Correlation Between Bumps on a Pavement Surface and IRI

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ABSTRACT: The bump in this paper is the height difference of road surface created between earth structure and concrete structure by subsidence of earth. This is the study report on finding the locations of bumps with size of 20mm or larger making use of International Roughness Index of 10 meters Interval (hereinafter "10mIRI") through examination of correlation between the size of bumps and the 10mIRI value.

For better service for the expressway users, both safety and comfort should be enhanced forward. Then the shock caused by bumps is troublesome because they increase nuisance for the users.

The survey of the road surface on the bumps is not periodically done because a mere survey purpose work lane restriction is unallowable. However, recent development of High Speed Road Profiler with profiling system has turned it easy to measure bumps size without lane restriction. The basic data of the profiler are relative height, and such data enables to estimate (relative height of) bumps on the road surface.

In practice, engineers determine the point in need for repair form bump size. That criterion is 20mm or more at the joint of the bridge.

If close correlation between 10mIRI value and the size of bumps is confirmed, engineers can find the point of repair from 10mIRI value instead of direct bump size.

KEY WORDS: bump, bumps size, IRI

1 INTRODUCTION

On the expressway, periodical surveys are conducted on rutting, cracks, IRI, and skid resistance, and present road surface condition is understood. (All surveys are executed without lane restriction.)

However in the case of bumps, the methods, "Bumps Survey Method" (Method No.227) and "Road Surface Roughness Measurement Method by 3m Profile-meter" (Method No.223), require lane restriction and have prevented periodical surveys.

As a survey method on bump size without lane restriction, a study is done on the method to identify bump-formed-location from ride quality value (IRI)

Table1: Criterion Applied
(from NEXCO-Design-Manual, Volume 1 “Pavement”.)

	Rutting (mm)	Bump Size (mm)		Skid Resistance (μV)	Flatness by IRI (mm/m)	Crack Ratio (%)
	100m -interval	The Joint Area of Bridges	The Area of Culverts		200m -interval	100m -interval
Criterion of Repair	25	20	30	0.25	3.5	20

※IRI stands for International Roughness Index that recently is attracting attention as an Index for the appreciation of ride quality.
IRI is proposed by World Bank in 1986. It has good correlation with other survey data. It is regarded as a good Index since it can find super-long-wave-length corrugation and makes it possible to appreciate airport runways, paved roads, unpaved roads and others on the same basic idea.

2 ISSUES TO LOCATE BUMPS

The values of International Roughness Index of 200 meters Interval, (hereinafter “200mIRI”), on Kisei Expressway are shown in Table-2. On that expressway, the subsidence is so obvious at the embankment that the expressway users are complaining. However, Table-2 tells no places exceed the criterion value of 3.5mm for repair. The value so taken tends to become small. Since even there is localized subsidence, the data are averaged in the area of 200m district including sound places.

2.1 Examination of 10mIRI Evaluation

It is necessary to shorten the interval of IRI, so as to specify the points of bumps. This time, the interval of IRI was changed from 200m to 10m, and the processed data were shown in Table-3. As seen in Table-2 and 3, the data of 200mIRI had little capability to identify the location of bumps. On the contrary 10mIRI revealed the local subsidence.

Table2: Kisei Expressway 200mIRI Values

Problem Zone (Unit;Places in 200m)

Section	Whole Sum	0-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-5.4	5.5-6.4	6.5-7.4	7.5-8.4	8.5-9.4	9.5 以上
Inside Lane Up-bound	124	88	34	2	0	0	0	0	0	0	0
Passing Lane Up-bound	9	5	4	0	0	0	0	0	0	0	0
Inside Lane Down-bound	124	72	50	2	0	0	0	0	0	0	0
Passing Lane Down-bound	12	7	5	0	0	0	0	0	0	0	0
Total	269	172	93	4	0	0	0	0	0	0	0

Table3: Kisei Expressway 10mIRI Values

Problem Zone (Unit;Places in 10m)

