

# An assessment of the performance of Fluorescent Retroreflective Traffic Control Devices

By the Department of Transport Engineering, SINTEF Civil and Environmental Engineering in partnership with the Norwegian Public Roads Administration and 3M Traffic Control Materials.

## *Introduction*

**This study comprises a series of separate but related investigations into the performance of different retroreflective signing materials for road traffic signs**

Specifically it outlines the performance of durable fluorescent materials in comparison with other typical signing materials used today. A variety of signing features were investigated and the methodologies employed and the results obtained are outlined in brief in this document.

The results confirm that the correct choice of signing materials can make a significant difference to sign performance. It can increase the visibility and legibility of signs, and the distance at which drivers can view and act on sign information. It is hoped that this particular study will aid those responsible for signing in making informed decisions that will ultimately improve road safety.

The results of subjective rankings by an expert panel (Phase 1), objective measurements of visibility distances of full-size signs using both older and younger drivers (Phase 2), and eye-tracking performance of subjects in real roadway environments (Phase 3) show that the visibility and conspicuity properties of fluorescent traffic control devices are significantly better than standard non-fluorescent traffic control devices. Additional traffic engineering studies (phase 4) show significant positive changes in driver behaviour in the presence of fluorescent signs.

## Phase 1

### Evaluation of fluorescent and non-fluorescent colour combinations for traffic signing applications

A number of signs were prepared using different colour combinations for the legends and backgrounds. A panel rated the colour contrast and legibility of 36 fluorescent and non-fluorescent colour combinations. All colours were presented alternately as background and legend, except black, which was used as legend only.

The table below shows how the different combinations were ranked by day against a green/brown camouflage background. Field studies have shown that 75-90% of traffic signs are seen against dark backgrounds such as trees and fields, buildings, and the roadway itself.

>> 10 best Daytime Colour Combinations<<		
Background	Legend	Ranking
FI Yellow-Green	Black	1
FI Yellow	Black	1
FI Yellow	Red	3
Yellow	Black	3
FI Yellow-Green	Blue	5
Yellow	Blue	6
FI Yellow-Green	Red	7
Blue	FI Yellow	7
Red	FI Yellow	9
Blue	Yellow	10
-	-	-
*White	Black	16

### Phase 1 – Summary of Results

The results of Phase 1 show fluorescent yellow and fluorescent yellow-green signs with dark legends ranked the highest during daytime.

## ***Phase 2***

### **Study of the daytime and night-time visibility performance of fluorescent and non-fluorescent traffic signs using full size signs and realistic viewing distances**

In this phase, three standard sign designs (chevron, directional arrow, text information) were made up in order to directly compare the visibility performance of fluorescent and non-fluorescent traffic signing materials using full size signs and realistic viewing distances.

A controlled field experiment was conducted on a flat and straight railway track using specially modified railway cars equipped with a windshield and automobile headlights. The subjects' position relative to the two headlights when viewing the signs was the same as for a driver in a standard motor car on the road. Measurements were made of the distances that individuals would detect a sign, then correctly recognise its shape, colour and symbol in day and night-time driving conditions. A representative sample of the driving public including vulnerable groups, notably younger and older drivers took part in the experiment.

Two types of sign materials were used for the daytime trials. Combined performance 3M™ Scotchlite™ Diamond Grade™ Fluorescent Reflective Sheeting and the equivalent, but non-fluorescent version of the same Diamond Grade material having the same optical design. Combined performance materials offer the benefits of retroreflective performance for night-time visibility and durable fluorescence to enhance daytime conspicuity. In the night-time trials signs made from Scotchlite high intensity grade reflective sheeting and Scotchlite engineer grade reflective sheetings were also evaluated.

The results for Phase 2 which include the various combinations of driver age, sign designs/materials, and light conditions are too lengthy to reproduce here in full. The following results for yellow and black text information signs are illustrative of the most significant findings of the study.

