Innovative Technologies for High-Speed Roads
Moscow (Russia) - 13 October 2015

Novel technologies for Traffic Sign production and Best Practices related to Road Safety

Boris Nekrasov,
3M Russia

Presentation Plan

1. **Best Practices on usage of modern traffic signs:**
   1.1. Enhancing traffic safety in Black spots;
   1.2. Information systems on roads;
   1.3. Driver's needs and 3M response to meet these needs
2. **Reflection of modern requirements to traffic signs in National Standards**
3. **Novel technologies for traffic sign production**

1. Best practices on usage of modern traffic signs and other TCDs

Traditional View:

Modern Traffic Control Devices (TCDs) are used for Traffic Control Purposes

Wider View:

Modern TCDs can enhance traffic safety and give other economic benefits to the society

The second view is more important

1.1. Enhancing traffic safety in Black Spots

In Y2009 the RADOR working group on traffic safety initiated the following project:

«Analise effectiveness of low-cost measures to increase traffic safety in black spots on roads»

Methodology used in the project

The assessment of effectiveness of any traffic safety measure in black spots is implemented by criteria B/C (Benefit/Cost ratio):

R = B/C, where

C - Costs to implement the measure, RUR

B – Benefits, RUR - the reduction of socio-economic losses because of traffic accident reduction

Socio-economic losses are calculated as:

- Losses due to people killed & injured in traffic accidents;

- Losses due to damage of vehicles & goods;

- Losses due to damage of road infrastructure

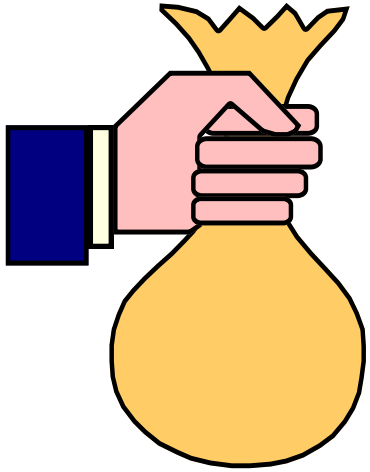
(The methods for socio-economic losses assessment are different in different countries.

The methods developed by NIIAT in Y2007 were used in this project

Economic approach on choosing measures in Black Spots:

The following question lays in the base of choice:

How to utilize the limited financial recourses in the most effective way?



Cost-Effective Measures in Spain

Measure	B/C	Payback Months
1 Marker posts with reflective materials	24.94	0.5
2 (1) on entering points	12.91	0.9
3 Retroreflective poles	11.13	1.0
4 (5) + road barriers	8.62	1.4
5 Warning signs on curves	5.76	2.1
6 (10) + warning signs on curves	5.11	2.4
7 Removing water from the surface	4.47	2.7
8 Road bumps (speed reducers)	4.43	2.7
9 Noise lanes	4.15	2.9
10 Traffic Signs reinstallation	3.88	3.1
11 Road barriers	3.87	3.1
12 (2) + road barriers	3.81	3.1
13 Elongation of transitional lanes	2.95	4.1
14 increasing Skid coefficient	0.40	30
15 Some road profile changes	0.25	48
16 Intersection modernization	0.20	60
17 Reconstruction of entering points	0.20	60
18 Surface treatment on transitional lanes	0.18	67
19 Intersection reconstruction	0.16	75
Average	**2.10**	**5.7**

Note: **In Orange: measures where retroreflective materials were used**

UK

Category	# projects	Av Cost £	Acc Red %	% FYRR	B/C Ratio
Antiskid surface	34	8620	37	392	4,9
Pavement Marking	43	2020	34	957	10,6
PM + Signs	63	2537	41	820	9,2
Safety Islands	65	10387	37	259	3,6
Warning Signs	**36**	**553**	**46**	**3491**	**35,9**
New Traffic Signals	15	40732	67	153	2,5

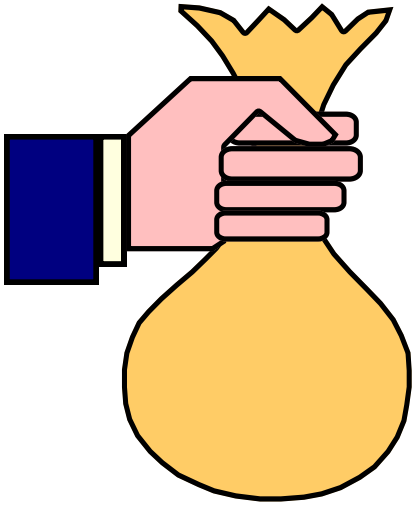
Highway Safety Improvements with the highest cost-benefit ratios, 1974 - 1995

Rank	Improvement Description	Benefit-Cost Ratio
1	Illumination	26,8
2	Upgrade Median Barrier	22,6
3	**Traffic Signs**	**22,4**
4	Relocated/Breakaway Utility Poles	17,7
5	Remove obstacles	10,7
6	New Traffic Signals	8,5
7	Impact Attenuators	8,0
8	New Median Barrier	7,6
9	Upgrade Guardrail	7,5
10	Upgrade Traffic Signals	7,4

Source: *Federal Highway Administration, US Dep. of Transportation*

Economic approach on choosing measures in Black Spots:

When the financial recourses are limited the most effective measures from the upper part of the tables are chosen first and then, provided the recourses are still available, the other measures are chosen from the lower part of the table



The main Goal:

To ensure the most effective usage of the limited recourses in terms of providing the maximum possible reduction of traffic accidents

The project main goals & scope:

- **On the base of foreign experience to implement a project on testing effectiveness of different traffic safety measures in black spots on roads**

- **2 regional & 4 federal road authorities supported the project: (Republic of KOMI, Perm' Krai, Federal Road Directorates of «Central Russia », «Sevzapuprdor» , Moscow – N. Novgorod & «Volgovyatskupravtodor».**

- **The project was implemented within Y2009/2010 (financial crisis). Due to lack of recourses the project was limited by mainly installation of special traffic signs in black spots**

Description of signs installed

The majority of black spots were equipped with special traffic signs according to STO 05204776.01-2008 FGUP Rosdornii:

- 2 special warning boards;

- If there were was clearly known the reasons of traffic accidents within the particular black spot then the additional standard signs on yellow-green boards were also installed.

