Novel Pavement Marking Which Provides Wet Night Visibility (All Weather Pavement Marking)

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ABSTRACT: As the statistical data indicates, the traffic accident in wet at night is more frequent than it in dry at night. One of the most critical reasons for these accidents is clearly due to the poor visibility of pavement marking for the driver when the road surface is wet at night. In current, glass microsphere works as optical lens and returns the light of car's head light to the driver efficiently (in general, it is called the retro reflection). Here, the current conventional glass microsphere provides the night visibility in fine day, but does not offer the retro reflective performance in wet at night because the glass microsphere is covered by water. To solve this problem, the profiled structure pavement marking is partially used, but still has the noise problem toward the residential quarters. After various investigations, it was found that the novel optical element having very high refractive index microspheres realize both the wet night visibility and the silent pavement marking, which will really contribute in enhancing the road safety and the environmental friendly.

KEY WORDS: Road safety, environmental friendly, retro reflection, pavement marking, all weather, glass microsphere, refractive index

1 INTRODUCTION

According to the previous research (Institute for Traffic Accident Research and Data Analysis, 2001), the fatal traffic accident happens more frequent at night than it in day time, and furthermore it in wet condition at night tends to be higher than it in dry at night. This statistical data is indicated in Figure 1, and it shows the most dangerous traffic situation is wet at night.

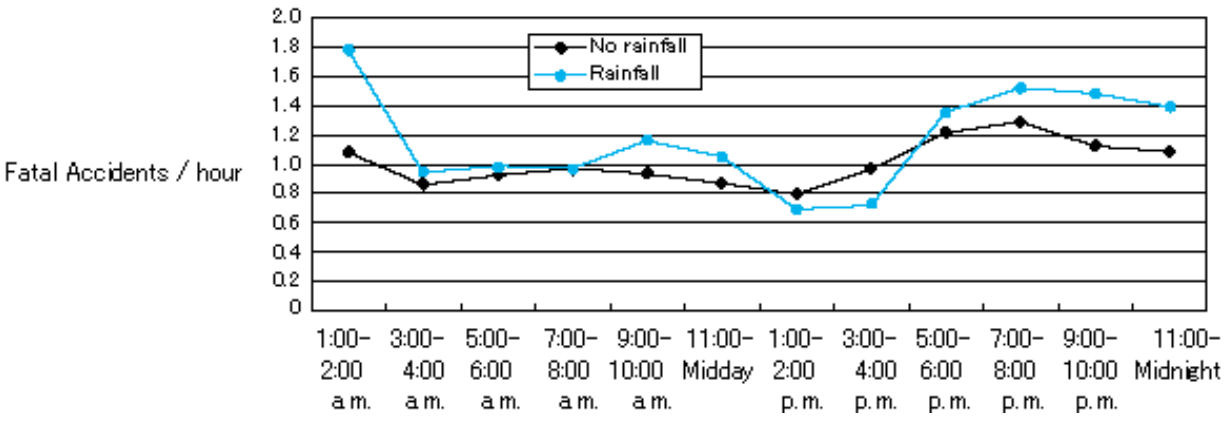


Figure 1: Fatal traffic accident numbers by time zone.

In addition, there happen many fatal traffic accidents when driving a car or waking a road as shown in Figure 2. And especially, the car accident in wet condition is 1.67 times higher than it in dry.

