Motor Vehicle and Pedal Cycle Conspicuity

Part 3: Retro-reflective and Fluorescent Materials - Disability Glare of Red Markings

Project Number 9/33/13

Undertaken on behalf of

The Department of Environment, Transport and the Regions (DETR)

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1.0 Aim

The aim of the assessment was to determine if the application of retro-reflective red material to the rear face of heavy and long vehicles and their trailers would mask the detection of the stop lamp signal. Stop lamp conspicuity is dependent upon the key characteristics of colour (red) and luminous intensity (up to 100cd). The placement of high performance retro-reflective red material in close proximity to the stop lights may reduce their conspicuity since the material would reduce both the colour and luminance contrast of the stop lamp.

2.0 Methodology

2.1 Introduction

Two tests were devised to measure the extent of the effect of the retro-reflective material on the detection of the stop lamp. Test 1 was designed to determine if drivers could distinguish between both the stop and tail lamps, or the tail lamp only, being on in the presence of the material. This would replicate the scenario where a driver, having looked in the rear view mirror, returns their attention to the truck which they are following and has to determine if the stop lamps have been applied in the intervening period. This was considered to be a difficult task since the driver would not have observed the change in state of the stop lamp from off to on, but would have to make an absolute judgement as whether the intensity of red light emitting from the truck was greater than just that of the tail light.

Test 2 similarly had the aim of detecting the stop lamp in its on state but this time it replicated the scenario where the driver's visual attention had been diverted from the truck to the opposite kerbside (as though a pedestrian was about to step out). Thus although the driver was not looking directly at the truck, there would be an awareness of it in their peripheral vision.

2.2 Variables

Both studies were conducted in the hours of darkness at a local test site. A rig was built to represent the rear of a truck and a light board containing off-the-shelf truck lights was mounted at 1.1m from the ground. A 2m long, 50mm wide strip of red retro-reflective material, of the reflective performance defined by the Draft Regulation, was positioned horizontally at 0mm separation above the stop lamps. It was moved vertically in successive 50mm increments to a separation distance of 300mm. This permitted testing above and below the 6” (150mm) material to lamp separation recommended by Olson et al 1992 and Ziedman et al 1981.

A worst case scenario was replicated in which the lights would appear at their dimmest and the material at its brightest. Using data from Cobb 1990 which measured the on-road performance of vehicle lamps, the tail lamp intensity was set at 2cd and the stop lamp intensity at 20cd. The viewing distance from the driver to the truck was 135m which was within the range where the materials would be viewed at their brightest and accommodated the 70mph stopping distance of 96m. The truck rig was viewed under main beam since it is feasible that a driver may find himself behind a truck in such a situation, and may have to make decisions in the scenarios described. Vehicle lights from a road passing behind the test rig added visual noise to the test scene similar to that encountered on the road.

2.3 Subjects / Participants

14 male and 6 female drivers aged between 22 and 75 participated in the study. 10 participants were young (less than 45 years old) and 10 were old (more than 60 years old).

2.4 Procedure

For Test 1, the participant was positioned in the drivers seat of a Ford Mondeo which was directly behind the truck rig at a distance of 135m from it. The participant was instructed to look into their laps until the experimenter instructed them to look up. On giving this instruction, the experimenter started a timer and the participant looked along the test site to the truck rig. The participant had to make a decision, as quickly as possible, as to whether the stop lamps were on or not and report their response to the experimenter. On hearing the response the experimenter stopped the timer and recorded the nature of the response and the time taken to give it. The participant then looked down and awaited the next instruction to look up. This was undertaken ten times but in only half those instances was the stop lamp on. When the ten repetitions had been completed the participant was instructed to rest briefly whilst the next condition was set up. The initial condition was that of no material, followed by the material being placed directly adjacent to the lamps at 0mm and then in successive 50mm increments. As soon as the same number of correct identifications had been obtained for two successive conditions as for the initial condition in which no material was present, the test was stopped.