Section	Whole Sum	0-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-5.4	5.5-6.4	6.5-7.4	7.5-8.4	8.5-9.4	9.5 以上
Inside Lane Up-bound	1,240	964	178	45	28	12	3	2	4	2	2
Passing Lane Up-bound	90	65	15	6	1	0	1	0	1	1	0
Inside Lane Down-bound	1,240	946	182	43	28	18	3	7	7	1	5
Passing Lane Down-bound	120	79	28	6	3	2	0	0	1	0	1
Total	2,690	2,054	403	100	60	32	7	9	13	4	8

3 CORRELATION BETWEEN IRI VALUE AND THE SIZE OF BUMPS

For establishing the method to estimate the bumps quantitatively, the correlation between the IRI value and the size of bumps was studied. Here, the criterion of repair is 20mm or more at the joint of the bridge.

IRI provides consistent evaluation on ride quality and flatness. Here the following processes were done to identify the locations of bumps with 20mm size from the data of 10mIRI.

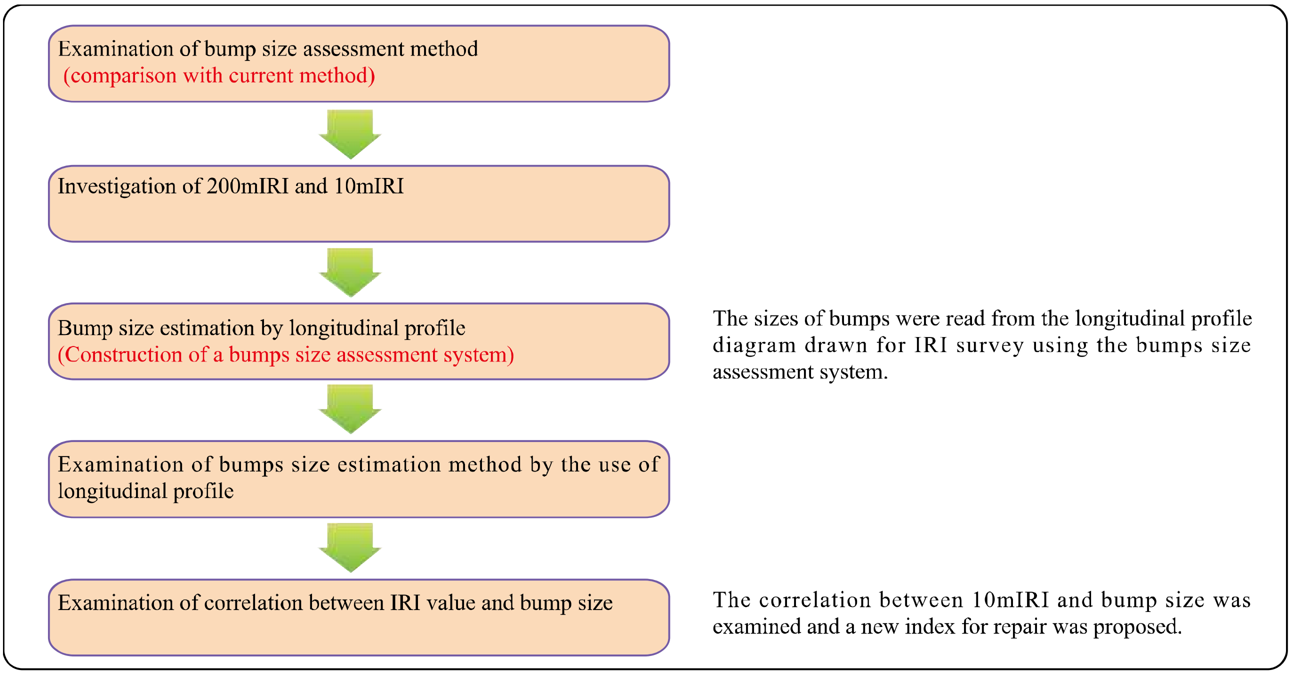


Figure1: Flowchart for Bumps Size Estimation

4 CONSTRUCTION OF THE SYSTEM FOR BUMP SIZE ESTIMATION DIAGRAM

For bumps size estimation, a bumps size estimation diagram that shows surface flatness and relative height was drawn, with Kilometer Post (hereinafter “KP”) for horizontal axis, by drawing both the flatness, i.e. the longitudinal profile value (0.1m interval) for IRI, and the 10mIRI profile view. And a system, Bump Size Estimation System, for drawing the diagram was constructed.

