The Relationship between Damages in Road Pavement and Customer Feedback

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ABSTRACT: Throughout Japan the road surface condition of expressways is monitored on regular basis. IRI is used as a measure of road roughness and visual inspection by expressway patrol teams is used to check for emergency road damages. Inspection using IRI is carried out every two years. When emergency road damages, such as potholes, are detected by expressway patrol teams, emergency repairs are executed as soon as possible.In addition to IRI and visual surface inspection, some customers lodge complaints about the trafficability of the expressways. In this study, damage probability of road pavement was evaluated using inspection result data between each interchange along an expressway. The relationship between damage probability and customer feedback for trafficability was also considered.

1 INTRODUCTION

In Japan, Road Act was revised in May 2014 due to the accident of Sasago Tunnel in 2012. And in accordance with the incidents, the consciousness of people for road facility has changed. Especially high safety is required in expressway. In addition, expressway management companies are carrying out daily and periodic inspections for structures of expressway and other related facilities. Besides they have requirement of accountability for stakeholders. Objects of these inspections are mainly classified into bridges, tunnels, pavement and facilities. In this study we focus on road pavement.

In road pavement, there are the structural destructions and the functional destruction, which lose safety and comfort of user. Deteriorations and damages occur depending on the usage of the road which is traffic conditions, ground conditions, climate conditions and so on. For this reason, road have some risks that damages which can't be detected between inspection intervals may occur. On the other hand, some users of expressway lodge complaints when they encounter damages on the road. Such damage included pothole and crack, and other unsafe road surfaces. In considering accountability of pavement condition, to comprehend the road surface condition is quantitatively with inspection records. However relations between this condition and complaints lodged by users haven't been described before.

The purpose of this study is confirming the relationship between complaints lodged by users and damages occurring on road surface.
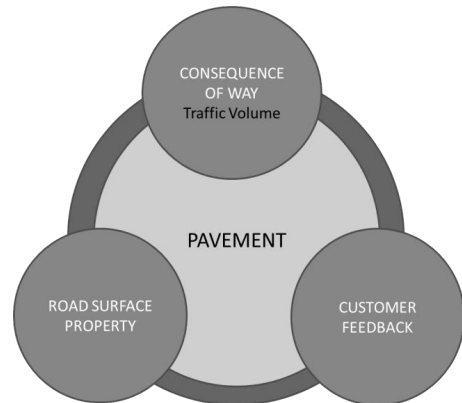

Figure 1. Property Factors of Managing Pavement Including Customer's Complaint

2 PROPERTY FACTORS OF MANAGING PAVEMENT INCLUDING CUSTOMER'S COMPLAINTS AND POTENTIAL RISK

We defined the relationships between property factors, "consequence of road" "road surface property" "customer's feedback', as we think about the management including customer's complaint. (See Fig.1) That is it is necessary for road manager to secure the quality of pavement considering consequence of road and customer's feedback. Therefor, at first, we need to grasp the each relationship between these
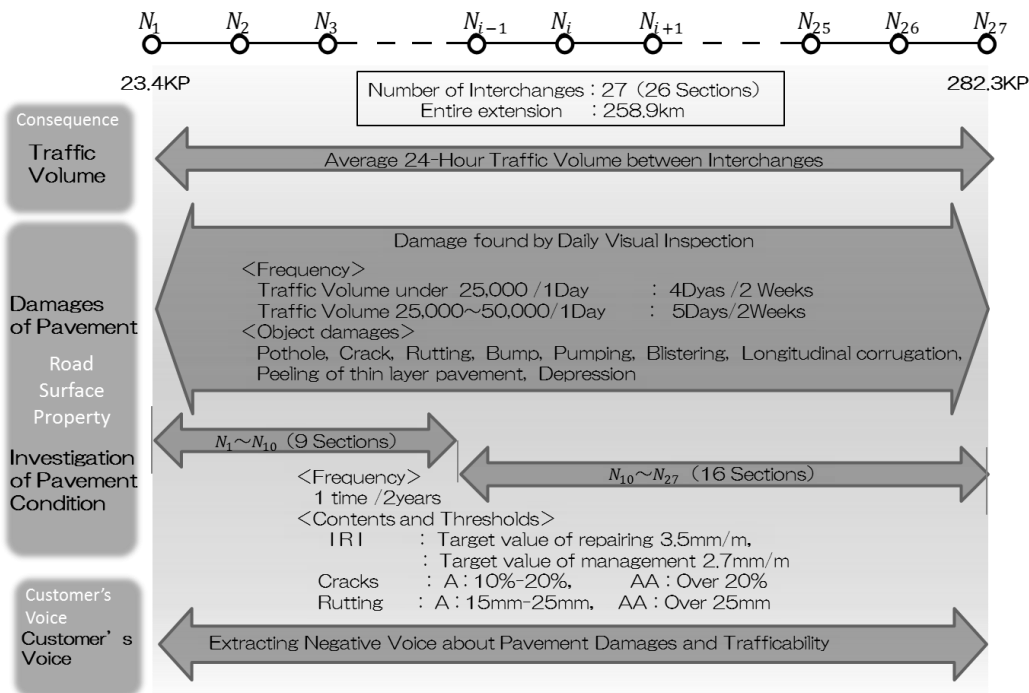
Figure 2. Inspection outline of property factors (2011, 2012, 2013)