For Test 2, the participant was again seated in the drivers seat of a Ford Mondeo but this time they were instructed not to look directly at the truck but instead to offset their line of gaze in the order of 5°. The participant had to maintain their offset gaze throughout each condition but were prompted at 8-10 second intervals that the stop lamp may come on. At each prompt the participant had to be aware that the stop lamp may be activated at some time over the next 8 seconds. Ten repetitions were undertaken with the stop lamp being activated for half those instances. On the occasions when it was activated, a time delay was incorporated varying from 0-4 seconds. A second experimenter activated the stop lamp, after the given time delay, which in turn started a timer. If the participant noticed the stop lamp coming on, they had to call out to the main experimenter, who stopped the clock and recorded the time.

3.0 Results

3.1 Test 1

The aim of the test was to identify the level of material-lamp separation at which the stop lamps were correctly detected as on or off with the same degree of accuracy as for the ‘no material’ condition. A safety check was included by requiring that this was achieved for two successive separation conditions so reducing the possibility that the first incidence of the correct matching of responses was due to chance.

The graph below shows the level of material-lamp separation at which participants identified the stop lamp status with the same degree of accuracy as for the no material conditions. For three-quarters of the subjects the material appeared to have no effect at all since the number of times they correctly identified the stop lamp as on or off was the same for the material at a separation of 0mm, i.e. directly adjacent to the stop lamp as for the no material condition. For three subjects a vertical separation of 50mm was required and for the remaining two, a separation of 100mm was needed. This data would suggest that for a vertical separation distance of 100mm between the lamp and the material all subjects could identify the status of the stop lamp with the same degree of accuracy as if no material was present.

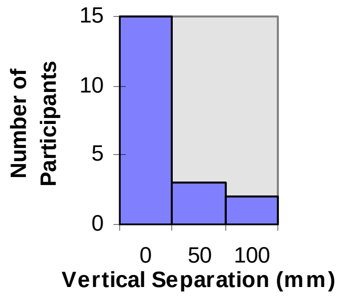

Fig.1: Graph to show the minimum level of material-lamp separation at which participants matched their no-material detection rates

However, whilst the subjects may have been as accurate at their given separation distances as for the no material condition, it is important to note any effect on their decision time. Correctly identifying if the stop lamp is on or off with the same degree of accuracy as for the no material condition can still be detrimental to road safety if it takes drivers longer to arrive at those correct decisions. Further analysis of the participants response times was therefore undertaken to investigate this factor.

The reaction time data was analysed by comparing the time taken to respond when the material was at the different separation distances with the reaction time in the no material condition. The reaction time for correctly detecting the stop lamp as on (termed a ‘hit’), was analysed separately from the time to correctly detect the stop was off (termed a ‘correct rejection’).

Analysis of the participants' hit reaction time is illustrated in graph 2 below. This confirms that for over half of the subjects there was no significant difference in the time taken to identify a stop lamp as on when the material was at 0mm compared to when there was no material in place at all. However there were four subjects who correctly identified the stop lamps as on for two successive conditions, but were affected by the presence of the material to the extent that the time taken to confirm the lamp as on was always significantly longer in the presence of the material.

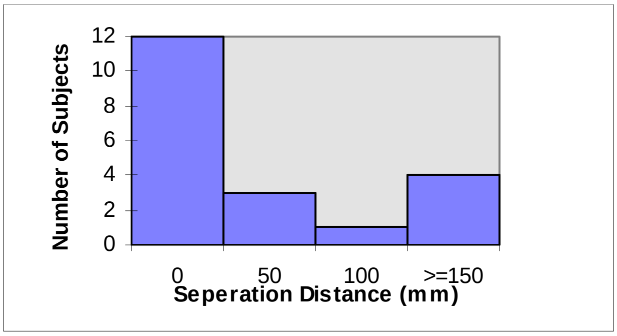

Fig.2: The minimum level of separation at which the material did not affect the correct detection time of an ON stop lamp

Analysis of the participants' correct rejection reaction time i.e. the time it took them to correctly confirm that the stop lamp was off, is illustrated in graph 3 below. This shows that, compared to the hit reaction times, only a quarter of the participants were unaffected by the material when it was placed at 0mm from the lamp. Similarly six, compared to four, participants who were always able to distinguish off from on were so affected by the presence of the material that the time taken to confirm the lamp as off was always significantly longer than when the material was present.

