhesion of beads to the paint. The code MB designates a bead of similar size to class B, but with quite different size distribution.*

(i) New seal, edgelines on curves.

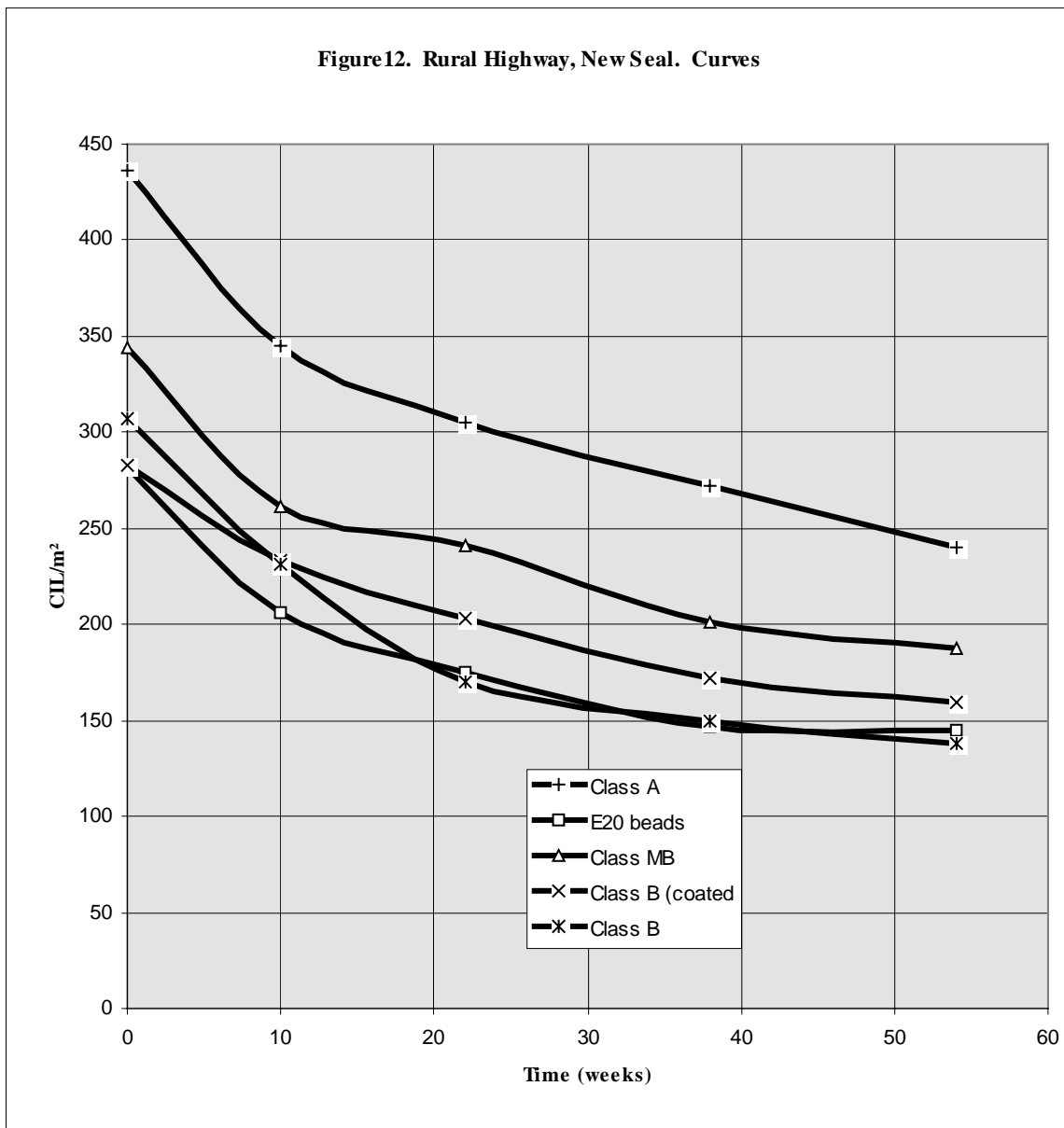


Figure 12 illustrates the rate at which the retroreflectivity decreases with time under very unfavourable traffic conditions, that is, lines applied to curves on a new seal pavement. The values plotted are raw data, showing the different initial values obtained with the different beads. The rate of loss is very similar regardless of the type of beads used, with the exception that the lines using uncoated class B beads may initially deteriorate at a slightly faster rate than any of the other beads used.