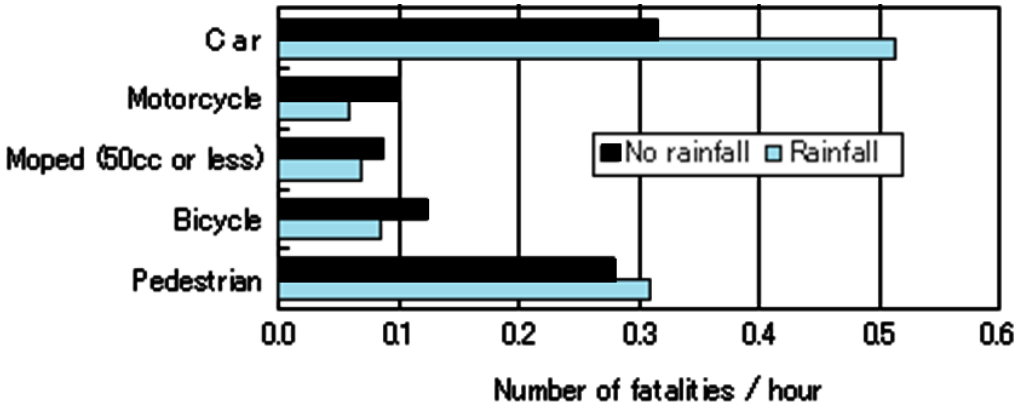
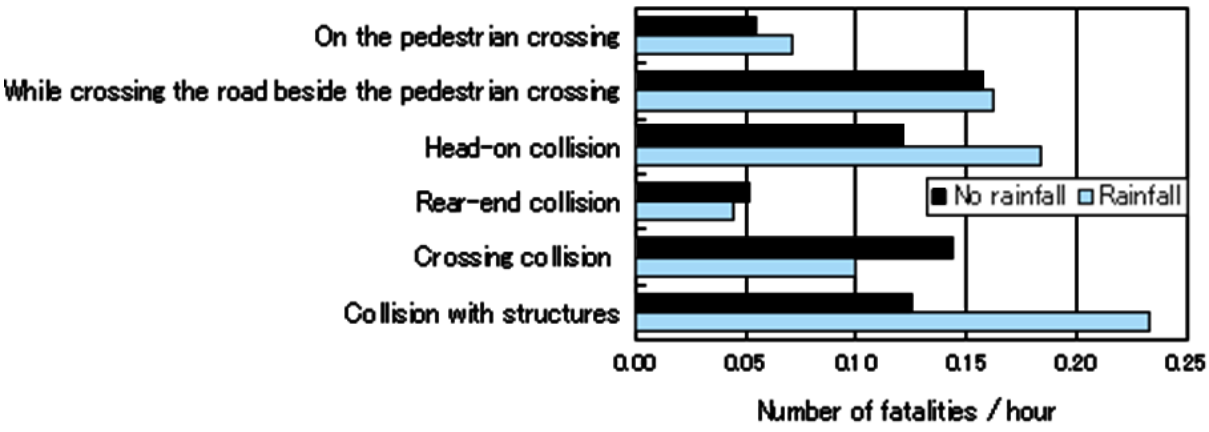


Figure 2: Number of fatalities by vehicle type.

And according to the statistical data in Figure 3, the fatal accident caused by the head on collision and the hit with road structure in wet condition is 1.53 and 1.88 times higher than it in dry, respectively.



From the above statistical results, it is expected that there are various factors which cause the fatal traffic accident, such as the vehicle, the driver, the pedestrian, the road environment, etc. But one of the most critical factors is easily presumed to be the poor visibility of road marking when the road surface is wet at night. If the visibility of pavement marking such as center line, edge line, stop line and cross walk were improved drastically in wet at night, it would contribute in enhancing the traffic safety.

2 EXISTING PAVEMENT MARKING

In general, the road marking is made of water base paint or solvent base paint or thermoplastic paint. And in Japan, the thermoplastic paint is mainly used since its fast drying property fits to the busy Japanese road environment. The thermoplastic paint is applied on the

road using screed or spray type applicator as shown in Figure 4.

Figure 4: Thermoplastic paint applicator, Spray type (Left), Screed type (Right)

In current, the glass microspheres whose refractive index is 1.5 is applied on the top surface of the thermoplastic paint to improve the night visibility since the glass microsphere works as optical lens and returns the light of car's head light to the driver efficiently (Figure 5, in general, it is called the retro reflection). The existing conventional glass microsphere provides the night visibility in dry condition, but does not offer the retro reflective performance in wet at night because the glass microsphere is covered by water.

