

## THE PRESENT CONDITION AND THE MECHANISM OF THE URBAN ELEVATED ROAD STAIN

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abstract: It wouldn't be achieved the purpose that the design taking account of improving landscape on the urban elevated road, if the urban elevated road stained. As a result of analyzing the stain adhering to the road structures, it is caused by the exhaust gas, and observing morphology, there is an intimate relationship between the stain and rain, structures, material of urban elevated road. As we consider the adhesive mechanism of the stain, we need to build the urban elevated road that has less the umbo and use covering material of less surface energy.

### 1. INTRODUCTION

In recent years, it has been necessary of high quality life space for realizing abundance of citizen life. Especially, because the road is close to life and indispensable for it, it is demanded from the environment with familiar, charming utility of characteristic of Area,

Hanshin expressway has influence on urban appearance, because it often passed through the commercial region and the park where is the streets place people gathers.

In such locale, Hanshin expressway public corporation have carried out various measures to improve landscape by painting of special colors (except regular colors of public corporation), painting of picture or pattern that is devised colors, covering and so on. However, because even if we design for landscape improvement, we would have a problem of stain and could not maintain early color of road structures for long time, we would be able to realize landscape improvement.

We report the results of the investigation for the composition, the cause, the morphology of the stain of the urban elevated road and consider the adhesive mechanism.

## 2.THE COMPOSITION OF THE STAIN OF THE URBAN ELEVATED ROAD STRUCTURES

Before we examine the measures,it is necessary to specify stain for measures.At first,we investigate the composition and the cause of the stain adhering to the road structures. 1) 2)

At central part of Osaka city,we collected the stain on the metallic girder that isn't exposed to the rain,at Hanshin expressway the east Osaka line.And also,as a reference,we collected the particle adhering to the muffler of diesel engine cars.

These collected samples was analyzed by the next three methods.

- ① The organic element quantitative analysis of C·H·N·ash content
- ② The X-ray fluorescence analysis
- ③ The gas chromatography mass analysis

It shows results in Table.1,2,and 3.

Table.1 The consequence of the organic element analysis  
(The stain on the metallic girder)

Carbon	17.0 %
Hydrogen	2.0 %
Nitrogen	0.98 %
ash content	65.4 %

Table.2 The inorganic element to be contained in the particles of the metallic girder and the exhaust gas

Detection element		The stain particles on the metallic girder	The stain particles in exhaust gas
Si	S i l i c o n	+++++	+++
S	S u l f u r	++++	++++
Ca	C a l c i u m	+++	++
Al	A l u m i n u m	+++	++
Fe	I r o o n	+++	+
K	P o t a s s i u m	++	
Cl	C h l o r i n e	++	
Mg	M a g n e s i u m	++	
Na	S o d i u m	++	
Ti	T i t a n i u m	++	
P	P h o s p h o r u s	+	
Zn	Z i n c	+	

Note) +++++ Very large amount                      +++++ A large amount  
 +++ Large amount    ++ A small amount  
 + Very small amount

Table.3 The organic substance to be contained in the particles on the metallic girder and in the exhaust gas

The stain particles on the metallic girder	The stain particles in the exhaust gas particles
Propanoic acid,2-methyl,1-(1,1 dimethyl ethyl)-2-methyl-1,3-propanediyl estel	Propanoic acid,2-methyl,1-(1,1 dimethyl ethyl)-2-methyl-1,3-propanediyl estel
Hexadecanoic acid	
Octadecanoic acid	
1,2-Benzendicarboxic acid, bis(2-ethyl hexyl) 1estel	1,2-Benzendicarboxic acid dibthyl estel
n-C <sub>17</sub> ~C <sub>33</sub> Paraffin +aromatic compound	n-C <sub>19</sub> ~C <sub>22</sub> Paraffin +aromatic compound

According to Table.2,3

About the inorganic element,

1)Sulfur was much detected from the both particles.

And also,about the organic substance,

2)Propanoic acid,2-methyl,1-(1,1dimethyl ethyl)-2-methyl-1,3-propanediyl estel was detected from the both particles.