The modern reflective & fluorescent materials were used for manufacturing of boards and standard signs

All requirements to these materials and construction of signs were set in the STO.

Special Boards:

The usage of signs according to STO RDNII corresponds to Par. 9 ODM 218.4.004-2009 «The Guide for black spots management"

(Approved by Federal Road Agency 21.07.09 №260)

The Results: 76 Black Spots on federal & regional roads where special signs according to the STO were installed

Traffic Accidents Statistic"BEFORE" installation:

# of accidents: 324; # of killed: 82; # of injured: 398.

Traffic Accidents Statistic"AFTER" installation:

# of accidents: 191; # of killed: 30; # of injured: 235.

Relative indicators:

# of accidents: minus 133 (- 41%);

# of killed: minus 52 (- 63%) !!!

# of injured: minus 163 (- 41%)

Socio-Economic Effect:

Benefits: **723,3 mln. RUR**

Costs: 5,4 mln. RUR (71 th. RUR per 1 black spot)

R=B/C = 134 !!!

Proposals: What to do next?

1. **Use the results of the pilot project and develop & implement such projects on federal & regional roads, at least in 3000 most dangerous & progressive black spots**

   Preliminary calculations:
   - # of killed reduction – 2000
   - # of injured reduction – 6400
   - Costs – 0,220 Billion RUR
   - Benefits - 30 Billion RUR

2. **Widen the project and implement on federal & regional roads testing of other measures in black spots in order to rank them and develop recommendations for road authorities to use the most cost-effective measures for black spots management (it can be done also within the FDA Plan on Research Works (NIOKR)**

1.2. Information Systems on Roads (Directional Traffic Signage)

World Wide Environment Issue:

- **Fleet rising: about 1 billion cars in the World (about 43 million in Russia)**

- **Automobile transport is one of the major contributor to environment pollution;**

- **45% of air pollution outside & 80-90% in big cities occur because of motor vehicles (NIIAT Data);**

- **Annual ecological losses due to automobile transport is estimated at the level of near $5 billion in Russia**

The result of lack or poor quality directional signage on roads:

- **In accordance with IRF data each year all vehicles in the world drive unnecessary 10 billion km because of lack or poor quality directional signs on roads. The biggest share of this amount belongs to developing countries;**

- **Each vehicle in the world drives annually unnecessary 10 km;**

- **Russia's share is appr. <u>280 mln. Km</u> of excessive trips – "astronomic figure – the way to the Sun & back to the Earth!!!!**

Socio-Economic Losses:

- **Loss due to purchasing of excessive 30 Th. Cubic Meters of gasoline - $25 mln. – a pool of gasoline equal to a soccer field with a depth of 5 meter;**

- **Additional harm to the environment;**

- **Other economic losses, incl. loss of profit due to loss of time, not on-time delivery of goods, etc. ;**

- **Socio-economic losses due to traffic accidents occurred because of non-adequate maneuvers of drivers: fast changing of traffic lanes, hard braking, fast turns, etc. ;**

- **Additional negative contribution to traffic volume increase**

Current Directional Signage System in Russia:

It is poor on the average:

- **It is estimated that only 1/3 of necessary directional signs are installed on roads & streets;**

- **A lot of poor quality directional signs are still present on roads: they are hardly readable during a day and are out of view at night;**

- **A lack of directional signs with Roman Alphabet on international routes;**

- **A lack of directional signs for tourists though the Amendments to GOST R 52290, 52289 effective Feb. 28, 2014, prescribe usage of signs on brown background**

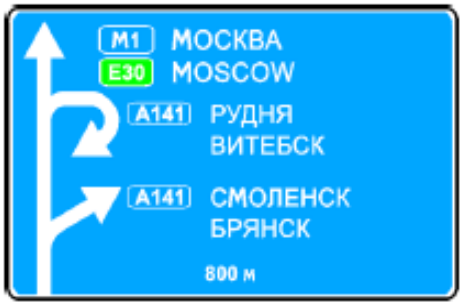

M4 РОСТОВ
M4
400м


КРАСНОДАР 210
НОВОРОССИЙСК 418
СОЧИ 494
ТИХОРЕЦК 116
КРОПОТКИН 170
АРМАВИР 240
МАХАЧКАЛА 882


ЭЛЕКТРОУГЛИ
БАЛОБАНОВО

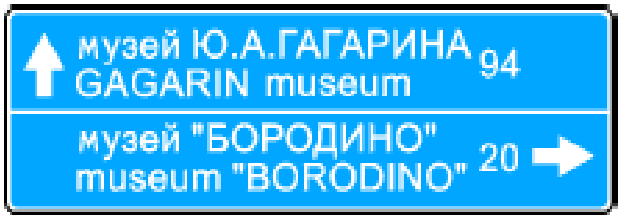

M4 РОСТОВ
550м

Directional Signs with Roman Alphabet in GOST R 52290

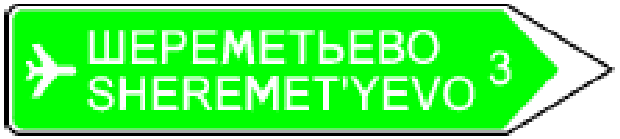


6.9.1*

Предварительный указатель направлений



6.10.1*



6.10.2*

There is lack of directional signs for tourists in Russia

Examples: Italy

Figura II 294 Art. 134

SEGNALI TURISTICI E DI TERRITORIO *

Great Britain

Belarus

Proposals for development of directional sign systems on Russian roads & streets:

1. **Develop & implement programs on directional signs installation on federal, regional & municipal road network;**

2. **Install more directional signs and signs with touristic information**

General Conclusion:

- **Traffic sign & other TCDs on the base of modern materials & technologies are able to effectively work on roads & streets**

- **Socio-economic benefits of their usage exceed their installation costs by many times**

1.3. Driver's needs & 3M Response:

Researches on Driver's Needs in the USA (2000)

#1 *"Characteristics and Needs for Overhead Guide Sign Illumination from Vehicle Headlamps"* FHWA-RD-98-135, Russell, et al, Kansas State University)

#2 *"A FIRST LOOK AT VISUALLY AIMABLE AND HARMONIZED LOW-BEAM HEADLAMPS"* UMTRI 2000-1, Sivak, et al, University of Michigan Transportation Research Institute)

#3 *"Line of Sight Distances to Signs"* Hummer et al; TRB-05-1473 , North Carolina State University.

#4 *"Driver Eye Fixation and Reading Patterns while Using Highway Signs under Dynamic Nighttime Driving Conditions: Effects of Age, Sign Luminance and Environmental Demand"* Schieber, Frank; Heimstra Human Factors Lab – University of South Dakota, TRB 2004-001951

#5 *''Traffic Sign Luminance Requirements of Nighttime Drivers for Symbolic Signs''* Schnell et al, Operator Performance Lab - University of Iowa, TRB 2004

#6 *"Reducing Crashes at Controlled Rural Intersections"* Harder, et al, University of Minnesota for MnDOT.

#7 *''The Safety Effects of Traffic Sign Upgrades''* Ripley, D. A.; H.R. Green and Associates, Presented at 2004 ITE Annual Meeting

Meeting Driver's Needs

#4

"Driver Eye Fixation and Reading Patterns while Using Highway Signs under Dynamic Nighttime Driving Conditions: Effects of Age, Sign Luminance and Environmental Demand"

Schieber, Frank; Heimstra Human Factors Lab – University of South Dakota, TRB 2004-001951

#5

"Traffic Sign Luminance Requirements of Nighttime Drivers for Symbolic Signs" **Schnell et al, Operator Performance Lab - University of Iowa, TRB 2004**

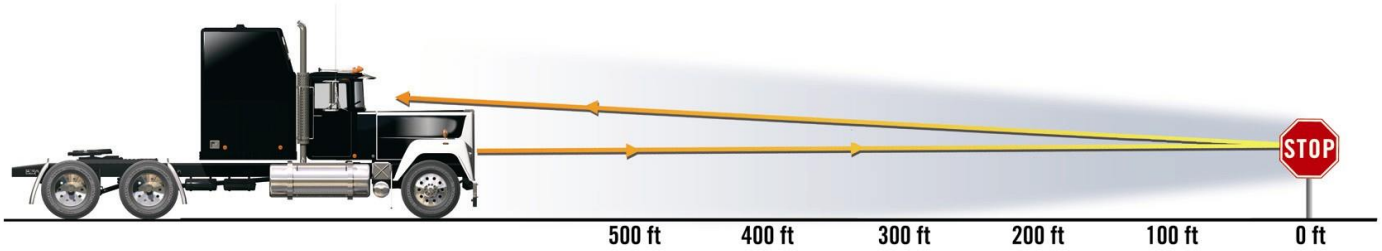
(Schnell et al, Operator Performance Lab - University of Iowa, Report TRB 2004)

How bright should a traffic sign be?

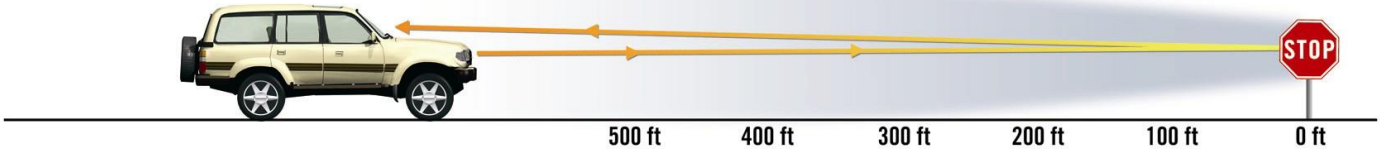
Summary of Human Factors Research

Obs angle

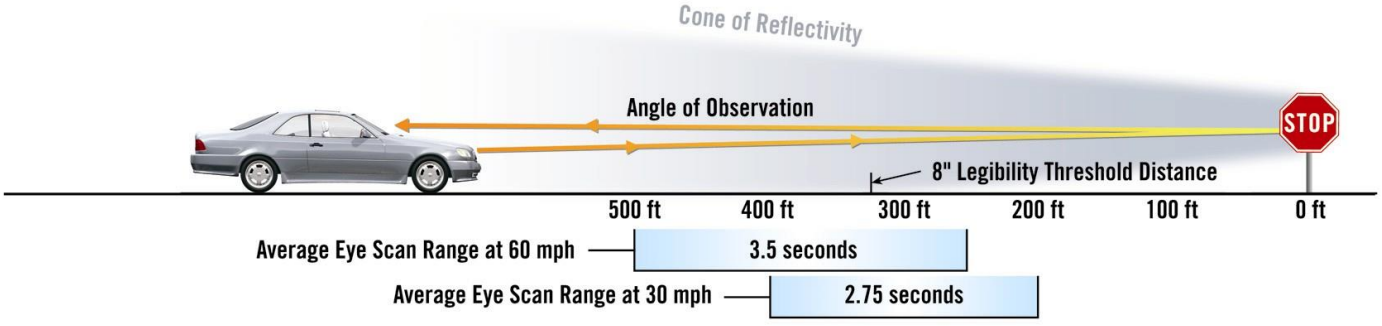
500’ = 0.70⁰
400’ = 0.90⁰
300’ = 1.20⁰
200’ = 1.75⁰



500’ = 0.35⁰
400’= 0.45⁰
300’ = 0.60⁰
200’ = 0.90⁰



500’ = 0.30⁰
400’ = 0.40⁰
300’ = 0.50⁰
200’ = 0.75⁰



Meeting Driver's Needs

#6

"Reducing Crashes at Controlled Rural Intersections"

Harder, et al, University of Minnesota for MnDOT.

