Research and development of polyurea pavement marking paint

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Abstract:

Pavement markings make an important contribution to the safety of people and vehicles on roads. Many types of pavement marking materials have been used, and most recently, polyurea materials have been used as a binder in pavement marking paint. This type of paint has high retro-reflection and durability, so it has been widely applied for use at airports and on highways around the world. This article introduces the results of our research and the making of polyurea pavement marking paint using the formula: binder/harder ratio (1.3/1 by weight), 42% of pigment and filler, 10% of reflective balls, rheological additive, and dispersive additive to create outstanding features (retro-reflection > 260 mcd/m^2/lux).

Keywords: *pavement marking material, polyurea, retroreflection.*

Classification number: *2.3*

Introduction

Outlined reflective traffic guides serve an important role in controlling the flow of traffic. The painted lines on roads include centerline stripes, lane dividing lines, and marked areas due to obstacles, parking areas, road signs, and walkways. The standards of these marking materials consider their durability, dry time, and their impact on the environment [1, 2].

Currently in Vietnam, solvent reflective marking paints based on alkyd resins or styrene acrylic are usually used in the transport sector. It has been found that signal reflective paints based on alkyd resins and solvents provide better visibility for pedestrians, both during the day and at night, compared to signal reflective paints that are based on thermosetting plastics. Under oxidation, alkyd paints become brittle and lead to decreased adhesion on road surfaces, as well as developing glass particles in the paint. Besides that, solvent signal reflective paint also contains volatile organic compounds (VOC) that are not suitable for traditional usage, transport, and removal methods.

Reflective marking paints based on thermoplastics are also being widely used today on express ways, highways, and airplane runways. For highways, roads, and airplane runways, the abrasion resistance and reflectiveness of these coatings are still having many shortcomings, resulting in increasing maintenance and repair costs, being inefficient, and not ensuring traffic safety [1, 2].

Polyurea elastomer-based marking paints contain two components that are new materials recently applied to the transport sector. Polyurea paints have several features, like two-component-modified polyurethane paints; polyurea coating is a unique coating technology, which is unlike polyurethane coating [3].

Two-component polyurea coatings are applied using specialized spray equipment that provides high-pressure application, fast drying time, and an achievement of optimal adhesion. The fast drying feature is contained within a wide temperature range and is unaffected by moisture. A fast drying time of paint leads to time to put the product into use more quickly. Polyurea coatings have color stability, abrasion resistance, and good adhesion to all surfaces. In particular, polyurea reflective marking paints have high reflectiveness and are sustainable over time. Polyurea materials claim to have a lifespan of up to five years [4, 5].

Despite their appearance in many countries, polyurea coatings have yet to be applied broadly in Vietnam, particularly in the field of transportation. In this study, with an aim of mastering the technology and initial identification of polyurea coating applications in the conditions of Vietnam, marking materials based on polyurea elastomer have been studied on a selection of basic components including: curing agent

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ratio, filler content, dispersing additives, rheology additives, and loading of glass bead.

Materials and experiment

Materials

- The binder is Bayer NDT1-Desmophen® (amine number 190 mg KOH/g, viscosity at 25°C: 1,000 mPa.s, the density at 20°C: 1.06 g/ml);

- The curing agent is polyisocyanate Desmodur VP LS 2371 (Bayer - Germany);

- Titanium oxide pigment, yellow organic pigment, calcium carbonate, and talc fillers (China);

- Dispersing additives including dispersants, DP-1 of BYK (solution of copolymers with acid groups, acid number: 53 mg KOH/g, specific weight: 1.03 g/ml, concentration of volatile substance: 52%);

- Dispersing additives including dispersants, DP-2 of Cognis (neutralization of acid salts polycarbonic with polyamines, the density: 0.88 to 0.90 g/cm^3, acid number: 50 mg KOH/g);

- Rheological additives including rheological additives FS 1 (compound of hydrophilic silica surface of the carrier Aerosi, specific surface: 200 m^2/g, average particle size: 12 nm, SiO_2 content: 99%);

- Rheological additives, FS 2 Elements (organic derivatives of hectorite clay, fine powder, specific weight: 1.8 g/cm^3);

- The glass bead, DPI Class I, according to AASHTO M247.