## Daytime results

### Key

DG > Diamond Grade reflective sheeting

DG Fluor > Diamond Grade fluorescent reflective sheeting

HIS > Scotchlite high intensity grade reflective sheeting

EG > Scotchlite engineer grade reflective sheeting

<b>&gt;&gt; Daytime – Yellow background with black text &lt;&lt;</b>						
<b>Distance in metres at which sign was</b>						
<b>Driver Age</b>	<b>Material Type</b>	<b>Conditions</b>	<b>Detected</b>	<b>Shape determined</b>	<b>Colour identified</b>	<b>Text read</b>
<b>elderly</b>	DG Fluor	day	700	661	510	105
<b>elderly</b>	DG	day	684	571	469	101
Distance (m) gained by use of DG Fluor			16	90	41	4
Extra reaction time (seconds) at 100km/h			0.6	3.2	1.5	0.1

<b>&gt;&gt; Daytime – Yellow background with black text &lt;&lt;</b>						
<b>Distance in metres at which sign was</b>						
<b>Driver Age</b>	<b>Material Type</b>	<b>Conditions</b>	<b>Detected</b>	<b>Shape determined</b>	<b>Colour identified</b>	<b>Text read</b>
<b>young</b>	DG Fluor	day	812	756	657	123
<b>young</b>	DG	day	773	699	612	131
Distance (m) gained by use of DG Fluor			39	57	45	(8)
Extra reaction time (seconds) at 100km/h			1.4	2.1	1.6	(0.3)

## Night-time results

The tables below compare the effectiveness of combined performance Diamond grade reflective sheetings in comparison with traditional materials such as high-intensity and engineer grade sheetings.

<b>&gt;&gt; Night-time – Yellow background with black text &lt;&lt;</b>						
<b>Distance in metres at which sign was</b>						
<b>Driver Age</b>	<b>Material Type</b>	<b>Conditions</b>	<b>Detected</b>	<b>Shape determined</b>	<b>Colour identified</b>	<b>Text read</b>
<b>elderly</b>	DG Fluor	night	815	671	452	81
<b>elderly</b>	HIS	night	713	522	265	65
Distance (m) gained by use of DG Fluor			102	149	187	16
Extra reaction time (seconds) at 100km/h			3.7	5.4	6.7	0.6
<b>elderly</b>	DG Fluor	night	815	671	451	81
<b>elderly</b>	EG	night	628	383	186	52
Distance (m) gained by use of DG Fluor			187	288	266	29
Extra reaction time (seconds) at 100km/h			6.7	10.4	9.6	1.0

<b>&gt;&gt; Night-time – Yellow background with black text &lt;&lt;</b>						
<b>Distance in metres at which sign was</b>						
<b>Driver Age</b>	<b>Material Type</b>	<b>Conditions</b>	<b>Detected</b>	<b>Shape determined</b>	<b>Colour identified</b>	<b>Text read</b>
<b>young</b>	DG Fluor	night	849	750	481	95
<b>young</b>	HIS	night	829	603	379	81
Distance (m) gained by use of DG Fluor			20	147	102	14
Extra reaction time (seconds) at 100km/h			0.7	5.3	3.7	0.5
<b>young</b>	DG Fluor	night	849	750	481	95
<b>young</b>	EG	night	720	442	223	80
Distance (m) gained by use of DG Fluor			129	308	258	15
Extra reaction time (seconds) at 100km/h			4.6	11.1	9.3	0.5

## Phase 2 – Summary of Results

Durable Diamond Grade fluorescent sheeting traffic signs show highly significant increases in both daytime and night-time sign detection and shape recognition distances when compared with non-fluorescent high-intensity and engineering grade signs of identical size and design.

The daytime visibility distances increased for both elderly and younger adults with the greatest increases being found for the elderly adults.

In general the results for text legibility were positive, although they were not statistically significant in this phase of the study.