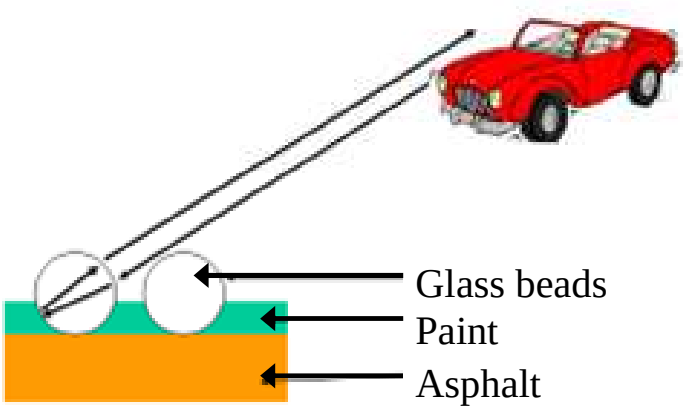


Figure 5: Mechanism of retro reflection of glass microsphere

To improve the night visibility of the current conventional road marking in wet condition, the profiled structure thermoplastic paint (Figure 6) is partially used. This profiled pavement marking may work somehow in wet at night since the profiled structure prevents the water coverage on the glass microsphere of the convex part, but still remains the noise problem due to the concavity and convexity pattern structure. Whenever the vehicle run through the profiled pavement marking, it causes the noise pollution to the environment.

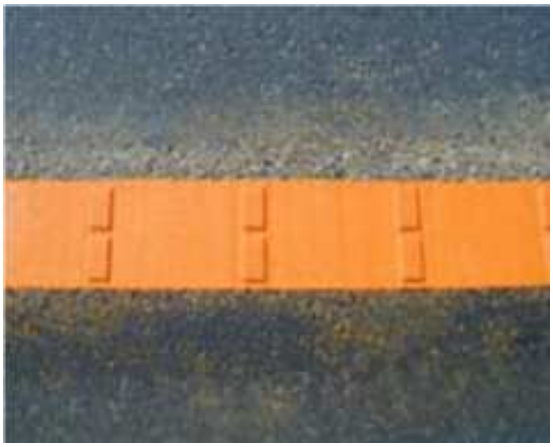


Figure 6: Profiled structure thermoplastic paint pavement marking

3 OPTICAL DESIGN TO REALIZE THE ALL WEATHER NIGHT VISIBILITY

We investigated the optical design of microsphere to realize the retro reflection in dry and wet condition; this means the excellent night visibility in fine and rainy day.

The optimal refractive index of glass microsphere can be calculated by Snell's law in below..

$$\frac{\sin\alpha}{\sin\beta} = \frac{n_2}{n_1} \tag{1}$$

Here, α is the angle of incidence, β is the angle of refraction, and n_1 and n_2 are the refractive index of material on the surface of glass microsphere and the glass microsphere itself, respectively.

Figure 7 shows the light path of retro reflection when the surface of glass microsphere is dry environment. After the calculation, the optimal refractive index of glass micro sphere is shown to be 1.9 to 2.0.

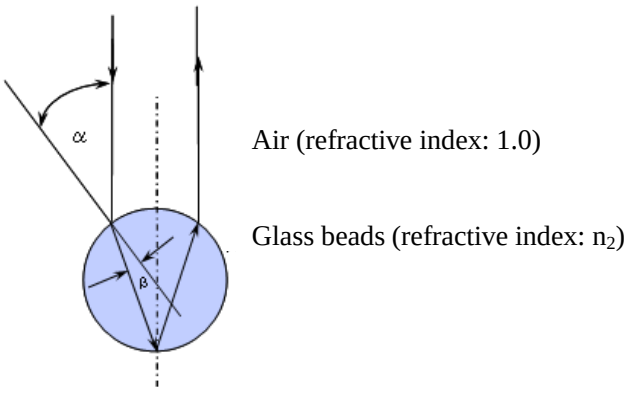


Figure 7: Light path of glass microsphere in dry condition.