Experiment

The determination of paint properties is according to the following tests: KU viscosity, smoothness, luminosity, impact resistance, oil resistance, salt resistance, alkali resistance, retro-reflectivity, and abrasion. The testing methods are specified in ISO standard 8787: 2011.

Results and discussions

Resin/curing agent

Based on a published document and standards prescribed about polyurea marking materials, the specifications for polyurea marking paints are chosen as follows [3-5]:

- Paints having 100% solid content;

- A mixing ratio between A and B components is varied from 2:1 to 3:1 by volume;

- Loading of pigments, filler powder is greater than 15% by weight;

- Using amino resin NDT1 and isocyanate Desmodur VP LS 2371 to making polyurea coatings. The components are blended according to the formula in Table 1.

Table 1. Polyurea marking paint components.

	% by weight		
	Sample 01	*Sample 02*	*Sample 03*
A component			
NDT1	30	37	45
TiO_2	15	15	12
Filler	27	20	17
Rheology agent FS-1	1	1	1
Dispersing agent DP-1	1	1	1
B component			
Desmodur VP LS 2371	28	28	28

Table 2. Drying time, adhesion, and abration of coating films.

Properties	Drying time (min)	Adhesion (MPa)	Abration (g)
Sample 01	5	3.5	0.08
Sample 02	8	3.0	0.07
Sample 03	12	4.0	0.06

Table 3. Paint with differences in titanium oxide content.

	% by weight		
	Sample 01	*Sample 02*	*Sample 03*
A component			
NDT1	37	37	37
TiO_2	7	13	18
Filler	28	22	17
Rheology agent FS-1	1	1	1
Dispersing agent DP-1	1	1	1
B component			
Desmodur VP LS 2371	28	28	28

Then, prototyping and testing the properties of coating film including the drying time (minutes), the abrasion (g), and the adhesion (MPa). The results are shown in the Table 2.

From the obtained results, the ratio 1.3/1 of A/B is chosen to carry out the next survey.

Effect of pigments on properties of paint

The brightness of road markings has major influence on the ability to recognize road markings of driving. Typically, the rutile titanium oxide powder was used with the aim to increase the brightness of the paint. With amine compound NDT1 and isocyanate curing agent, the paints were conducted with titanium oxide content changing 7, 13, and 18% by weight (Table 3).

After fabricating the prototypes, the brightness of the paint was measured (Fig. 1). The results showed that the brightness of the coating increases when the content of titanium oxide is increased. Specifically observed was the brightness of the paint at 60% with 7% by weight of titanium oxide, further increased to 13 and 18% by weight at the brightness of 76 and 80%, respectively. The chosen content of titanium oxide in white paint polyurea was at least 13% by weight. Polyurea yellow paint is made with the following formula (Table 4):

The measured brightness of marking paint is 55% in accordance with standard yellow marking paint.

Effect of additives on properties of paint

The effect of dispersing additives signed DP-1 and DP-2 on the properties of paints having the same content of 1.0% by weight is shown in Table 5.

The results from Table 5 show that using dispersing agent DP-1 makes better dispersion of pigment powder and filler than that of DP-2.

The effect of rheology agent FS-1 and FS-2 on the properties of marking paints having the same content of 1.0% by weight is shown in Table 6.