3)The estel of very similar structure was detected.

4)The paraffin of the same molecular weight was detected.

According to the above,it is considered that the stain on the road structures was combined air dust with paraffin by exhaust gas.Therefor,one of the cause to stain road structures in city area like Hanshin megalopolis.

### 3.THE FORM OF STAIN

The elevated road structures have various countenances by the each shapes and materials.And also,the stain adhering to these showed various form by shapes and materials on road structures surface.These stain can be classified by shapes and materials on structures surface.<sup>3) 4)</sup>

One of the reason to be classified above is intervention of rainwater.

Therefore,we classified into next two and investigated the form of the stain.

1)The stain owing to investigation of rainwater

2)The stain owing to non-investigation of rainwater

The typical form of thr stain shows as follows.

1)The stain owing to investigation of rainwater

1)-1 The stain to be caused by rainwater and the umbo(photo.1,2,3)

The linear stain was observed under the umbo,like the strut of the soundproof walls and the road sign on handrail.

1)-2 The stain to be caused by a water leak from the expansion joint(photo.4)

A lot of stains to be caused by a water leak from the expansion joint were observed. Especially,these make us an worst impression in stains of the pier.

1)-3 The stain to be caused by rainwater and concrete structures surface(photo.5)

The linear stain of white,black,brown and green were observed on concrete structures (non-coat)surface that were exposed by the rainwater.

1)-4 The stain to be caused by rainwater and metallic structures surface(photo.6)

The linear stain of black were observed on metallic structures surface that were exposed by the rainwater.