It therefore appears that the value of the *initial retroreflectivity* is the most important factor in determining the life of the applied line under these traffic conditions (provided that the paint is of adequate thickness and fully dry before traffic exposure).

(ii) Asphaltic Concrete, edgelines on curves.

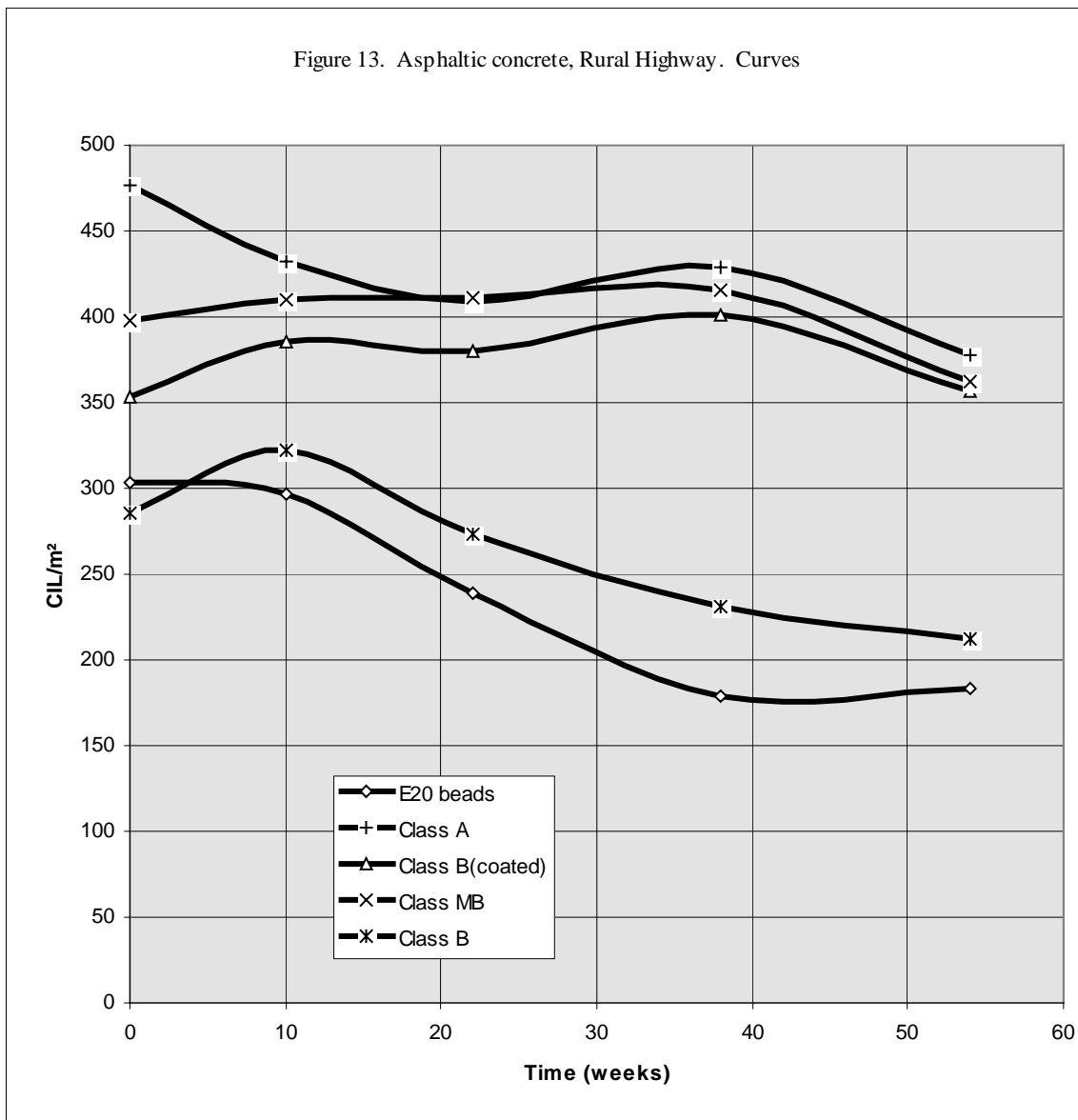


Figure 13 illustrates the rate at which the retroreflectivity decreases with time under these conditions. The values plotted are raw data, showing the different initial values obtained with the different beads. In this trial, the initial values are higher, and the rates of decrease are significantly less for the two imported beads and the class A beads.