- "At intersections with crashes, the use of more and larger STOP signs appears to reduce the number of Ran the STOP crashes."

- "The use of brighter retroreflective sheeting material appears to reduce the frequency of both total crashes and right angle crashes. The highest usage of diamond grade sheeting was at intersections with no crashes and the lowest usage was at intersections with multiple Ran the STOP crashes."

Conclusions…

- Drivers use signs only when they can read them easily or seek for them on purpose.
- The majority of signs are read at the distance from 40 to 100m. In urban settings 0.5^0 to 1.5^0 observation angles are critical to motorists needs (sign replacement/performance is often measured at 0.2^0/-4.0^0 and should be revised)
- In urban areas most signs do not provide the needed luminance levels at the distances where they are viewed and the driver processes information.
- Signs in urban and suburban areas are obstructed by different obstacles.

Conclusions…

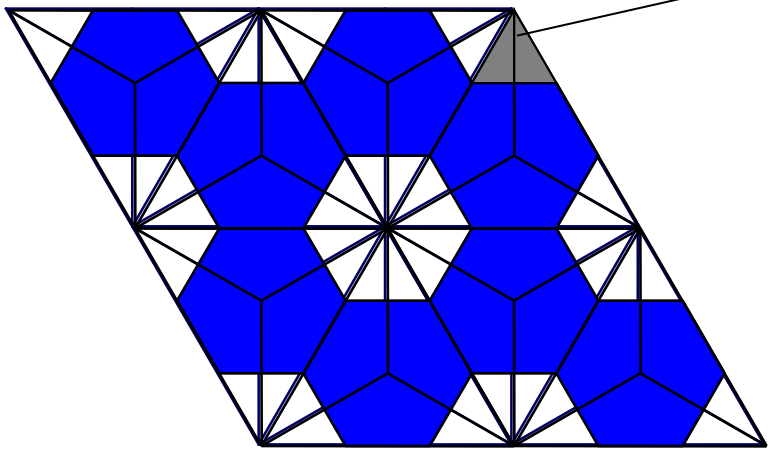
- Signs should perform to address the needs of the 85%tile driver, aged 65 or older.
- Truck, bus and minivan drivers observe signs at higher observation angle than the ones in cars. Nevertheless, at 40-100m distance to signs (obs. angles 0.5° to 2°), the majority of current retroreflective materials do not provide the required brightness of signs.
- Replacement of existing signs with new and much brighter ones in black spots reduces # of traffic accidents substantially. Benefits of such measures exceed costs by many times.

Meeting Driver's Needs – 3M Response

3 Diamond Grade™ DG^3 (DG Cubed) Reflective Sheeting Series 4090:

- Full cube construction
- Unique patented solution
- No analogs at the market
- Has the highest performance characteristics among premium class retroreflective sheetings.
- Provides high visibility and readability of signs within a wide range of observation and entrance angles when approaching the sign

Sheeting construction of other producers – truncated cubes

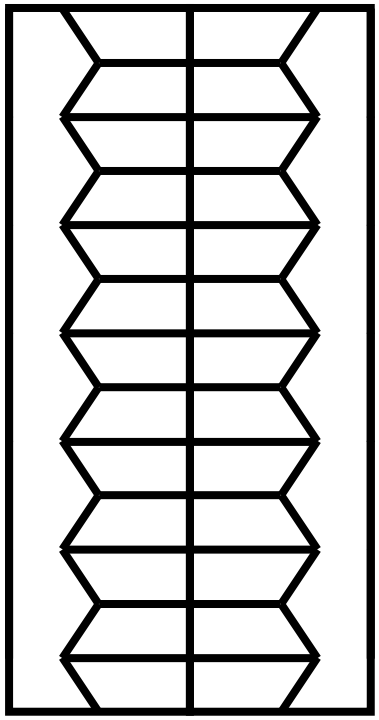


Light Entering the Corner only Reflects Twice

Those Rays are NOT Retroreflected!

Light that Strikes about 65% of the Surface is Retroreflected

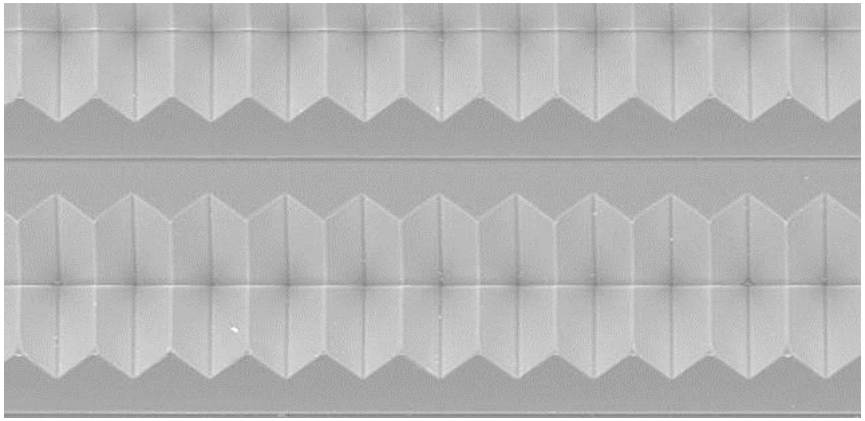
3M DG3 construction - Full Cube Corner Optics