4.1 Bump Size Estimation Diagram

At the places where IRI exceeds repair criterion, bumps, corrugation and others are understood from the longitudinal profile of bumps size estimation diagram. The system draws a diagram like Fig.2 when road name and KP are input in the system. And bump size (relative height difference) is read from the part ③ (detail view) of bumps size estimation diagram.

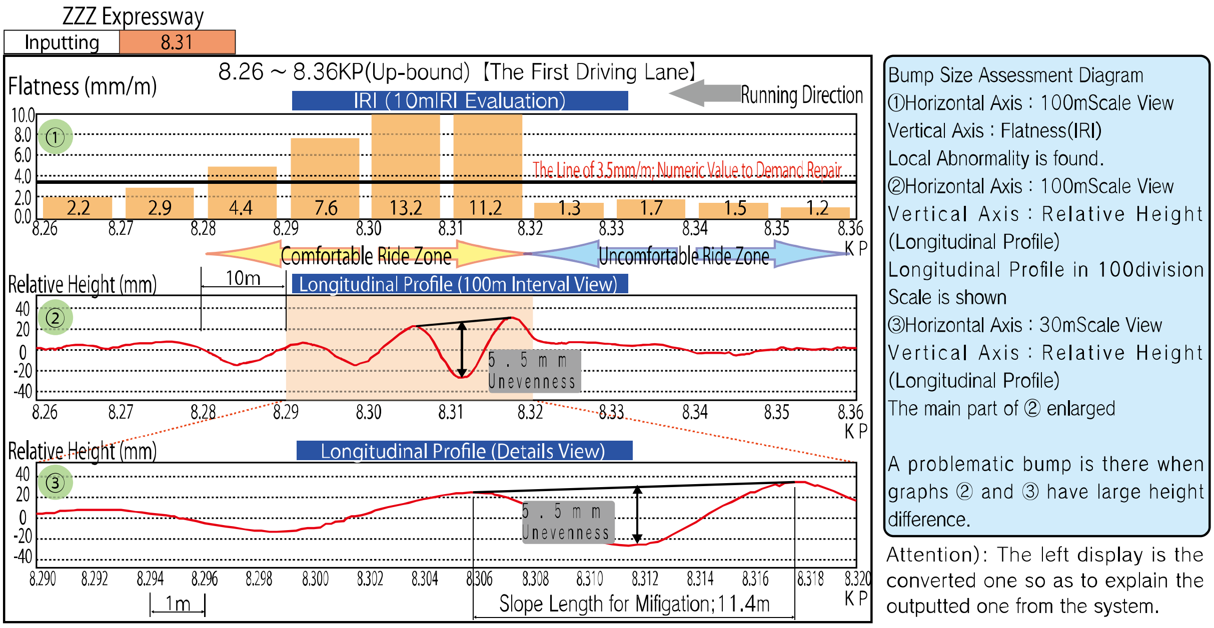


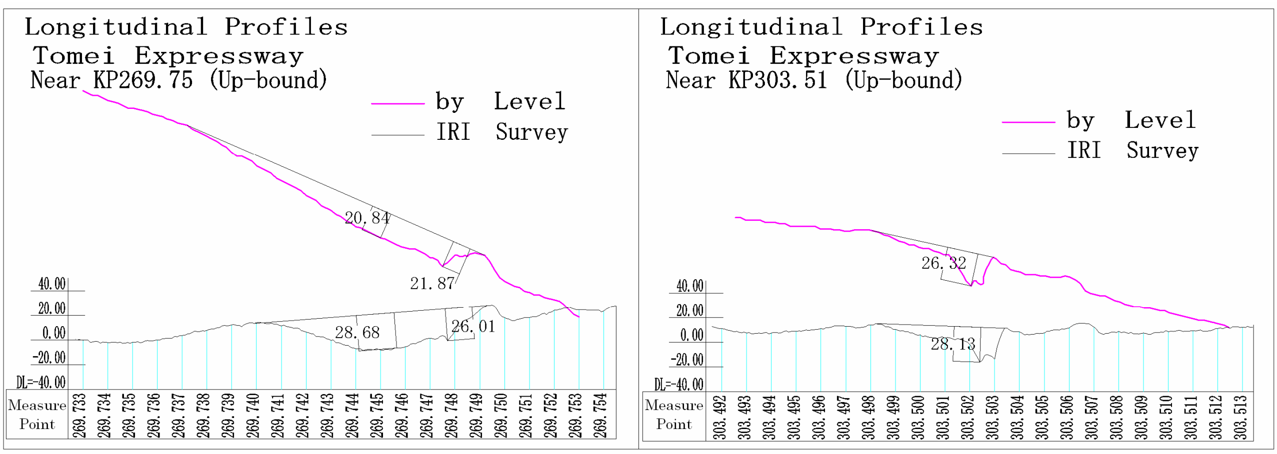
Figure2: Bumps Size Estimation Diagram

5 EXAMINATION OF THIS METHOD

The longitudinal profile contains errors because it is obtained by the survey from a vehicle running at 80km/h. And estimation on the effectiveness of this method has to take into account of those errors. The values obtained by this method were compared with the longitudinal profile obtained by level measurement under lane restriction. The level measurements were done at places where bumps are noticed relatively easily between Mikkabi IC and Toyota IC of Tomei Expressway.