D. DRY AND WET RETROREFLECTIVITY

Two sets of field tests were carried out to assess the performance of both class A and class B beads in wet weather. One set of tests was carried out on asphaltic concrete on a rural highway: the second set was carried out on a new spray seal pavement on a rural highway. Firstly the retroreflectivity of the dry marking was measured. Then the area was flooded with water, and the retroreflectivity measured after one minute. The two sets of measurements represent the extremes of pavement surface texture likely to be found in practice, from very smooth to very coarse.

It can be seen from Figure 14 that class A beads give adequate wet retroreflectivity on very coarse-textured pavements. This adequate performance will, however, be short-lived, because in a relatively short time, highly texture pavements become smoother due to compaction of the aggregate and repainting of the lines. On smooth-textured pavements (Figure 15) the wet performance of class A beads is markedly inferior to that of class B beads, despite the more rapid loss of class B beads. Figure 15 also shows that good bead retention of class B beads (obtained with class B coated beads) results in excellent wet retroreflectivity.

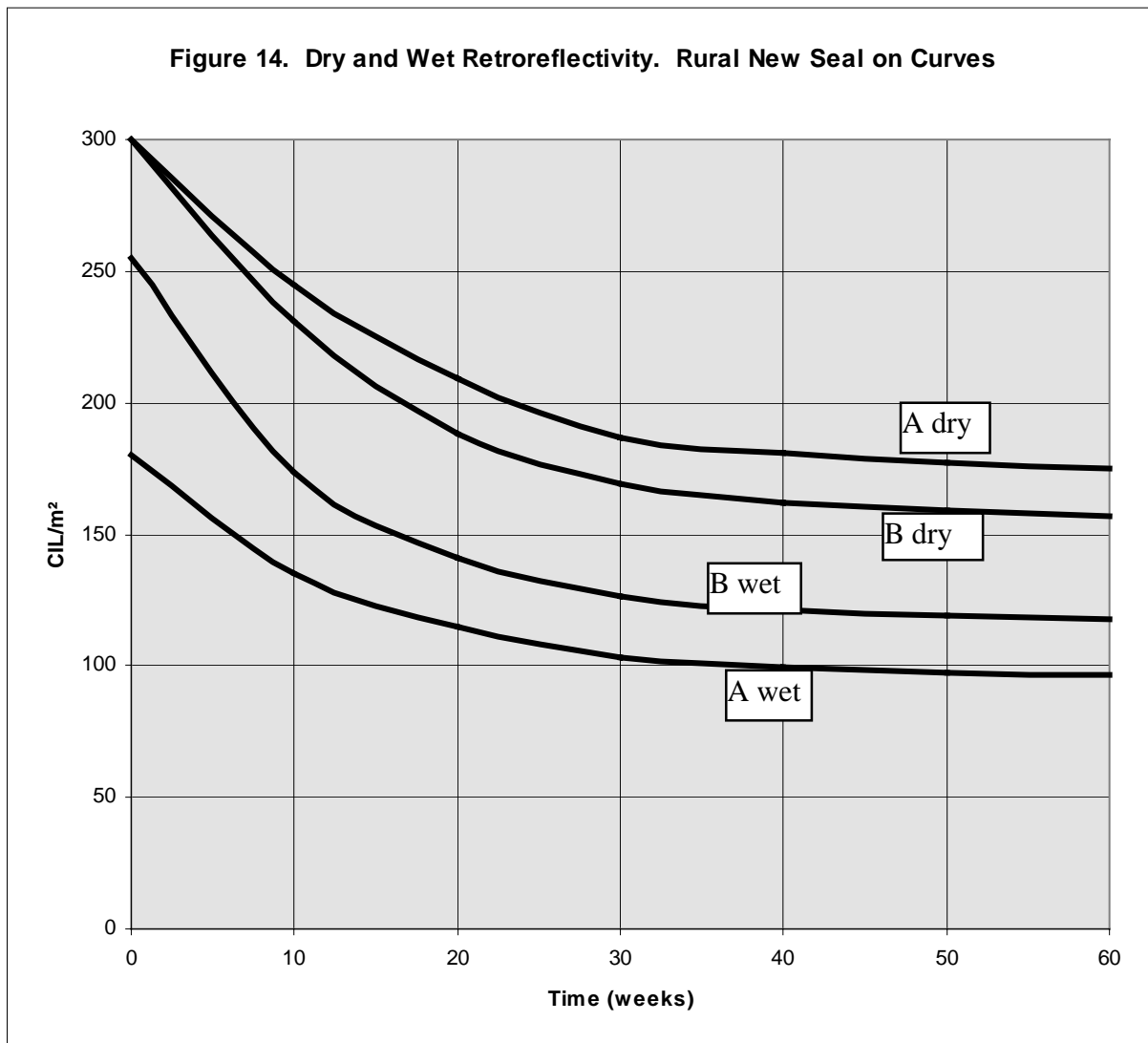
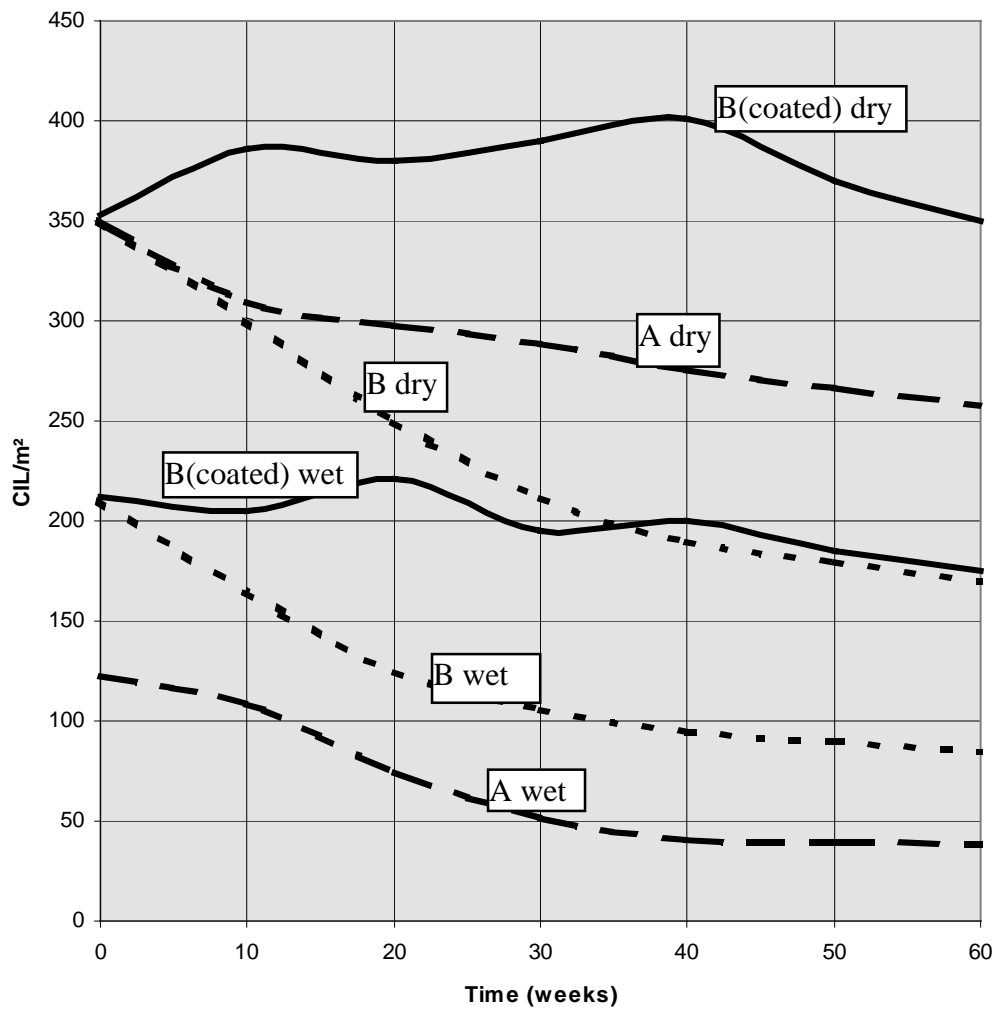