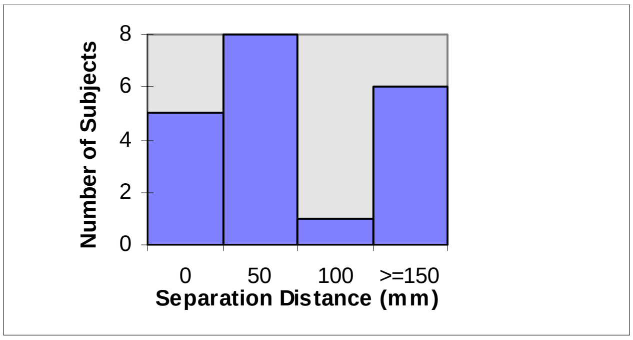

Fig.3: The minimum level of separation at which the material did not affect the correct detection time of an OFF stop lamp

3.2 Test 2

The aim of the test was to identify the level of material-stop lamp separation at which the stop lamps were correctly detected as on or off with the same degree of accuracy as for the ‘no material’ condition. This was conducted for the situation when the participants were not directly observing the stop lamps. When there was no material present, all the participants were able to distinguish with complete accuracy between the stop lamp being on and off i.e. all participants obtained all 5 hits (i.e. correctly identified the stop lamp as being on when it was on) and all obtained all 5 correct rejections (i.e. correctly identified the stop lamp as being off when it was off).

Since the material must not interfere with the detection of the stop lamp it is important to know at what level of material-lamp separation, the hit and correct rejection rates obtained in the no material condition are matched. In terms of the number of hits there are significantly fewer correct identifications when the material-lamp separation is 0mm, 50mm and 150mm. At 200mm and above there is no difference in the number of correct identifications of the stop lamp as on compared to the no material condition. See Table 1.

Table 1: Mean number of correct detection for an ON stop lamp

Subject	Material condition							
	None	0mm	50mm	100mm	150mm	200mm	250mm	300mm
1	5	No data	4	5	4	4	4	5
2	5	5	5	5	5	5	5	5
3	5	5	4	5	4	5	5	5
4	5	3	5	5	5	5	5	5
5	5	5	5	5	5	5	5	4
6	5	5	5	5	5	5	5	5
7	5	5	5	5	5	5	5	5
8	5	4	3	5	2	4	4	3
9	5	5	4	5	4	4	5	5
10	5	3	4	5	5	5	5	5
11	5	5	5	5	5	5	5	5
12	5	5	5	5	5	5	5	5
13	5	5	5	4	5	4	5	5
14	5	2	3	3	3	0	1	3
15	5	5	3	5	4	4	3	1
16	5	5	5	5	5	5	5	5
17	5	5	5	5	5	5	5	5
18	5	5	5	5	4	5	5	5
19	5	4	4	4	4	5	5	5
20	5	5	5	5	5	5	5	5
Mean	5	4.53	4.45	4.80	4.45	4.50	4.60	4.55
T-test compared to no material condition		0.03	0.00	0.10	0.01	0.07	0.09	0.07

In terms of the number of correct rejections i.e. the number of times that the stop lamp is correctly identified as being off, the material appears to have no effect at all; whatever the material-lamp separation distance, the number of correct rejections does not differ significantly from the no material condition. See Table 2.

Table 2: Mean number of correct detection times for an OFF stop lamp

Subject	Material condition							
	None	0mm	50mm	100mm	150mm	200mm	250mm	300mm
1	5	No data	5	5	5	5	5	5
2	5	5	5	5	5	5	5	5
3	5	5	5	5	5	5	5	5
4	5	5	4	5	5	5	5	5
5	5	5	5	5	5	5	5	5
6	5	5	5	5	5	5	5	5
7	5	5	5	5	5	5	5	5
8	5	5	5	5	5	5	5	5
9	5	5	5	5	5	5	5	5
10	5	5	5	4	4	5	5	5
11	5	5	5	5	5	5	5	5
12	5	5	5	5	5	5	5	5
13	5	5	5	5	5	5	5	5
14	5	5	5	5	4	5	5	5
15	5	5	5	5	5	5	5	5
16	5	5	5	5	4	5	5	5
17	5	5	5	5	5	5	5	5
18	5	5	5	5	5	5	5	5
19	5	5	5	5	5	5	5	5
20	5	5	5	5	5	5	5	5
Mean	5	5	4.95	4.95	4.85	5	5	5
T-test compared to no material condition		No difference	0.33	0.33	0.08	No difference	No difference	No difference