three property factors.

Fig. 2 illustrates outline of inspection to grasp property factors of objective road. The objective road consider in this study is the Hokuriku-expressway which has been in service for over 30-year. This object road has 27 interchanges and its total length is 258.9 km. We analyzed with investigation data form 2011 to 2013.

We conceive consequence of road to be the 24-hour average number of passing vehicles per each interchange because this factor indicates circumstance of road with fact that how many vehicles use the road.

We grasp road surface property with two inbestigations. First data set is record of road surface damages detected by daily visual inspection which is carried out 4 times or 5 times every 2 weeks. Another data set is investigation record of pavement condition carried out every two year by a road surface condition survey vehicle. Customer feedback is complaints that users lodge about trafficability of expressway.

With these 3 property factors, we reveal each relationship. Fig.3 shows an example of the relationship between traffic volume and occurrence probability of pavement damages. Occurrence probability of pavement damages is based the on daily visual inspection. Fig.4 shows an example of relationship between traffic volume and section average of IRI. IRI is based on the investigation record of pavement condition.
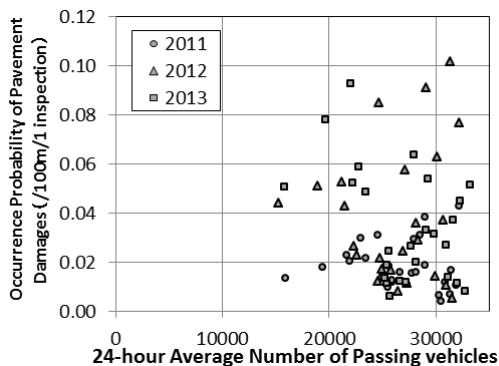

Figure 3. The relation between traffic volume and occurrence probability of pavement damages
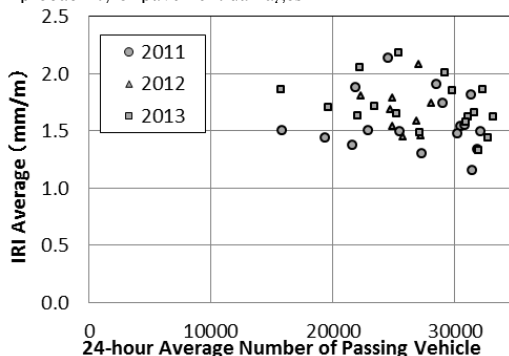

Figure 4. The relation between traffic volume and IRI average per a section

Now, the rage both axes are high means that many users use the section of road, and also it means that the risk on safety and comfort is high. Therefor in this road section which risk is high, expressway management companies need to endeavor to improve the pavement condition.

Correlations are not observed in these two figures.

3 CHARACTERISTIC OF ROAD SURFACE PROPERTY

We explain about the previously mentioned two data sets as road surface property, and conduct comparison and consideration.