5.1 Comparison of Longitudinal Profiles

The longitudinal profiles were compared for the both, this method and level measurement, on the configuration of the profile. While the data of level measurement reflect the real shape of the road including longitudinal grade, the data of IRI longitudinal profile are relative heights. Therefore bumps were compared taking account of the condition difference. For the sake of comparison, figures were drawn. Figure3 shows the profiles at 4points. The two profiles are alike, and bumps seemed to be detected from IRI profile.



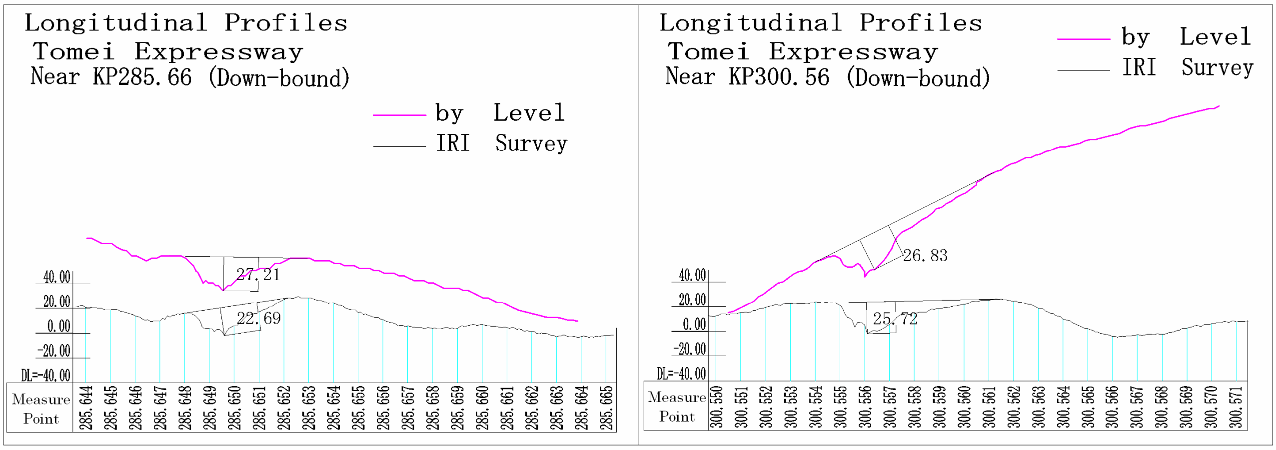


Figure3: Comparison of Longitudinal Road Shape

5.2 Examination on the method

Bump sizes were read from the two profiles, namely the one by IRI profiler and the other by level machine. The bump sizes by both methods were compared in Figure4.