However, as for Test 1, it is important to take into account the effect of the material on the time taken to make the decision when determining suitable levels of separation. Due to the design of the test, it was only appropriate to record reaction times for the number of hits. Analysis of this data indicates that at material-lamp separation distances of 0mm, 50mm and 100mm it takes significantly longer to correctly identify the stop lamp coming on compared to the no material condition. However for separation distances of 150mm and greater, there is no difference in the time to correctly detect the stop lamp compared to the no material condition. See Table 3.

Table 3: Correct detection times for an ON stop lamp

Subject	Material condition							
	None	0mm	50mm	100mm	150mm	200mm	250mm	300mm
1	1.36	No data	1.88	2.09	2.03	1.60	1.44	2.28
2	1.74	1.48	1.19	1.97	1.15	1.29	1.38	1.24
3	1.87	1.61	2.34	1.86	1.35	1.33	1.34	1.42
4	1.13	1.13	1.10	1.15	1.02	0.97	1.46	0.93
5	1.56	2.68	1.85	2.69	1.91	1.38	1.49	1.90
6	1.24	1.53	1.42	1.57	1.33	1.36	2.01	1.38
7	1.05	0.97	0.89	0.98	0.80	1.02	0.92	0.96
8	1.24	1.40	1.19	1.18	1.40	1.28	1.19	1.21
9	1.41	2.29	2.03	2.20	2.01	1.61	1.78	1.64
10	0.95	1.14	1.80	1.00	0.92	0.92	1.00	0.97
11	0.93	1.68	1.23	0.92	0.99	0.93	0.99	0.84
12	0.84	1.12	1.73	1.00	0.88	1.29	0.94	0.91
13	0.89	0.95	0.92	1.01	0.92	1.17	0.97	0.89
14	1.00	1.44	0.99	1.12	1.03	No data	1.45	1.03
15	1.07	1.39	1.05	1.98	1.28	1.35	1.16	1.87
16	1.02	1.85	1.35	1.14	1.10	1.06	1.20	1.11
17	1.00	0.85	0.87	0.85	0.84	0.85	0.79	0.83
18	0.93	1.24	1.37	1.23	1.49	1.86	1.51	1.45
19	1.11	1.13	1.21	1.24	1.23	1.53	1.28	1.24
20	1.29	1.64	1.37	1.27	1.59	1.74	1.72	1.48
Mean	1.18	1.45	1.39	1.42	1.26	1.29	1.30	1.28
T-test compared to no material condition		0.01	0.02	0.01	0.28	0.22	0.10	0.23

4.0 Conclusions

To ensure that the addition of red retro-reflective material does not detract from the conspicuity of the stop lamps, the separation distance between the material and the lamp must be such that the rate of detecting the stop lamp is equivalent to that of the no material condition.

The results of Test 1 suggest that, in terms of the number of times that the stop lamp is correctly reported as being on or off, the material-lamp separation should be a minimum 100mm. However, when an allowance is made for the time taken to make these responses, a separation distance of 200mm would be more appropriate.

The results of Test 2 suggest that in order to maintain the same number of correct identifications of the ‘on’ stop lamp as in the no material condition, the minimum material-lamp separation should be 200mm. This separation distance would also accommodate the number of correct identifications of the ‘off’ top lamp since these could be accommodated by a separation of 0mm. If account is taken of the time to correctly identify the ‘on’ stop lamps, a minimum separation distance of 150mm is suggested.

Taking these results as a whole it would seem prudent to suggest a minimum material-lamp separation distance of 200mm. This would accommodate both the *numbers* of responses and the *time taken* to make them under the conditions of looking directly at the truck (Test 1) and observing it in the visual periphery (Test 2).

5.0 References

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