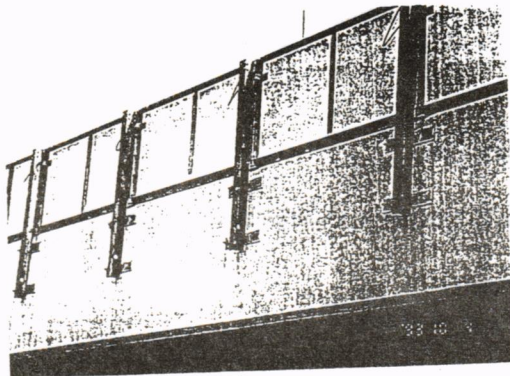


Photo.1

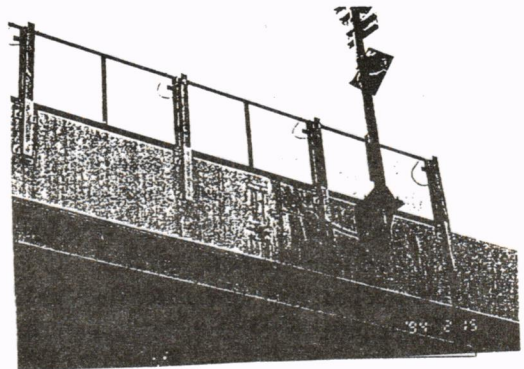


Photo.3

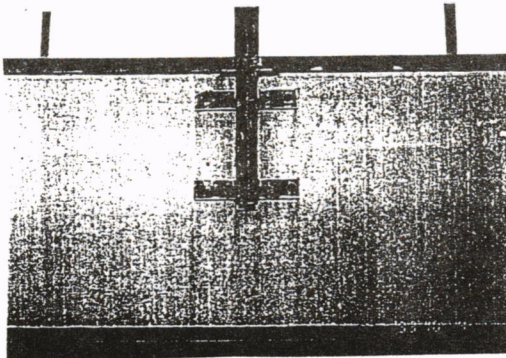


Photo.2

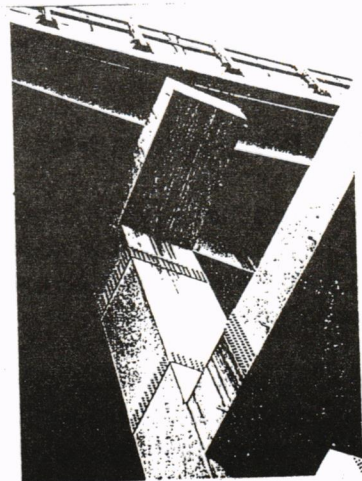


Photo.4

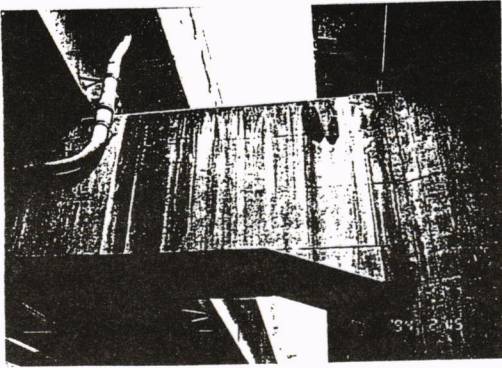


Photo.5

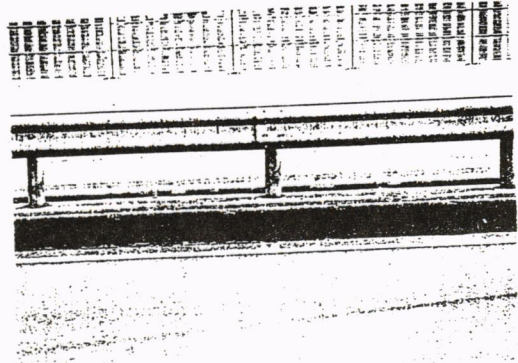


Photo.6

2)The stain owing to non-intervention of rainwater

2)-1 The uniform stain on the pier(photo.7)

2)-2 The stain around the umbo(photo.8)

It seems that the stain tends to adhere around the umbo,however rainwater don't intervene.

2)-3 The stain of the drainpipe(photo.9)

The much stain adhered upon the drainpipe.

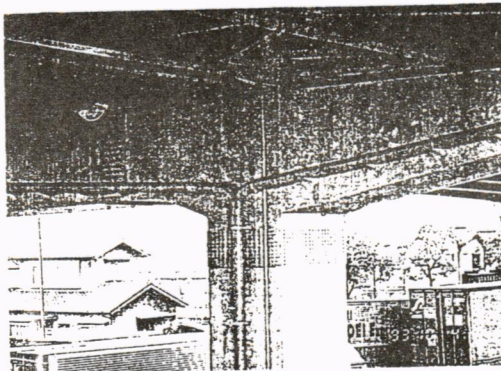


Photo.7

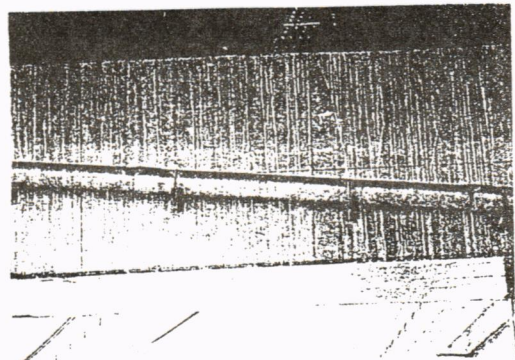


Photo.9

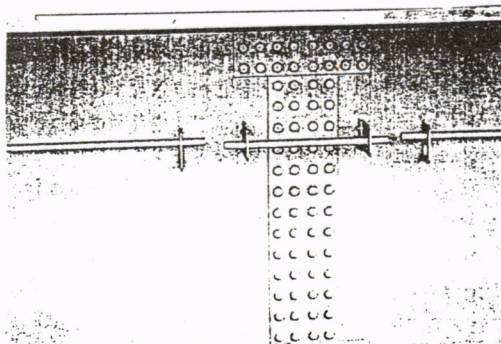


Photo.8

According to photo.1 to 7,the characteristic form of the stain on the road structure is summarized at next three. <sup>5) 6)</sup>

- (1)Every stain owing to intervention of rainwater was linear,and the stain owing to non-intervention of rainwater was uniform.
- (2)The umbo was a cause of the stain in spite of intervention or non-intervention of rainwater.
- (3)The color of the concrete structure(non-coat)differed from the metallic structures one.