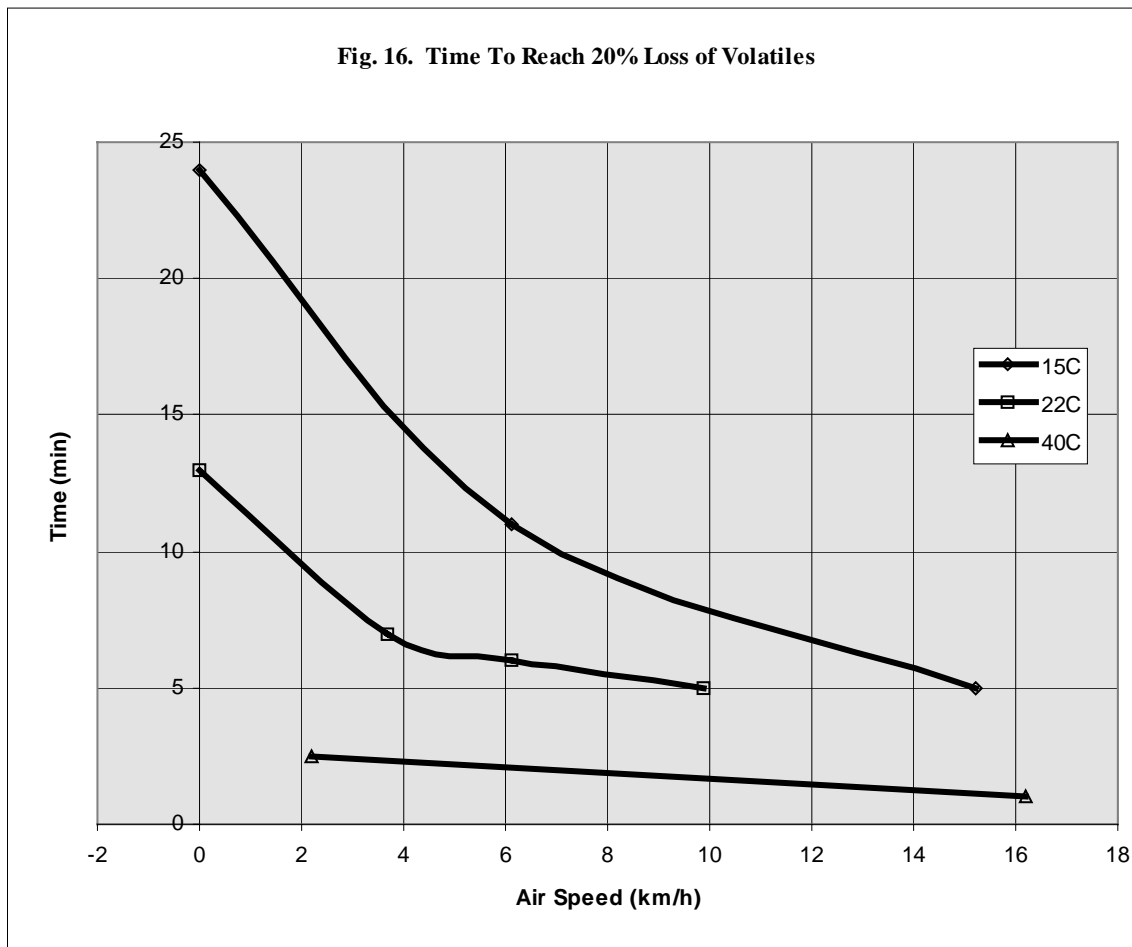
Figure 15. Wet and Dry Retroreflectivity. Rural AC on Curves



E. DRYING RATE OF PAINT AND BEAD RETENTION

1. Drying time required to avoid tracking

Laboratory tests have shown that at relative humidities between 30% to 70%, waterborne paints become dry enough to avoid tracking (no-pick-up) when about 20% of volatiles (water and other solvents) have evaporated. Figure 16 shows the time required to achieve 20% loss of volatile at various air temperatures and wind speeds as determined in laboratory tests. These test conditions are similar to that which would exist in the field on a cloudy day, or in the shade. It is expected that in full sun the times would be considerably shorter. At high humidities (above 70%) the times would be longer.



2. Drying time required to avoid bead loss

By using both mechanical thumb and scratch tests it has been estimated that for a waterborne paint to achieve sufficient hardness to retain large (class B) glass beads under traffic, approximately 80% of volatiles must evaporate. Figure 17 shows the time required to achieve 80% loss of volatiles at various air temperatures and wind speeds.

These test conditions are similar to that which would exist in the field on a cloudy day, or in the shade. It is expected that in full sun the times would be considerably shorter. At high humidities (above 70%), (and not in full sun) the times would be longer than those obtained in the laboratory tests.

It should be noted that on the “Beaufort Scale” of wind speed

light wind	0 - 11 km/hr
gentle wind	12 - 19 km/hr
moderate wind	20 - 30 km/hr