Since the data of IRI profiler are taken from running vehicle at the speed of 80km/h, they are corrected with the acceleration measurement. By this some errors were caused in some cases. However, it was seen that the places where the bumps were larger than 20mm IRI profile were also larger than 20mm. Judging from the figure4, IRI profile gave larger value for bump size. The discrepancy was occurring to the safe side for the use in primary judge.

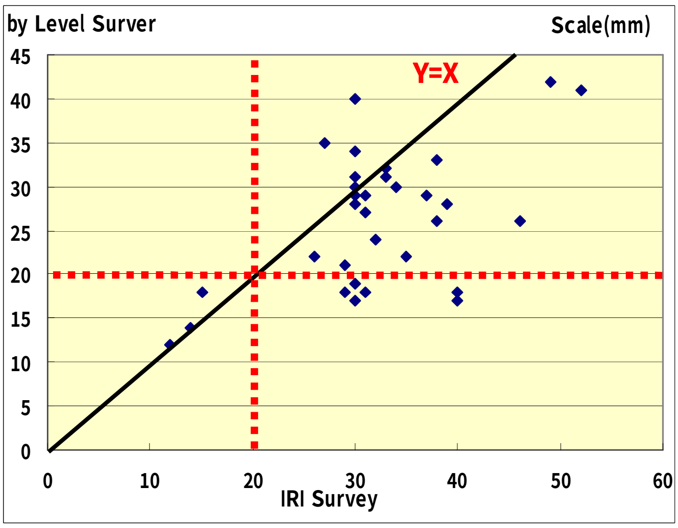


Figure4: Comparison Graph of Unevenness Height

6 CORRELATIONS BETWEEN IRI VALUE AND BUMP SIZE

The places where 10mIRI exceeds 3.5mm/m (Maintenance Criterion for 200mIRI) were picked up in the districts as shown below. For all selected places, bumps size estimation diagrams were drawn and bridge joint areas and subsidence-likely-to-occur places were identified. Then, the size and the length of bump were read out from the diagram and compared with IRI value. However, the data related to joint-passing-through shocks were omitted because the examination is about the correlation of bump size.

6.1 Road Districts for Checking the Method

Table4: Number of the Checked Points by Expressways

Subject Line	Locality	Up-bound/ Down-bound	Lane	Number of the checked points
KiSei EXPWY※	Seiwataki ~ Omiyaodai	Both-bounds	Driving Lane	90
Chuo EXPWY	Ihoku ~ Nakatsugawa	Both-bounds	Truck Lane	202
Tokai-kanjo EXPWY	Toyotahigashi JCT※~ Minoseki JCT	Both-bounds	Passing Lane	296
Tomei EXPWY	Mikkabi ~ Kasugai	Both-bounds	Driving Lane	1313
Total				1901

※EXPWY=expressway, JCT=Junction

6.2 Bumps by Categories

1,901 checked points are shown by category in Table5.

Table5: Number of the Checked Points by Category

Category	Number of the checked Points	Number of the omitted Points	Correlation Checked Points	Number by Roads
Subsidence of Earthwork	812	–	Total Number 1350, Kisei EXPWY 75, Chuo EXPWY 144, Tokai-kanjo 158, Tomei EXPWY 973	Total Number 1901, Kisei EXPWY 90, Chuo EXPWY 202, Tokai-kanjo 296, Tomei EXPWY 1313
Approach Area of Bridge Joints	437	–		
Tunnel	19	–		
Subsidence of Bridge Surface	82	–		
Double Counting at the part of the Joint, on Thin-layer Pavement, or with Unevenness Height	–	551	–	

6.3 Correlation between 10mIRI Value and Bump Size

6.3.1 Correlation by Each Lain

The correlations between 10mIRI value and the bump size read from the estimation diagram were examined. In this examination, those points that had 3.5mm/m or more of 10mIRI value were selected.