3.1 Damages of pavement

Figure 5 shows the total number of pavement damages in each category detected by daily visual inspection in 2011, 2012 and 2013. This inspection carried out 4 times or 5times every 2 weeks depends on traffic volume.

According to this inspection, pavement damages are compounded from 74% pothole, 14% cracks, 5% rutting, 2% bumping and others 4%. In this study the all kind of these damages are considered as pavement damages. Pavement damages found by this inspection have each management threshold. Potholes are dealt immediately with emergency measure like patching after they are detected by this visual inspection. On other kind of damages, if they are worse deterioration than thresholds, they are also dealt as well as pothole or planned for maintenance.

Occurrence probability of pavement damages is number of pavement damages per unit length and per one inspection based on this daily visual inspection.

3.2 Investigation of pavement condition

Another data set is investigation of pavement condition carried out every two year by a road surface condition survey vehicle and evaluated by three measuring items, IRI, which is index of pavement roughness, cracks and rutting every 100m. IRI, International Roughness Index, was proposed by the World Bank as index of evenness influencing ride comfort. Crack is ratio of crack per unit area. Rutting is depth of unevenness in transverse direction. These 3 items also have each two management thresholds - target value of repairing and target value of management (Tab.1). If IRI = 3.5mm/m then repairs required soon and if IRI = 2.7mm/m then the surface is carefully monitored.

For example, figure 6 shows the normal distribution of IRI measurement in three years. Two probabilities of excess thresholds are following below.
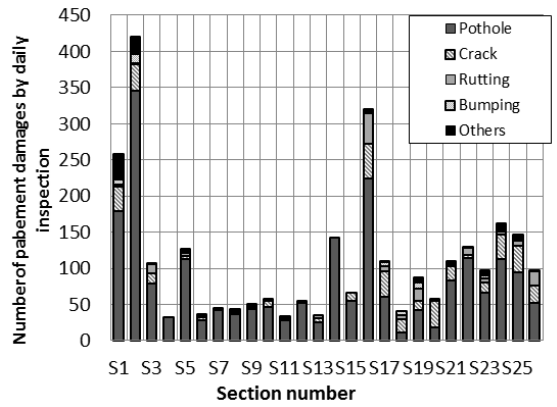

Figure 5. Number of damages in each category (total of 2011, 2012 and 2013)
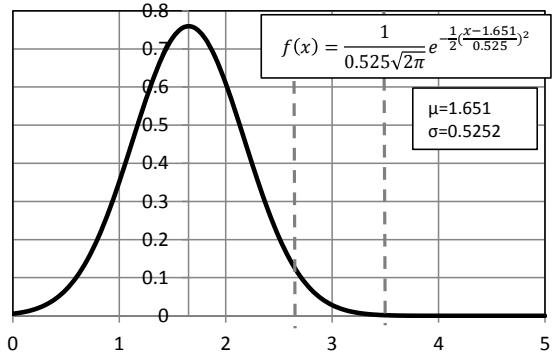

$$f(x) = \frac{1}{0.525\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{x-1.651}{0.525})^2}$$

μ=1.651
σ=0.5252

Figure 6. Normal distribution of IRI measurement for three years

Tale 1. Management thresholds of three items of investigation of pavement condition

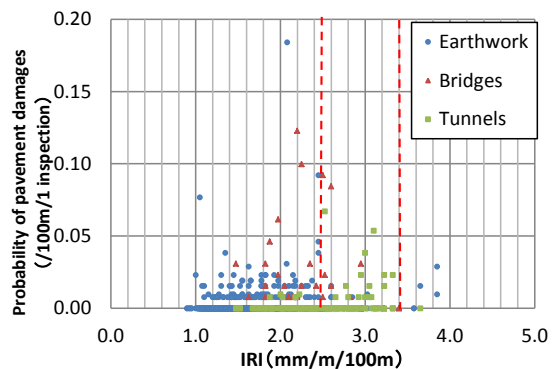| Measuring Items	IRI mm/m	Cracks %	Rutting Mm
Target of Management	2.7	10	15
Target of Repairing	3.5	20	25

Figure 7. The relationship between occurrence probability of pavement damage and IRI measurements $(S_1 \sim S_{26})$

$$P(2.7 < x) = 0.022750$$
$$P(3.5 < x) = 0.000216$$

It can be explained by these results that management with IRI is good standing.