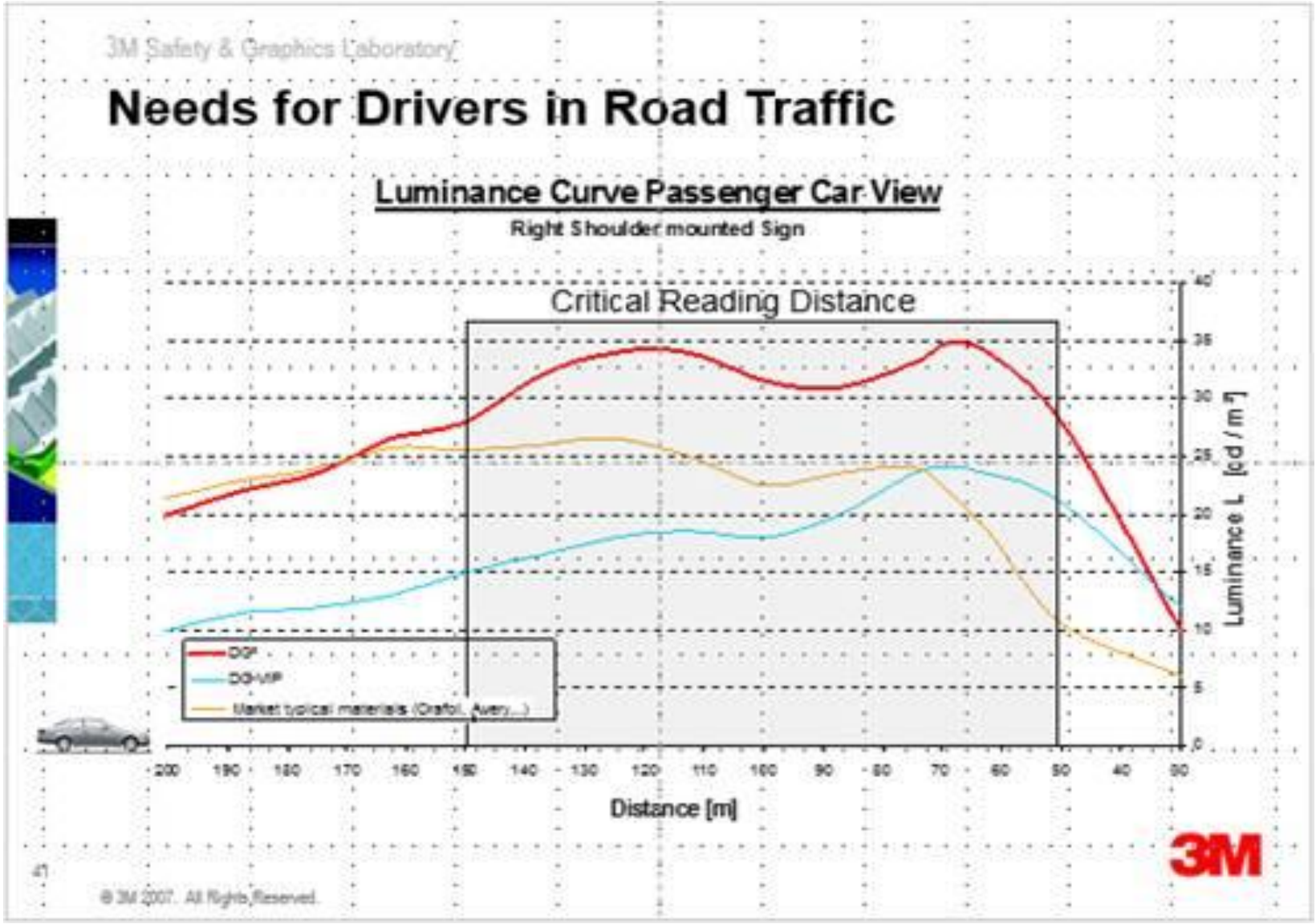


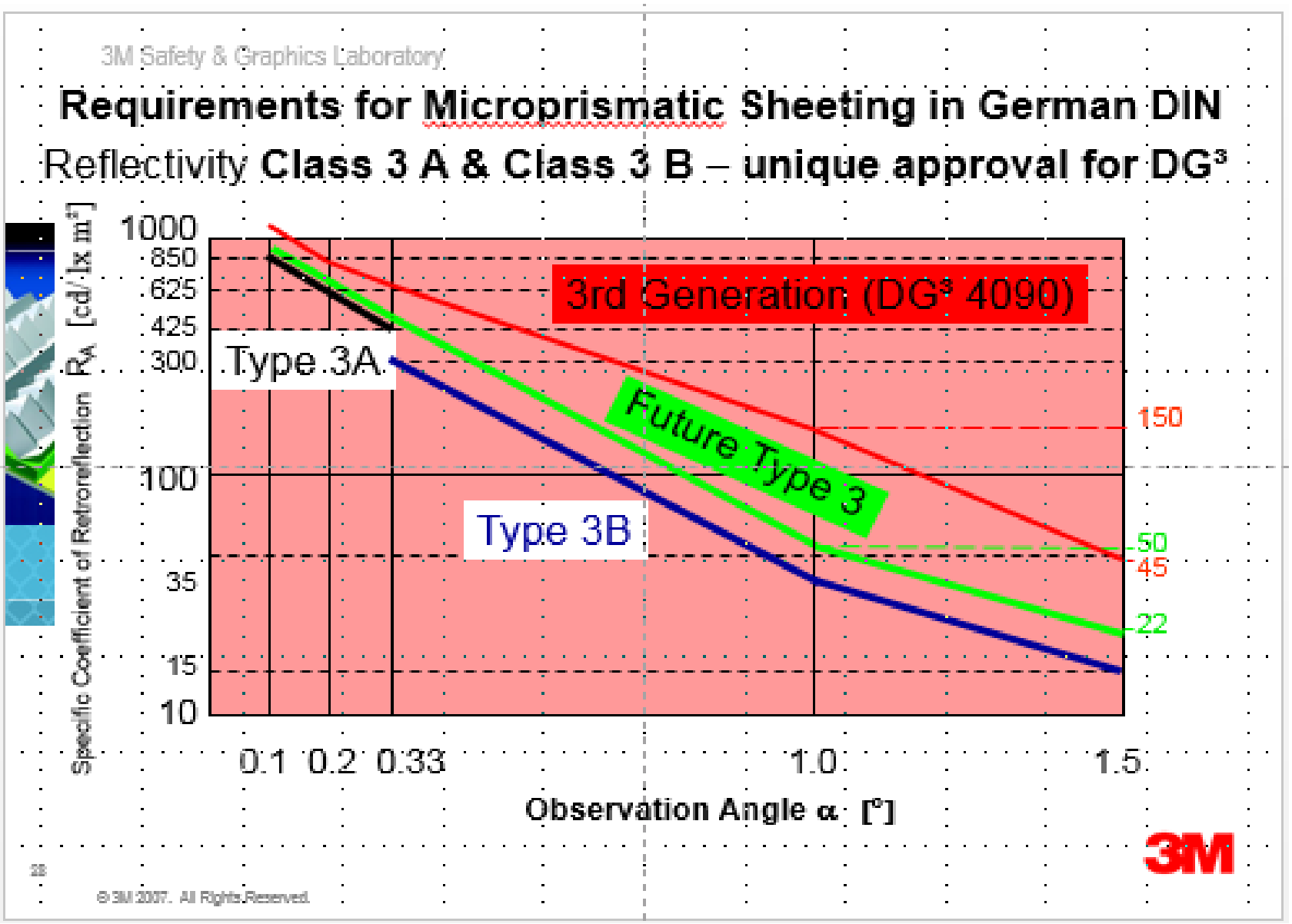
Still Uses 3 Bounce Mirror Reflection

100% Efficient Retroreflection

But, There Are No Dead Corners




3M Safety & Graphics Laboratory
Needs for Drivers in Road Traffic
Luminance Curve Passenger Car View
Right Shoulder mounted Sign
Critical Reading Distance
DG³
DG-VIP
Market typical materials (Orafol, Avery...)
Distance [m]
Luminance L [cd / m²]
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30
0 5 10 15 20 25 30 35 40
41
© 3M 2007. All Rights Reserved.
3M


3M Safety & Graphics Laboratory
Requirements for Microprismatic Sheeting in German DIN
Reflectivity Class 3 A & Class 3 B – unique approval for DG³
Specific Coefficient of Retroreflection R_A [cd/lx m²]
1000
850
625
425
300
100
35
15
10
3rd Generation (DG³ 4090)
Type 3A
Future Type 3
Type 3B
150
50
45
22
0.1
0.2
0.33
1.0
1.5
Observation Angle α [°]
3M
© 3M 2007. All Rights Reserved.

Meeting Driver's Needs – 3M Response

3 Diamond Grade™ DG^3 (DG Cubed) Reflective Sheeting Series 4090 provides high visibility and readability of signs:

- at the most required distances from 40 till 150 m.
- placed over road or on a roadside of a multilane road
- for all drivers – cars, trucks, buses and minivans
- for all age categories of drivers and, especially, for drivers aged 65 or older.
- under difficult road and traffic conditions

Snow storm

2. Reflection of modern requirements to traffic signs in National Standards