(1) Kisei Expressway

Selected 75 points of all 90 points by excluding joints area, 15 points, were examined.
A regression equation y=3.4483x was obtained. For 20mm bump size, IRI value of 5.8mm/m was found. It can be said there is a correlation with correlation coefficient R=0.643 that is rather small on account of limited number of data.

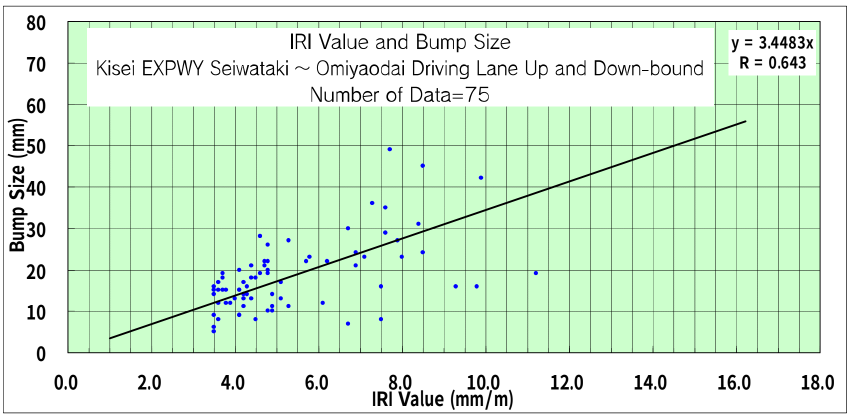


Figure5: IRI value and Bump Size of Kisei EXPWY

(2) Chuo Expressway

Selected 144 points of all 202 points by excluding joints area, 58 points, were examined.

A regression equation y=3.2762x was obtained. For 20mm bump size, IRI value of 6.1mm/m was found. It can be said there is a strong correlation with correlation coefficient R=0.704.

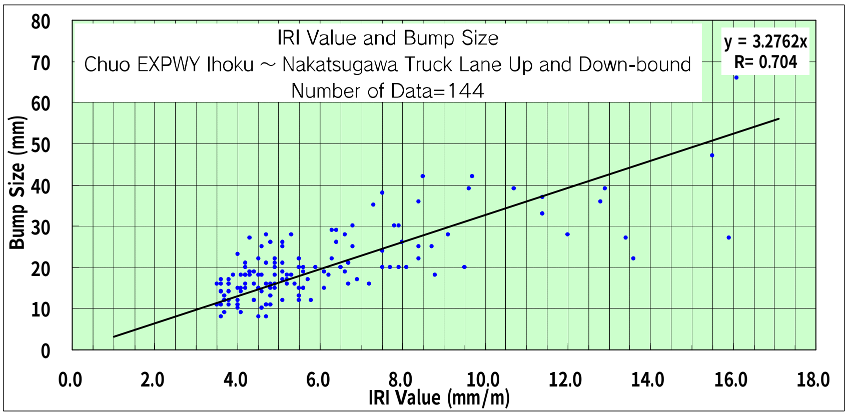


Figure6: IRI value and Bump Size of of Chuo EXPWY

(3) Tokai-Kanjo Expressway

Selected 158 points of all 296 points by excluding joints area, 138 points, were examined.