3.3 The relation between damages of pavement and investigation of pavement condition

Fig.7, fig8, and fig9 illustrate each relationship between occurrence probability of pavement damage and measurements of pavement condition (IRI, crack, rutting). Three kinds of pavement, "embankment", "bridges" and "tunnels" are divided in the figures because these construction is deference. It can be confirmed that by these figures that occurrence probability of pavement damages is even high below the management thresholds for IRI, cracks, and rutting. Therefor pavement damages occurring sporadically such as potholes don't entirely correspond with pavement condition.

4 THE RELATION BETWEEN COMPLAINTS AND ROAD SURFACE PROPERTY

4.1 Reliability evaluation method on user complaints

Tab 2. Number of complaints and number of sections indicated by user

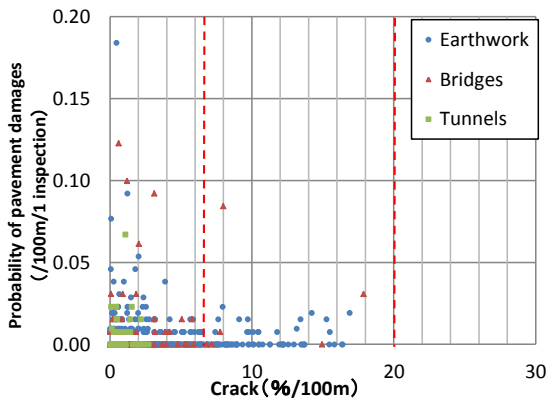|	Number of Complaints	Number of Complaints Which Can Be Identified Damage Site	Number of Sections Pointed by Complaints	Average Number of Section Pointed by A Complaint
FY2011	52	34	77	2.27
FY2012	51	32	51	1.59
FY2013	43	22	60	2.73

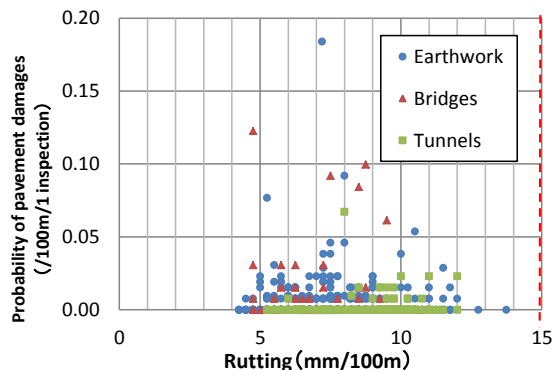Figure 8. The relationship between occurrence probability of pavement damage and crack measurements $(S_1 \sim S_{26})$

Figure 9. The relationship between occurrence probability of pavement damage and rutting measurements $(S_1 \sim S_{26})$

Tab 3. Reliability evaluation of user complaint

Hierarchy of Reliability	Index of Reliability Evaluation		Keywords of complaint(2012)	Number of Cases		
				FY2011	FY2012	FY2013
Reliability Ⅰ	(1) States of Damage	○	Pothole, Cave-in, Rutting, Hole, Bumping, Repair mark of hole, Dent, Impact, Swing, Shaking of tire, Pulling out of ETC-card, Uncontrolling steering wheel	15	6	29
	(2) Location of Finding damage	○				
	(3) Fact Identified or not by inspection	○				
Reliability Ⅱ	(1) States of Damage	△	Pothole, Cave-in, Rutting, Hole, Bumping, Channel, Deteriorarion with over time, Impact, Gap, Damage, Patchwork, Some onomatopoetic words like shaky and bumpy.	17	23	68
	(2) Location of Finding damage	△				
	(3) Fact Identified or not by inspection	△				
Reliability Ⅲ	(1) States of Damage	×	Hole, Badly, Roughly, Some onomatopoetic words like shaky, bumpy, roughly and shabby	19	14	49
	(2) Location of Finding damage	×				
	(3) Fact Identified or not by inspection	×				
TOTAL				51	43	146

More accurate time and point that complaints lodged are sought to consist user complaint with pavement condition. However one complaint often indicate through some sections or it is impossible to identify where. Complaints to the managing company are something only a few user lodge and they are quite subjective. At first, reliability of user's voice needs to be analyzed.