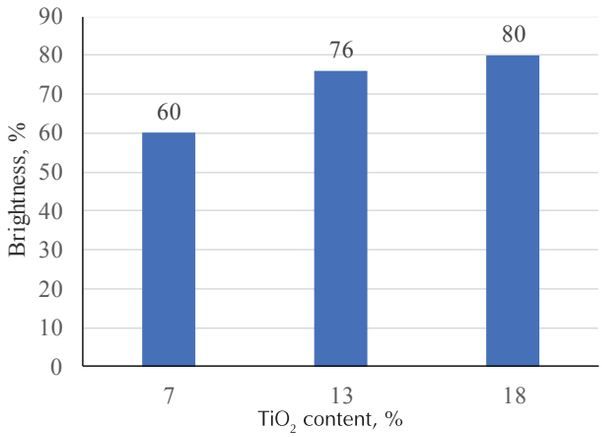

Fig. 1. Effect of TiO_2 content on the paint brightness.

Table 4. Formula of polyurea yellow paint.

	% by weight
A component	
NDT1	37
TiO_2	8
Yellow pigment	5
Filler	22
Rheology agent FS-1	1
Dispersing agent DP-1	1
B component	
Desmodur VP LS 2371	28

Table 5. Effects of additives on properties of paint.

Dispersing agent	Appearance	Fineness (µm)
DP-1	Homogeneous. Normal surface	25
DP-2	A few small cracks appeared	30

Table 6. Properties of marking paint having rheology agent.

Anti-deposition aadditives	Flow ability	State
FS-1	Non flow	Non deposition
FS-2	Flow	Slight deposition
Not rheological additives	Flow	Deposition

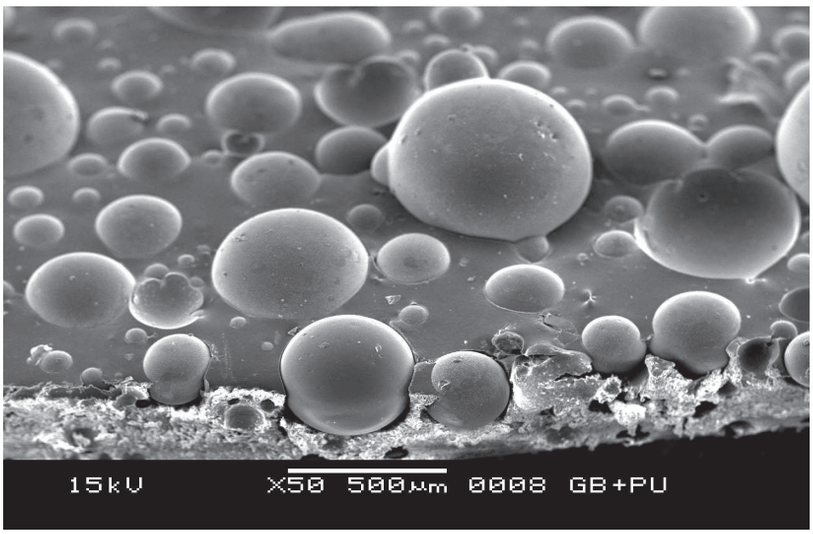

Fig. 2. SEM image of polyurea reflective paint.

Table 7. Effects of glass bead contents on the retro-reflectivity of polyurea marking materials.

Glass bead content (% by weight)	Retro-reflectivity (mcd/m^2/lux)
5	175
10	260
15	300

Table 8. The formula of polyurea marking paint (% by weight).

	White paint	Yellow paint
A component		
Amine NDT1 resin	37	37
TiO_2	13	8
Yellow pigment	-	5
Filler	22	22
Rheology additive FS-1	1	1
Dispersing additive DP-1	1	1
B component		
Desmodur VP LS 2371	28	28

The results show that when rheological additives FS-1 are used, the viscosity of paint increases and the paint layers do not flow. Therefore, the rheological additive FS-1 was selected for making paint in the next experiments.