A regression equation y=3.6680x was obtained. For 20mm bump size, IRI value of 5.45mm/m was found. It can be said there is a correlation with correlation coefficient R=0.696

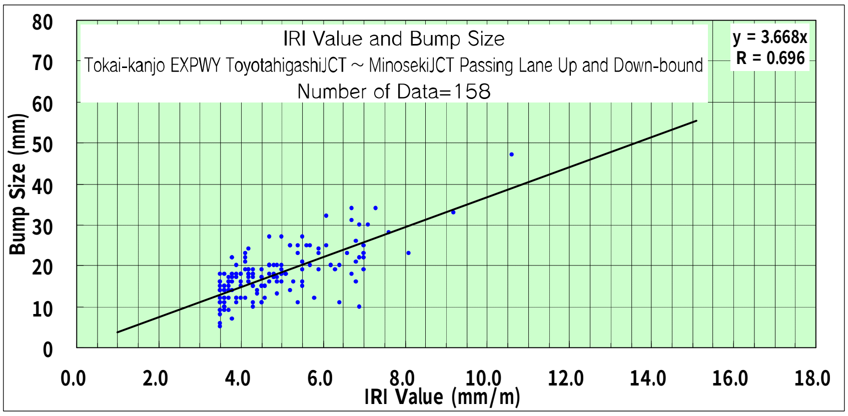


Figure7: IRI value and Bump Size of Tokai-Kanjo EXPWY

(4) Tomei Expressway (Up-bound)

Selected 566 points of all 704 points by excluding joints area, 138 points, were examined.

A regression equation y=3.5132x was obtained. For 20mm bump size, IRI value of 5.69mm/m was found. It can be said there is a strong correlation with correlation coefficient R=0.813

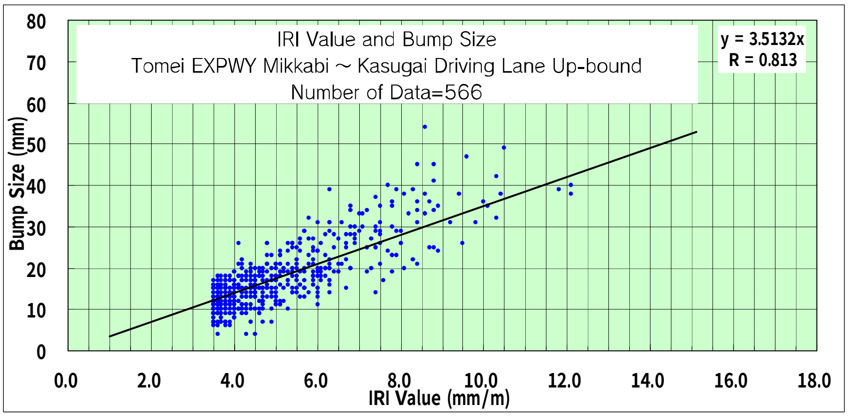


Figure8: IRI value and Bump Size of Tomei EXPWY

(5) Tomei Expressway (Down-bound)

Selected 407 points of all 603 points by excluding joints area, 196 points, were examined.
A regression equation y=3.2802x was obtained. For 20mm bump size, IRI value of 6.10mm/m was found. It can be said there is a strong correlation with correlation coefficient R=0.719.

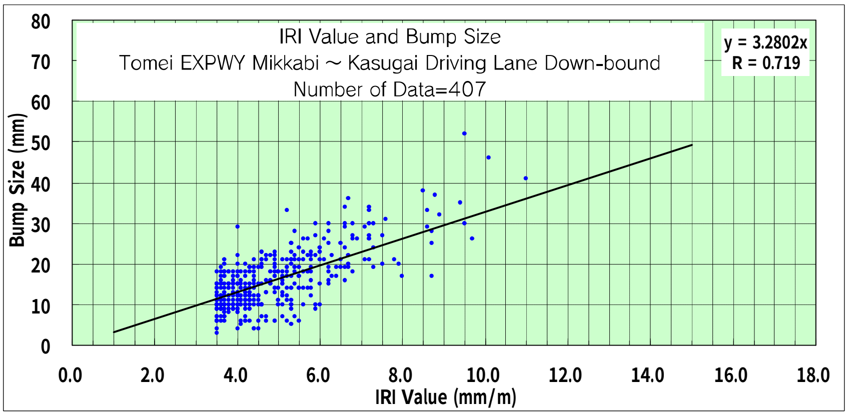


Figure9: IRI value and Bump Size of Tomei EXPWY

6.3.2 Correlation between 10mIRI value and Bump Size (For All Points)

The IRI values that correspond to bump size 20mm take different values from 5.45mm/m to 6.10mm/m. Here all the points, 1,350 points, were examined together