However, the surface of glass microsphere is in wet condition, the light pass is influenced by the water since the refractive index of the water is much higher than it of air. The Figure 8 indicates the light pass of glass microsphere when the bead surface is covered by water. As shown in Figure 8, the glass microsphere does not retro-reflect the light when the refractive index of microsphere is 1.9 to 2.0, and the very high refractive index such as 2.4 to 2.5 is needed to realize the retro reflection in wet condition.

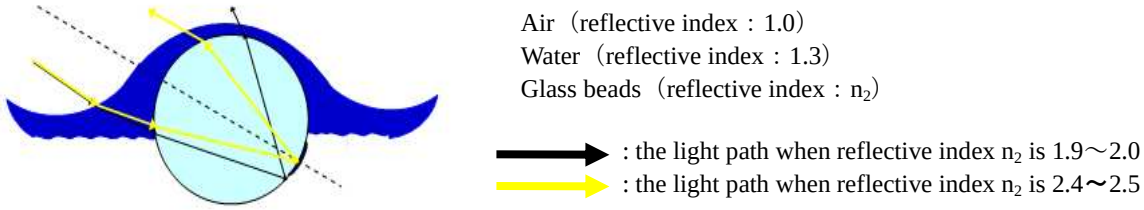


Figure 8: Light path of glass microsphere in wet condition.

In the current pavement marking industries, the glass microsphere having refractive index of 1.5 to 1.9 is used in general since the glass microsphere with the refractive index of 2.4 or more does not exist commercially. That's why, the profiled structure thermoplastic paint is proposed to improve the visibility in wet at night though there still remains the noise problem. Here, the reason that 1.5 refractive index glass microsphere is widely used in the pavement marking industry is clearly due to its reasonable pricing.

4 DEVELOPMENT OF HIGH REFRACTIVE INDEX RETRO REFLECTIVE ELEMENT

The optimal particle size of retro reflective element is thought to be around 0.1 mm to 1.5mm range since the thickness of current major thermoplastic paint is 1.0mm to 2.0mm in Japan. When the particle size of reflective element is smaller than 0.1mm, the night time visibility is poor since the element tends to be buried in the thermoplastic paint. On the other hand, the element size is bigger than 1.5 mm, the durability tends to be poor due to the insufficient sink of optical element in the thermoplastic paint.

As the pavement marking application, we succeeded in making very high refractive index glass microsphere though the particle size is less than 0.1mm. And this time, we also succeeded in making the optimal particle size retro reflective element using said high refractive index glass microsphere whose refractive index is 2.4 to 2.5, as shown in Figure 9. This retro reflective element comprises a bonded resin core and a plenty of glass microspheres partially embedded in the core. (Burns et al. 2008)