### Examples

- An elderly driver travelling at a speed of 100km/h would be able to correctly recognise a combined performance Diamond Grade sheeting sign 3.2 seconds (90 metres) earlier than the equivalent non-fluorescent sign during daytime.
- At night the elderly driver would be able to recognise the Diamond Grade fluorescent sheeting sign 5.4 seconds (149 metres) earlier than a high-intensity sign and 10.4 seconds (288 metres) earlier than an engineering grade sign.
- Younger drivers with better eyesight detect and recognise signs at greater distances than older drivers. However, they would still benefit during daytime, when travelling at 100km/h, by having an extra 2.1 seconds reaction time (57 metres) when viewing the combined performance Diamond Grade sheeting sign, compared with its non-fluorescent equivalent.
- At night the younger driver can benefit, when viewing the combined performance Diamond Grade sheeting sign, from an extra 5.3 seconds reaction time (147 metres), compared with a high-intensity sheeting sign, or an additional 11.1 seconds reaction time (308 metres) when compared with an engineering grade sign.

## **Phase 3**

### **Study of the conspicuity of fluorescent and non-fluorescent traffic control devices in normal traffic using in-vehicle eye-tracking**

Eye-tracking studies have been used in transportation safety research for a number of years. This method provides detailed information about where the driver is actually looking while driving in real traffic. Subjects with eye-tracker equipment drove during daytime through and 8.8 kilometre test route before and then again after replacement of all the existing ordinary traffic signs (a total of 29 individual signs) with fluorescent versions of the same signs.

For the first test-drive the signs were faced with high-intensity grade or engineer grade sheeting; for the second drive-through the signs were all made with combined performance Scotchlite™ Diamond Grade™ Fluorescent VIP Reflective Sheeting. The test subjects were all licensed drivers with normal colour vision, and visual acuity. They knew they were part of an experiment, but they were told that the purpose was to test the eye-tracking equipment for use in traffic safety research. The results, which follow, use the term “first fixation distance”. This is the distance the driver is from the sign at the instant that the driver’s eye first looks at that sign.

### **Phase 3 – Summary of Results**

The analysis of the results show that in all cases the fluorescent signs were first looked at by the driver at greater distances than their non-fluorescent counterparts. The mean first fixation distance for the fluorescent signs was 130 metres versus 75 metres for the non-fluorescent signs. For a driver travelling at 80km/h this 55 metres fixation distance difference translates into an additional 2.5 seconds of decision and reaction time. In addition, it was found that fewer fluorescent signs were missed (not fixated on) by the test subjects. The eye-tracking data illustrates that, for these drivers, the fluorescent signs are more conspicuous during daytime (fixated earlier) than ordinary signs.

## **Phase 4**

### **Traffic engineering studies of driver attention and behaviour before and after replacement of conventional non-fluorescent traffic signing with fluorescent retroreflective signs**

A series of before and after traffic engineering field studies were conducted on public roads to investigate the effect of fluorescent signs on driver behaviour in real traffic situations. Measurements were conducted at several test sites, including road work sites, before and after replacement of the existing high-intensity and engineer grade traffic signing with combined performance Diamond Grade fluorescent VIP signing. Vehicle speed and speed distribution were measured. Roadside interviews of drivers were also conducted to measure their perception of the signs. The following examples illustrate the results of the traffic engineering studies and driver surveys.

#### **Example 1 – Effect of fluorescent signs in a high accident area**

The first test site was within a 7.7 kilometre stretch of winding mountain road near Soknedal with many sharp curves that had previously been identified as high accident area. The existing traffic signs made from Diamond Grade fluorescent VIP sheeting. Stage 1 saw replacement of all existing chevrons with chevrons of identical size and shape but faced with Diamond Grade fluorescent yellow VIP sheeting. The second stage saw the replacement of all other warning and regulatory signs along the test route with Diamond Grade fluorescent yellow-green VIP versions of the same signs.

The Soknedal results demonstrate a decrease in both average speed (2.3km/h) and 85<sup>th</sup> percentile speed (2.0km/h) simply by the replacement of the standard yellow high-intensity chevrons with the Diamond Grade fluorescent yellow VIP equivalents. The replacement of all the remaining warning and regulatory signs with the fluorescent signs resulted in an additional drop in vehicle speeds.