#### 4.THE ADHESION MECHANISM OF THE STAIN <sup>8)</sup>

Above-mentioned 「 3.Form of stain 」 ,the characteristic form of stain on the road structure was roughly divided into the next three kinds.

- 4.1 The stain to adhere uniformly.
- 4.2 The linear stain by rainwater.
- 4.3 The stain to occur around the umbo.

This chapter was considered the adhesive mechanism of the stain about the the forms of these stains.

##### 4.1 The stain to adhere uniformly

The interaction that stain particles adhere to the structure surface is caused by four adhesive powers.Four adhesive powers were listed Table.4.

###### (1)van der Waals power

Originally, Van der Waals power is the power to interact between molecule(or atom).But, it is electromagnetismal power.It occurs also when two macro bodies slightly approach, like a particle and particle,particle and wall face,and so on.It mainly depends on electronic motion between the two bodies.Contribution of Van der Waals power is important about a lot of phenomena that are concerned with the adherence between the particles in powder body layer, the calm and the scattered again of particles. In general, Van der Waals power is larger than the static electricity suction power and smaller than the adhesive power by absorption water.

###### (2)The adhesive power by absorption water membrane

The adhesive power by absorption water membrane is hydrogen bond,when water amount is small,and liquid bridge when it is mush.It is condition that liquid bridges between two particles like a bridge when two particles of powder body touch.The adhesive power on particles surface that don't occur phenomenons such as crystallization,dissolution,reaction and so on,is capillary power.It relates to wetness and surface tension that occurs phenomenon,when it stands a fine pipe,liquid surface raises or downs.But the adhesive power is connection between solids phenomenon of compound power on the aquatic particles and particles surface that tends to occur chemical reaction.

Above-mentioned 「The stain composition of the road structure」, the main component of the stain adhering to the elevated road structures is paraffin that was caused by air dust and exhaust gas. Therefore, it is thought that because chemical reaction between the stain and water molecules is able to ignore, the adhesive power to interact with absorption water membrane is the capillary power and the surface tension. Size of adhesive power by liquid bridge is ruled humidity, in other words, steam absorption amount, form of liquid bridge.

The particles is influenced by size of affinity for vapor steam of particles surface, particles shape, contact circumstances. When we deal with this particles under atmosphere, existence of absorption water can't be ignored. Especially, the adhesive power by humidity is important in Japan that there is much humidity.

table.4 accounting of adhesion power

accounting of adhesion power		relation factor	characteristic
(1) van der Waals power		direct proportion to a particle diameter, (distance) <sup>n</sup> n=2 ~ 3	approach power, when they approach, the power become big. It is nature peculiar to matter. It is hardly influenced by a outward condition.
(2) absorption water elements or power by water	power by absorption water elements	resemblance to power between elements or effect of polarity	It appear as effect of humidity of atmosphere.
	surfactension of build bridge condensation water	inverse proportion relation to particle diameter, surfactension water quantity	There is hysteresis effect by repeat reaction of condensation of water, evaporation and so on.
(3) power by static electrical electrification		friction, flow, spout, collision destruction and so on causes.	It occurs by particles equal to or less than about 200 μ m, cause particles of plus, minus, neuter generally. When humidity is big at atmosphere, this power can hardly occur. Sometimes, it can occur to small particles. This is made up repulsion power, suction power.
(4) compound power		mechanical connection	elements power and inside friction
		solid connection phenomenon	separated fine crystal fill up among particles, it has a lot of power by mutual diffusion water. when it occur at no water atmosphere, it belong to the top chemistry. It contain a case of hydrogen combination.
		burn connection phenomenon	mutual diffusion of elements between particles

(3) The suction power by static electricity

The suction power by static electricity is guided by Coulomb's law. When the particles of particle diameter (a) have electric charge of plus (Q<sub>1</sub>) and minus (Q<sub>2</sub>) and separate at a distance (r) and face each other, suction power (F) interacts. It is showed to method.1 by Rumpf.