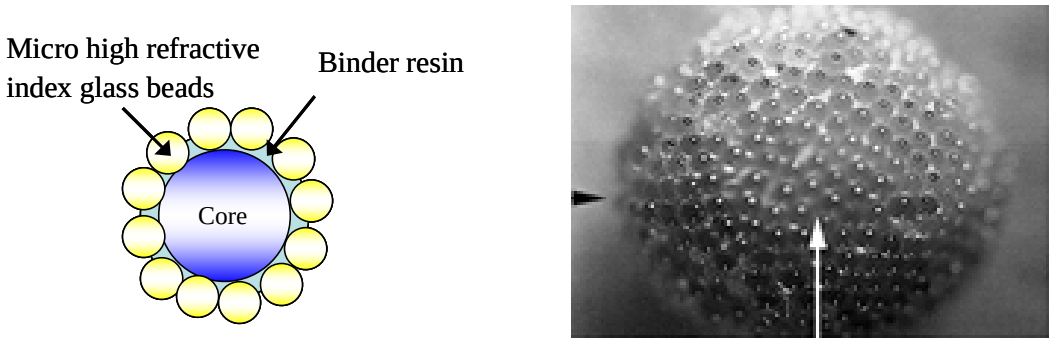


Figure 9: Bonded core structure retro reflective element

5 ALL WEATHER PAVEMENT MARKING

To coexist the night visibility in both dry and wet condition, we tried to blend the wet reflective bonded core element and the dry reflective conventional glass beads having 1.5 of refractive index. Here, the particle size of the wet reflective element and the dry reflective glass bead were around 0.6 to 1.4 mm and 0.8 to 1.7 mm, respectively. The pre-blended optical material was sprinkled on the thermoplastic paint as shown in Figure 10.

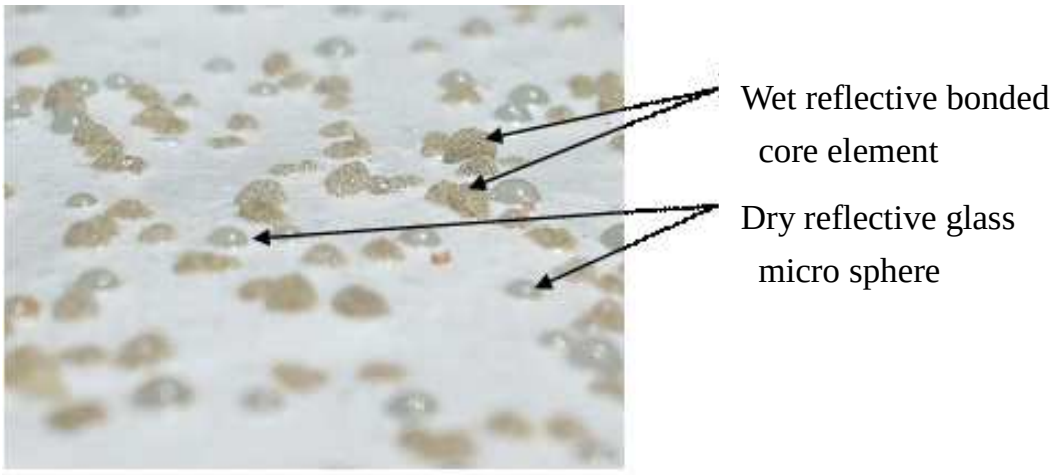


Figure 10: All weather pavement marking

The table 1 shows the results of retro reflectivity of pavement marking when the blend ratio of two kind of optical material is changed. The retro reflectivity is measured using commercial available retro reflectivity measurement instrument. The drop rate of the surface applied optical material is totally 215 gram/m^2. As shown, the retro reflectivity of the existing pavement marking (Sample 1) is very poor in wet condition, but it of all weather pavement marking this time (Sample 2, 3 and 4) is much improved in wet condition. These results indicate that the very high refractive index glass microsphere is mandatory to realize the excellent night visibility of pavement marking both in dry and wet condition. And Figure 11 shows the nighttime visual appearance of all weather pavement marking in wet and dry condition.

Table 1: Relationship of blend ratio and the retro reflectivity

Sample ID	Blend ratio		Retro-reflectivity (mcd/lx·m^2)	
	Dry reflective glass bead (R.I=1.5)	Wet reflective element (R.I=2.4-2.5)	Dry condition	Wet condition
Sample 1	1	0	380	90
Sample 2	1	2	475	555
Sample 3	1	3	395	545
Sample 4	1	4	370	500