Tab.2 shows a number of all complaints about rad pavement ledged by users, a number of complaints mentioning sections which damages exist, a number of sections where complaints indicate, and average number of sections pointed by one complaint, for each year. Tab.3 illustrates the index of evaluation to evaluate hierarchy of reliability, evaluation level by each hierarchy of reliability, and keywords that user use. The indexes are (1) States of Damage, (2) Location of Finding Damage, (3) Fact Identified or Not by Inspection. We check whether complain mentions correctly or not in regard to (1) and (2), and whether to detect or not while inspection with attending complaint in regarding to (3). User complaint giving accurate information with these indexes categorized into reliability- I and one giving nothing or vague information categorized into reliaility- II. Reliability- III is complaint ranking between the two indexes above.

Fig. 10 illustrates the result of reliability evaluation in each section in 2011, 2012 and 2013. It suggests there are specifically more reliability- I complaints in S16. And they are concentrated around from S23 to 25. Reliability- I complaint is customer feedback based on the fact. So it is required to be conscious in order to save the safety.

4.2 The relation between sections indicated by complaint and pavement damage

Fig.11, fig.12 and fig.13 illustrate sections corresponding complaint and occurrence probability of pavement damage. "×" overlapped in figures means S16 having specifically much reliability- I and "◇" means S23 – 26 alike. In 2012 and 2013, the two results are related to positive correlation. And in every result, "×" is observed in the rage that X-axis is high. In 2012 and 2013 "◇" is observed the range that X-axis is relatively high.

4.3 The relationship between sections indicated by complaint and pavement conditions

In order to distill the especially poor part of road from investigation record of pavement condition, we treat probability of exceeding target value of management as excess probability. Fig.14 and Fig.15 illustrate sections corresponding complaint and IRI/cracks excess probability. (Rutting is not over thresholds.) "×" and "◇" is treated as well as above. Correlation can't be observed with fig.14. On the other hand Fig.15 is related to negative correlation for some reason. No relationship is observed in with S16 and S23 – 26. According to that, most users tend to lodge complaints about sporadic damages such as pothole and not about long span problems.
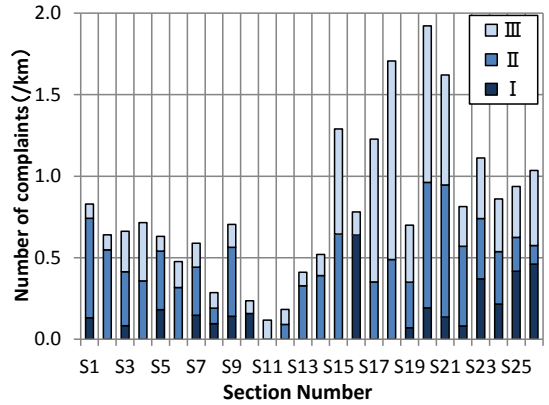

Figure 10. Number of complaints user indicate in each section (total of 2011, 2012 and 2013)
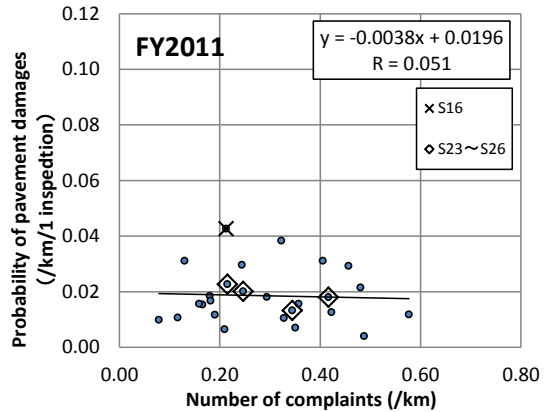