Effects of glass beads on retro-reflectivity of paint

In order to investigate the influence of glass beads on the retro-reflectivity of paint film, the paint has been made according to the results shown above. Then the film was made and sprayed with type I glass beads of different contents at 5, 10, and 15% by volume of paint. Fig. 2 shows an image of the paint surface under a scanning electron microscope (SEM). The results show that the contact area between the glass beads and the matrix depends greatly on the diameter of the glass beads. With glass beads of a diameter of less than 250 microns, the glass beads sunk to 3/4 diameter balls. Meanwhile, with glass beads of a diameter greater than 500 microns in diameter, only 1/3 of balls sunk into the paint matrix. Requirements for glass beads creating for the best retro-reflectivity paint and still ensuring good bonding strength with the matrix is that the sunken part of the ball in the paint matrix should be 2/3 of the ball. Glass beads having a diameter of about 250-500 microns are appropriate these requirements.

The results of retro-reflectivity of completely-dried paint films having glass beads are shown in Table 7.

The results show that the retro-reflectivity of polyurea marking paints increased with increasing content of glass beads and they were greater than 100 mcd/m^2/lux. However, in order to maintain the retro-reflectivity of marking line with time it is better to choose the content of glass beads of 10% by weight.

Thus, it is pleased to offer the optimum formula for making elastomer marking paint as shown in Table 8.

Quality assessment of elastomer marking paint

The marking paint with optimal formula was made and then testing the following properties: viscosity, fineness, drying time, adhesion… The results were shown in Table 9.

Besides, the subject has also been constructed according to tests of the marking paint used at the scene. The marking paint gained the retro-reflectivity of over 260 mcd/m^2/lux, adhesion on a cement, concrete road reached 3 MPa. The results showed

Table 9. Quality assessment of elastomer marking paint.

	Unit	Requirement	Results
Color	-	≥ Y 35	Y 35
Stability		≥ 8	8
Viscosity	KU	60÷80	80
Drying time	min	≤ 15	≤ 8
Luminosity: - White paint - Yellow paint	 % %	 ≥ 75 ≥ 50	 ≥ 76 ≥ 55
Flexibility	mm	≤ 12	4
Adhesion: - Concrete - Asphalt	 % %	 ≥ 90 ≥ 80	 95 92
Anti-shaded color	%	≤ 3	≤ 3
Impact resistance	-	The substrate is not exposed through the paint film	The substrate is not exposed through the paint film
Oil resistance		The coating is not peeling or blistering.	The coating is not peeling or blistering.
Salt resistance			
Water resistance			
Alkali resistance			

that the quality standards of painting materials was achieved, and even exceeded the requirements prescribed under TCVN 8787: 2011.

Conclusions

• The composition suitable for road marking paints made on the basis of polyurea elastomer including amino resin NDT1 at 37%, titanium oxide powder at 13% (white paint) and at 8% (yellow paint), organic yellow powder at 5%, fillers at 22%, dispersing additives DP-1 at 1%, rheology additives FS-1 at 1%, isocyanat plastic at 28%, and glass beads at 10% by weight of the paint.

• Polyurea reflective road marking paint has fast drying time (less than 8 minutes); greater adhesion to concrete bases of 3 MPa; and retro-reflectivity of more than 260 mcd/m^2/lux in standard conditions. This is truly the appropriate use for the airport runway and the highway in Vietnam.

• Reflective marking materials based on polyurea are made to both meet the specifications defined in TCVN 8787: 2011 and to have many advantages, especially adhesion to concrete pavement (3 MPa, greater than regulation of 1.2 MPa), and high flexibility, remaining highly durable with retro-reflectivity. With their advantages, reflective marking materials based on polyurea elastomer will improve expected durability and high reflective ability; contribute in the work of ensuring traffic safety.

REFERENCES

[1] A. Carlos, P.E. Lopez (2004), *Pavement marking handbook,* Texas Department of Transportation.

[2] Mark D. Purgett, David C. May, Mark D. Zender, Daniel J. Willie, Thomas R. Borden (2004), *Liquid pavement marking compositions,* US 6790880B2.

[3] U.S Department of Transportation (2006), *Polyurea Paint marking material study.*

[4] EPOPLEX (2014), *General Application Specification - Polyurea Pavement Markings.*

[5] http://news.3m.com/press-release/company/3m-introduces-next-generation-liquid-pavement-marking.