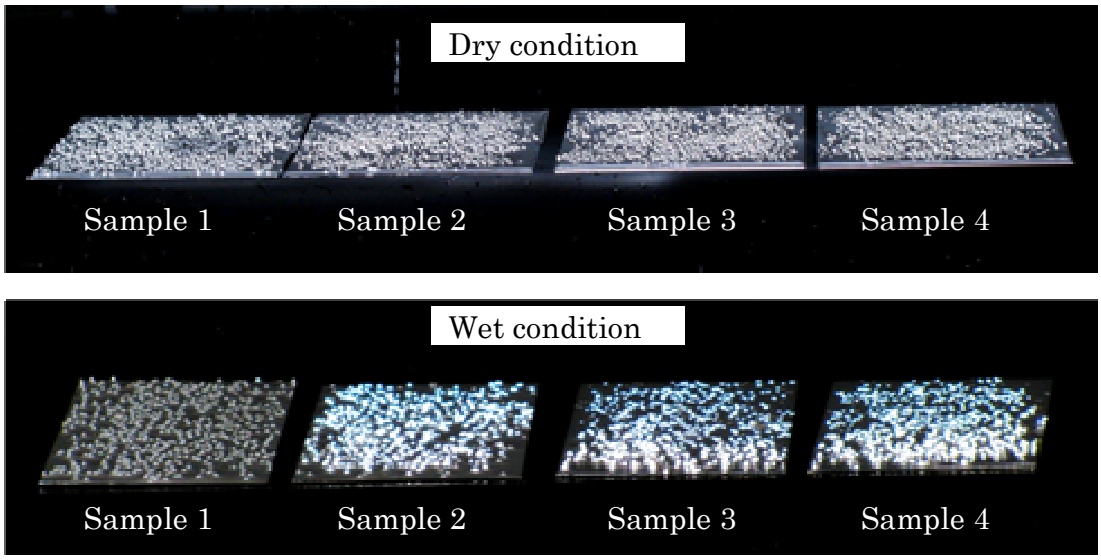


Figure 11: Night visibility of conventional and all weather pavement marking in wet and dry condition

6 DISCUSSION

According to the previous visibility research of pavement marking (Graham and King, 1991), when the retro reflective performance of pavement marking is higher than 93 mcd/lx·m^2, more than 98% observers can recognize the marking. This result indicates that the minimum retro reflectivity requirement of pavement marking for driver is 93 mcd/lx·m^2. From this result, an existing pavement marking (Sample 1 in Table 1 & Figure 11) has enough visibility in dry at night, but the marginal performance in wet at night.

The other hand, from another study (Gibbons and Hankey, 2007), the 200 mcd/lx·m^2 of retro reflectivity is needed to recognize the pavement marking in wet at night. From this result, the visibility of an existing pavement marking in wet at night should be insufficient.

The night visibility of all weather pavement marking applied on the road was shown in Figure 12, and indicated the excellent night visibility in both dry and wet condition. And when the cars run through the all weather pavement marking, the noise problem did not happen at all.

To keep the night visibility for long term, the incorporation of wet reflective element and the glass microsphere would be helpful. Even after the wear off of the surface applied optical material, the intermixed optical material helps to keep the performance.
Here, all weather pavement marking can be applied on any roads using existing conventional thermoplastic applicator, and also can provides the improved night visibility in both dry and wet condition.

Figure 12: Photo of existing and all weather pavement marking applied on the road

7 CONCLUSION

In this report, we could indicate the novel pavement marking which realized the excellent night visibility in all weather condition without having noise problem. By expanding this functional and environmental friendly pavement marking to the road in the world, we want to contribute in enhancing the road safety since the fatal traffic accident tends to happen in wet at night as the statistical data indicates.

REFERENCES

Institute for Traffic Accident Research and Data Analysis, 2001. *Increase in vehicle driver and pedestrian fatalities during rainfall.* ITARDA Information, No. 34, Japan

Burns, M., 2008. *Modern Pavement Marking Systems Relationship Between Optics and Nighttime Visibility,* Journal of Transportation Research Board, No. 2056, Washington, D.C., USA

Grahm, J., 1991. *Retroreflectivity Requirements for Pavement Markings*, Transportation Research Record, No. 1316, U.S.A.

Gibbons, R., 2007. *Wet Night Visibility of Pavement Markings*, Journal of the Transportation Research Board, No. 2015, Washington, D.C., U.S.A.