Amendments of GOST R 52290 и 52289 effective 28.02.2014:

To meet driver's need in signs observed at a distance of 40-150m and from a cabin of trucks and buses

– Additional requirements to coefficient of retroreflection for Type C sheeting at observation angles of 1 º and 1,5 º were introduced

Таблица 5.2а

Цвет элемента изображения знака	Тип пленки	Угол наблюдения $\alpha = 1°$				
		Угол освещения β_v (при $\beta_н = 0°$)				
		5°	10°	20°	30°	40°
		Коэффициент световозвращения, кд·лк$^{-1}$·м$^{-2}$				
Белый, серебристый	В	80,0	70,0	60,0	50,0	15,0
Красный	В	20,0	18,0	16,0	13,0	5,0
Оранжевый	В	18,0	16,0	15,0	10,0	2,0
Желтый	В	65,0	55,0	45,0	40,0	13,0
Зеленый	В	10,0	8,0	7,0	5,0	2,0
Синий	В	5,0	4,5	3,5	2,5	1,0

Таблица 5.2б

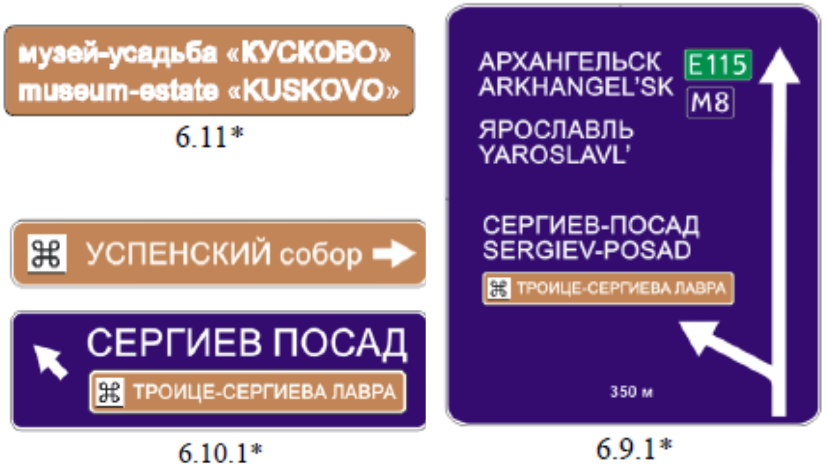
Цвет элемента изображения знака	Тип пленки	Угол наблюдения $\alpha = 1,5°$				
		Угол освещения β_v (при $\beta_н = 0°$)				
		5°	10°	20°	30°	40°
		Коэффициент световозвращения, кд·лк$^{-1}$·м$^{-2}$				
Белый, серебристый	В	15,0	14,0	13,0	9,0	1,5
Красный	В	3,0	2,8	2,5	2,0	0,5
Оранжевый	В	7,5	7,0	6,5	4,5	1,0
Желтый	В	10,0	9,0	8,0	6,0	1,0
Зеленый	В	1,5	1,2	1,0	-	-
Синий	В	1,0	-	-	-	-

Requirements to tourist signs

In order to develop sign information systems for tourists

- Signs background (parts or inserts) designed to indicate tourists objects should be brown

Brown signs icons for tourist and sport signs 6.9.1 - 6.11 .