$$F = Q_1 \cdot Q_2 / a^2 \cdot (1 - 2r/a) \tag{Method.1}$$

When a distance (a) is much smaller than a particle diameter (a) at method.1, that is, when the particles nearly touch each other, the method.1 is shown in the next.

$$F=Q_1 \cdot Q_2 / a^2$$

Method.2

That is,static electricity suction power is directly proportional to the product of electric charge and is inversely proportional to a particle diameter square.This is one of reasons that microscopic particles tends to cohere by static electricity.This standard of particle diameter differs from electrification condition to electrification condition,but it is thought that particle diameter is less than 100  $\mu$  m.

When the particle surface is hydrophobic such as high molecular material,the adhesive power remains because the electric discharge speed is slow even if it is high humidity. Because the elevated road structures are covered with high molecular materials like polycarbonate or are coated by synthetic resin,it is thought that it tends to stain greatly in suction power by static electricity.

#### (4)The suction power by compound power

The suction power by compound power is complication and it is difficult to classify it. For example,it is occurred by mechanical connection of fibrous powder body or water diffusion like connection between solids phenomenon or diffusion between particles like sintering phenomenon.

### 4.2 The linear stain by rainwater <sup>7)</sup>

The linear stain by rainwater is caused as follows.The stain adhering to road structures surface and rainwater mix and suspension is made up.It flows on the structures surface. The stain adheres to the structures surface again.The linear stain by rainwater is shaded.

This time,the stain of structures surfaces is an important factor for formation of the linear stain by rainwater.When the liquid(water)keeps equilibrium on the solid(face of the structure),three interfaces are made,gas-liquid,gas-solid and liquid-solid.Interfacial tension of  $\gamma_{gl}$ ,  $\gamma_{gs}$  and  $\gamma_{ls}$  interacts on every interface.(Cf.fig.1)When the angle( $\theta$ )between liquid surface and solid surface is contact angle,three interfacial tensions must match in equilibrium condition.Therefore,next method is made up.

$$\gamma_{gs} = \gamma_{ls} + \gamma_{gl} \cdot \cos \theta$$

Method.3

The rain on structures surface coheres and flows.The more hydrophobic surface,the more narrow width of the linear stain by rainwater becomes.The rainwater that greatly stains flows on the linear stain of narrow width.So,the linear stain is shaded.In a similar way, when there is the umbo,the rainwater rises by surface tension and a lot of suspension flow on the part to get rise.So,the linear stain around the umbo is shaded.

It is need for that prevention to make  $\gamma_{gl} \cdot \cos \theta$  on the method.3 small and make  $\gamma_{ls}$  on it large,so make structure surface hydrophobic.Therefor,it is thought that width of the linear stain by rainwater spread,the stain isn't shaded and the stain is hardly conspicuous.(Cf.fig.2)



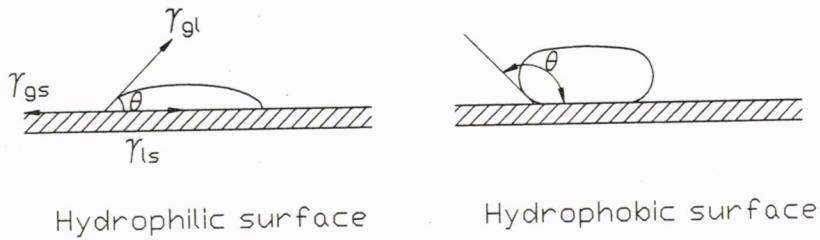


Fig.1 The contact angle and wetness of structures surface

	$\gamma_{ls}$ big	$\gamma_{ls}$ small
The agglomeration water molecules		
the stain of structures surface		