#### **Example 2 – Effect of fluorescent signs in a roadworks zone**

The Bratsberg site was an example of temporary roadworks with the introduction of a reduced speed limit, and involved the replacement of the conventional temporary roadwork signs with identical signs made from combined performance Diamond Grade fluorescent VIP sheeting.

The statistical analysis of the speed measurements at these roadworks shows a highly significant decrease in vehicle speeds of 1.6 to 3.3km/h after the combined performance Diamond Grade signing was put into place.

The data also shows a change in the vehicle speed distribution. Drivers exhibited lower speeds as they approached the roadworks and better compliance with the lower roadworks speed limit.

### **Example 3 – Driver perceptions of fluorescent signs based on roadside interviews**

With the assistance of the local police almost 500 interviews were conducted of randomly selected drivers who were stopped just after they had passed through the test sites. The purpose of the interviews was to capture whether the road users had noticed the change in signing.

When the combined performance Diamond Grade fluorescent VIP sheeting signing was in place, 89% of drivers rated the signs as conspicuous compared with only 68% of the conventional signs. When asked about the legibility of the signs (“how distinct was the text and symbols on the signs?”), more than twice as many drivers rated the signs as ‘very distinct’ when the fluorescent signs were in place (43%) compared to the conventional signs (20%).

At the Soknedal site, 17% of drivers reported seeing chevron signs when the fluorescent yellow chevrons were in place while only 2% of drivers recalled chevrons signs when the ordinary yellow chevrons were in place.

# Conclusion

## The four phases of this SINTEF study considered different aspects of sign performance

**Phase 1** of the study showed that the colour contrast of fluorescent signs is superior to that of non-fluorescent signs based on subjective analysis. The effect is most pronounced in daytime conditions. Black legends on fluorescent yellow or fluorescent yellow-green background are ranked highest for colour contrast and legibility.

As **Phase 2** showed, combined performance signs also outperform non-fluorescent signs in terms of detection and shape recognition at a distance. Elderly adults in particular recognise the shape of fluorescent signs on average 3.2 seconds (90 metres) earlier, when travelling at a speed of 100km/h, than they recognise non-fluorescent signs. At night, signs with combined performance Diamond Grade fluorescent VIP sheeting exhibit superior visibility than conventional high-intensity or engineering grade signs.

The eye-tracking study conducted in **Phase 3** showed that fluorescent signs are more conspicuous as indicated by their substantially greater first fixation distances. Whereas Phase 2 showed that drivers are able to see fluorescent signs at greater distances, Phase 3 demonstrates that drivers actually do detect fluorescent signs at greater distances.

The beneficial effects of fluorescent traffic signing were demonstrated in actual roadway situations in **Phase 4** of the study. The results show that drivers respond more appropriately, in a shorter time, when the signs are made from combined performance Diamond Grade materials. Studies have shown that speed reductions in critical road situations can be linked to reductions in collisions and also that speed reductions in critical road situations can be directly linked to the reduction in the severity of pedestrian injuries when road accidents occur. Roadside interviews indicated that fluorescent signs make a greater cognitive impression on drivers than ordinary signs as shown by the higher percentage of drivers being able to remember what traffic signs they had just passed on the road.

The results of this SINTEF project clearly demonstrate that the visual properties of combined performance (fluorescent and retroreflective) signs are strong enough to have a significant influence on driver attention and behaviour. Taken together, the results show that the visibility and conspicuity properties of fluorescent retroreflective signs can have a positive impact on driving behaviour in real traffic situations. Fluorescent retroreflective signs provide drivers with more time – time to see, time to think and decide, and time to act – which should result in improved safety on the roadway. The results of this SINTEF study make a compelling case for using combined performance 3M™ Scotchlite™ Diamond Grade™ Fluorescent VIP Reflective sheeting for important traffic signing wherever possible.