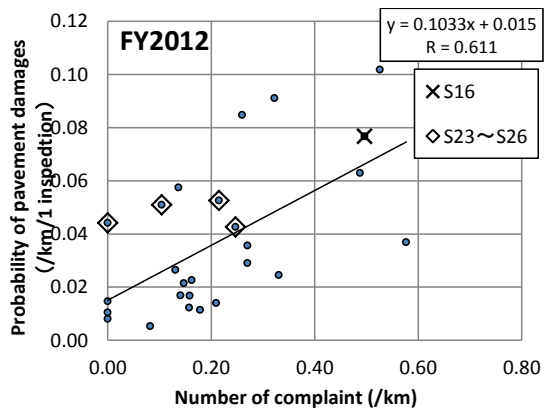Figure 11. Relationship between number of complaints and probability of pavement damages (FY2011)

Figure 12. Relationship between number of complaints and probability of pavement damages (FY2012)

5 CONCLUTION

In this study we considered validity of users' complaints comparing pavement conditions. The results are following bellow.

The relationship between the inspection surface condition used for pavement management and user complaints is not strong. In respect to Investigation of road surface, road of expressway is managed properly. However more pavement damages detected by daily visual inspection occur on the road which is under management thresholds. Most users tend to lodge complaints about damages on pavement like potholes. In addition to this, high reliability complaints based on the fact and are lodged in the section that occurrence probability of pavement damages is high.

We concluded bellow by these results above. Management of road pavement is carried out based on record of investigation of pavement condition like IRI. But they tend to lodge complaints about not roughness of pavement but sporadic damages like potholes when road users feel in danger. Thus it is possible to secure the quality of pavement which users seek by to reduce probability of pavement damages, namely to deal with these sporadic damages appropriately. And we think that expressway management companies can explain doing appropriate management including customer's feedback.

6 FUTURE WORK

This study doesn't include any repairing data following inspection result data and is not analyzed in time-series. In the future work, we are going to add repairing data and construction types in chronological order.

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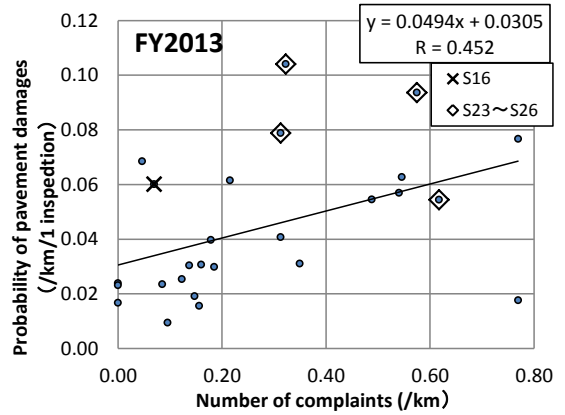
Figure 13. Relationship between number of complaints and probability of pavement damages (FY2013)
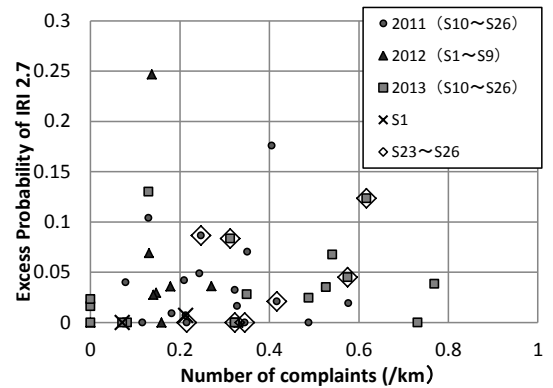

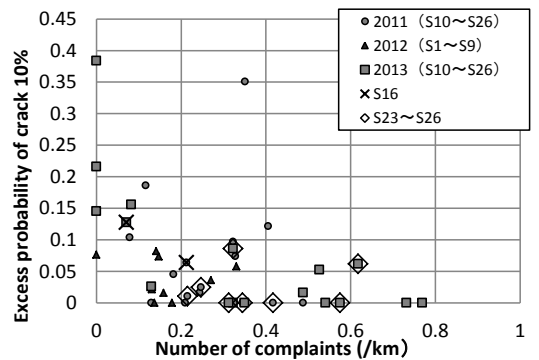Figure 14. Relationship between number of complaints and excess probability of IRI 2.7

Figure 14. Relationship between number of complaints and excess probability of crack 10%