Museums

Architectural monuments

Sports facilities
National parks

Requirements to signs on fluorescent boards

To enhance traffic safety in black spots and, in particular, on pedestrian crossings

- Mandatory requirements to use signs on fluorescent yellow-green boards were introduced.

Coefficient of retroreflection, Daytime Luminance Limit and Color Box must be as follows in tables below:

Цвет фона щита	Коэффициент яркости β, %, не менее	Коэффициент яркости флуоресценции $\beta_Ф$, %, не менее
Флуоресцентный желто-зеленый	60	35

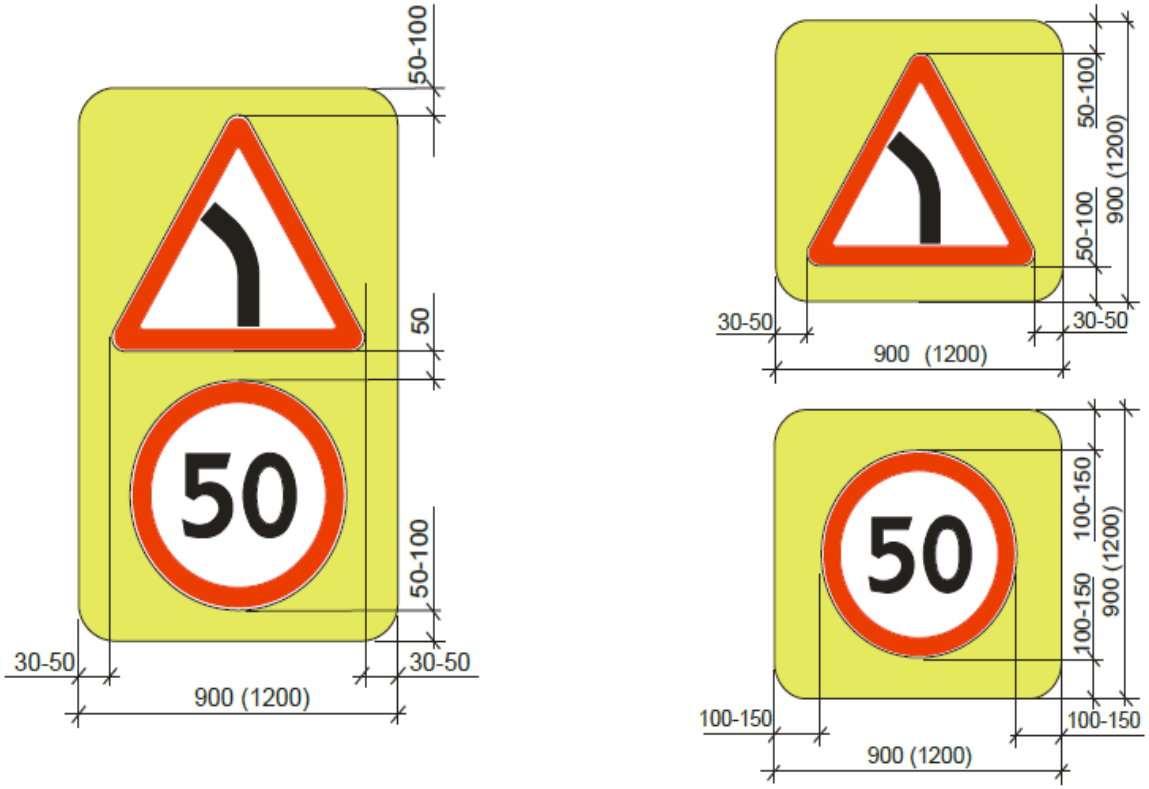
Цвет фона щита	Обозначение координат	Координаты цветности угловых точек цветовых областей			
		1	2	3	4
Флуоресцентный желто-зеленый	x	0,376	0,438	0,460	0,387
	y	0,568	0,508	0,540	0,610

Цвет фона щита	Угол наблюдения α														
	α=0,33°					α=1°					α=1,5°				
	Угол освещения β_v (при $\beta_н$ = 0°)														
	5°	10°	20°	30°	40°	5°	10°	20°	30°	40°	5°	10°	20°	30°	40°
	Коэффициент световозвращения, кд·лк$^{-1}$·м$^{-2}$														
Флуоресцентный желто-зеленый	270	180	120	80	50	96	80	55	36	20	17	16	14	9	1,5

Placement of signs on boards

Requirements to the boards:

- Signs of II и III sizes are placed on boards

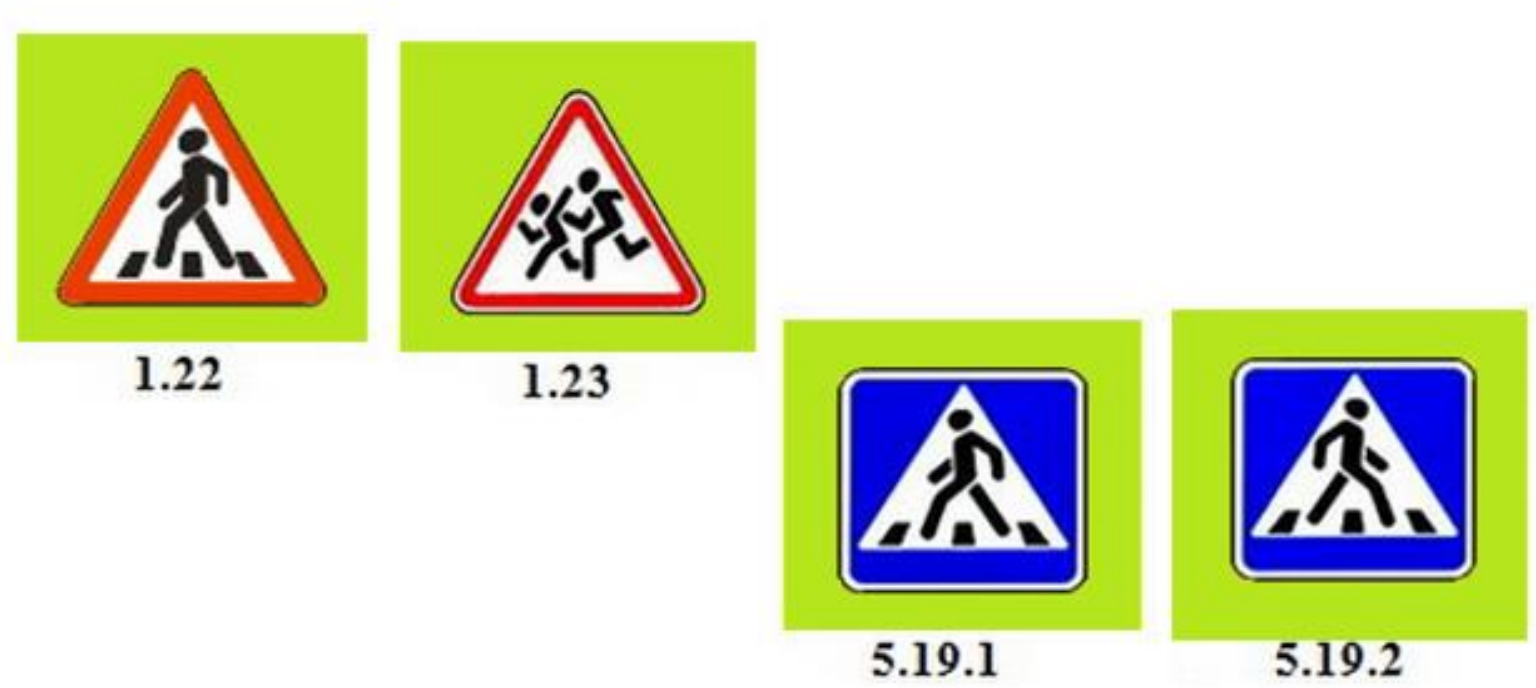


а *б*

В скобках указаны размеры щита для знаков типоразмера III

New requirements for the use of signs 1.22, 1.23, 5.19.1, 5.19.2

Traffic signs # 1.22, 1.23, 5.19.1 and 5.19.2 shall be placed on boards made of fluorescent yellow-green sheeting. Other signs can be also placed on the same boards in black spots and other hazardous areas to prevent traffic accidents.



New requirements for the use of signs in CWZ

Приложение А. Таблица А.1. Изображение знака 1.25 заменить новым:

Изображение и номер знака	Наименование знака
 1.25	Дорожные работы

Traffic signs # 1.8, 1.15, 1.16, 1.18-1.21, 1.33, 2.6, 3.11-3.16, 3.18.1-3.25 made on a yellow background, are used in CWZ. Sign 1.25 “Road Works” is used now only on a yellow background

New warranty terms for traffic signs

In order to use signs more effectively the following requirements were introduced:

New warranty period for retroreflective signs shall be as follows:

- For signs made with the use of Type A reflective material – not less than 5 years since installation on a road;
- For signs made with the use of Type B and C reflective material – not less than 7 years since installation on a road;

3. Novel technologies for traffic sign production

Requirements to modern traffic signs:

- High quality at an affordable price, i.e. good Price/Cost Ratio;
- Ability to meet growing driver's needs 24 hours per day under difficult traffic and road conditions
- High durability – min 7 years warranty period, but in reality – more than 10 years;
- Convenient maintenance – easy cleaning w/o damaging the surface, removability of vandal drawings

And the response is:

Digital Printing of Sign Faces

Digital Printing Advantages

- ***Digital printing technology***:
  - Allows to produce sign faces for any size of directional signs (≥35 sq.m.);
  - Provides an environmentally friendly production, durable sign faces, enhanced warranty period;
  - Cuts manual labor, reduces waste, reduces errors and defects, allows to work only with white material, etc.
- ***Lamination provides***:
  - Protection from UV-rays and fading of colors;
  - Protection for reflective sheeting and inks form mechanical damages and partly from vandal drawings (graffiti);
  - Smooth surface and, as a result, easy cleaning when maintaining the sign w/o damaging the surface, including waterjet cleaning

Cost of digitally printed sign faces

- Cost of police traffic sign faces digitally printed is usually 25% + higher than the one silk printed due to an additional cost of lamination.
- Cost of directional sign faces digitally printed is usually equal or even less than the one made by application method due to its high hand labor costs.
- If a customer order consists of the two equal parts of police and directional signs then the total cost can be equal to or slightly higher than the one made by both silk printing and application methods. But the quality and durability of digitally printed sign faces would be higher.

Digital Printing at 3M plant in Volokolamsk

- At its manufacturing facilities in Volokolamsk 3M producers digitally printed sign faces in co-operation with its partners – traffic sign manufacturers
- To produce the sign faces all 3 types (A, B and C) of microprismatic reflective materials are used according to GOST R 52290. They are also used with laminates and inks produced by 3M. All these materials form a so-called MCS™ (Match Component System). All sign faces produced by 3M according to MCS™ have necessary warranty from 3M.