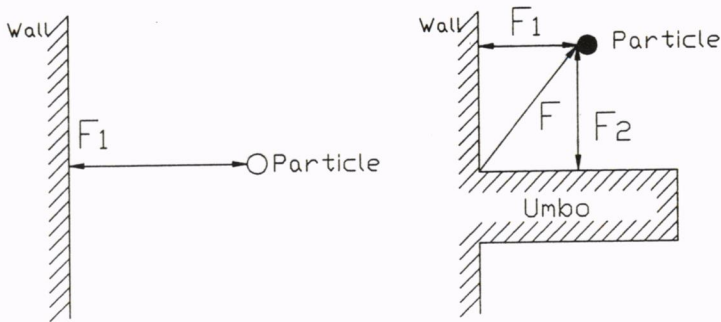
Fig.2 The relation between  $\gamma_{ls}$  and the stain

### 4.3 The stain occurred around the umbo

As mentioned 「3.The stain form」 above,a lot of stain adhere around umbo in spite of the intervention or non-intervention of rainwater.We considered as follows from two points of view,the static electricity suction power and the air flow.

(1)The static electricity suction power by the umbo

Fig.3 shows differences between the static electricity suction power of umbo existence and non- existence.From Fig.3,when the umbo doesn't exists,the power to suck the stain particles is power( $F_1$ ) only.On the other hand,when the umbo exists,the suction power to interact on the stain particles adds power ( $F_1$ )and newly power ( $F_2$ )to interact to direction of the umbo.Therefor,the stain particles is sucked by resultant force( $F$ )of  $F_1$  and  $F_2$ .Because of  $F_1 < F_2$ ,it is thought that the stain particles tends to gather around the umbo by the static electricity suction power.



The no-existence of umbo      The existence of umbo

Fig.3 The static electricity suction power by the umbo

(2)The air flow

Fig.4 shows differences between the air flow of umbo existence and non-existence. From Fig.4, because the air flow comparatively stabilizes when the umbo doesn't exist, it is thought that also flow and sedimentation of the stain particles stabilize and the stain uniformly adheres. However, when the umbo exist, the air flow is confused by the umbo and the stain becomes such as Fig.4. Because whirlpool wind velocity becomes slow, it is thought that a part of air dust to be floated by energy of air flow precipitates and adheres to structures surface.

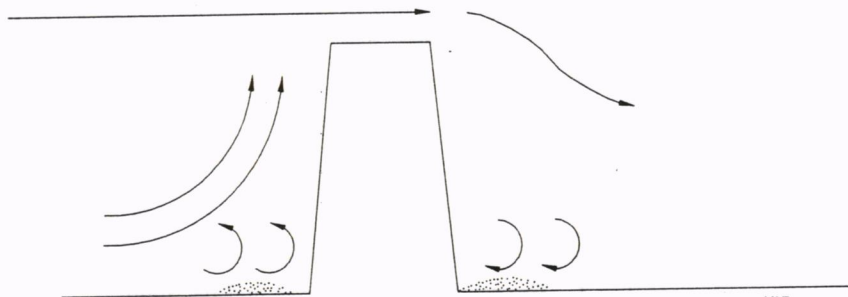


Fig.4 The air flow around the umbo

According to the above(1),(2), when we decrease the stain adhering around the umbo, it is thought that we need to lose the umbo on the road structures as much as possible and to change the form of the umbo into gentle form of the umbo that doesn't disturb air.

5.GENERAL CONCLUSION

It is considered that the stain on road structures in city was combined air dust with paraffin by exhaust gas of diesel engine cars.

According to the stain form of road structures, the next three shows the characteristic stain on road structures.

- The linear stain by rainwater intervention
- The characteristic stain by structure material
- The stain to be unrelate to rainwater intervention or non-intervention by the umbo

Also, the adhesion of stain relates to Van der Waals power, the adhesive power by absorption water membrane, static electricity suction power and compound power. It is thought that the linear stain by rainwater relates to surface tension and the stain around the umbo especially relates to the static electricity suction power and influence of air flow.

According to the above, when we consider the stain measures of the road structures, we need to build the road structures that has less umbo to stop air flow and use covering materials of less surface energy.

After this, the stain measures of road structures in city become increasingly importance as new technique to improve the environment with the promotion of landscape measures. However, because the examination of the stain measures has just started, it is necessary to examine actively after this.

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