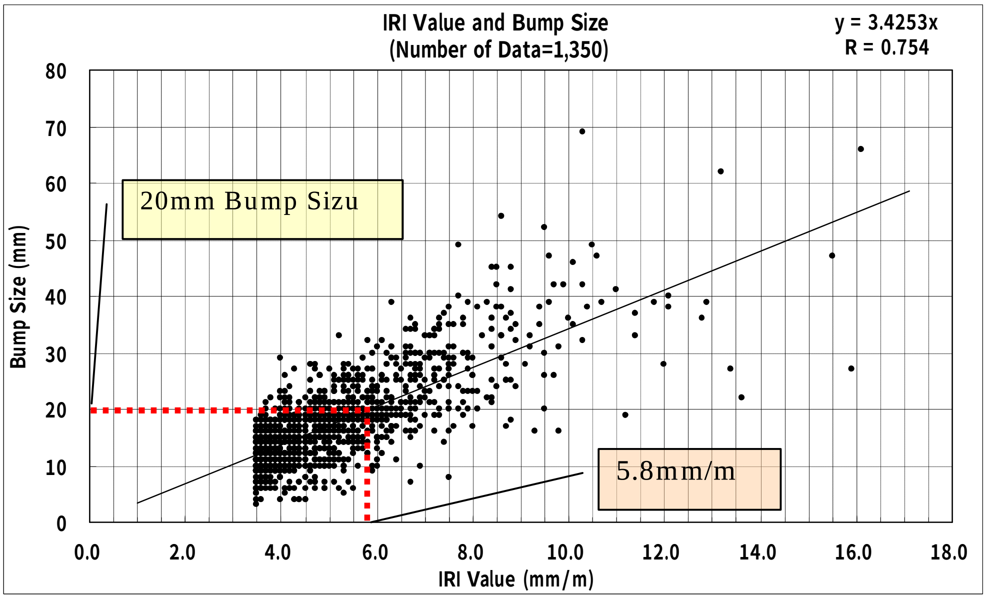


Figure10: IRI value and Bump Size

When the criterion value of 3.5mm for repair is used, corresponding IRI value becomes 5.83mm/m from regression equation y=3.4253x. The points that have IRI value larger than 5.8mm/m are suspected as having unallowable bumps. The correlation was strong with coefficient R=0.754. From this finding 10mIRI value is regarded as a good index to locate bumps.

6.4 Examination of 10mIRI Value 5.8mm/m for a New Index

The correlation between 10mIRI value and bump size was examined for 1,350 data in two cases where the size was over 20mm and over 30mm. The data of 10mIRI value were classified into 4 classes, namely over 5.8mm, over 7.0mm, over 8.0mm, and over 9.0mm. Then the ratio of data where the bump size is larger than 20mm or 30mm was calculated.

In the case 10mIRI was larger than 5.8mm/m, bump size larger than 20mm was at the ratio of 76%. And if 10mIRI is larger than 7mm/m, the same ratio was 91%. The possibility of bumps larger than 20mm seemed high.

Table6: Ratio Bumps Size Larger than Criterion

10mIRI Value	Number of Points	Bump Size 20mm or Up		Bump Size 30mm or Up	
		The Number of Measurement Point	Ratio	The Number of Measurement Point	Ratio
5.8mm or more	334	253	76%	105	31%
7.0mm or more	163	148	91%	83	51%
8.0mm or more	90	84	93%	56	62%
9.0mm or more	43	40	93%	32	74%

The 334 points of 1350 points showed 10mIRI value larger than 5.8mm/m. Those data were classified by size and shown in Figure 11.

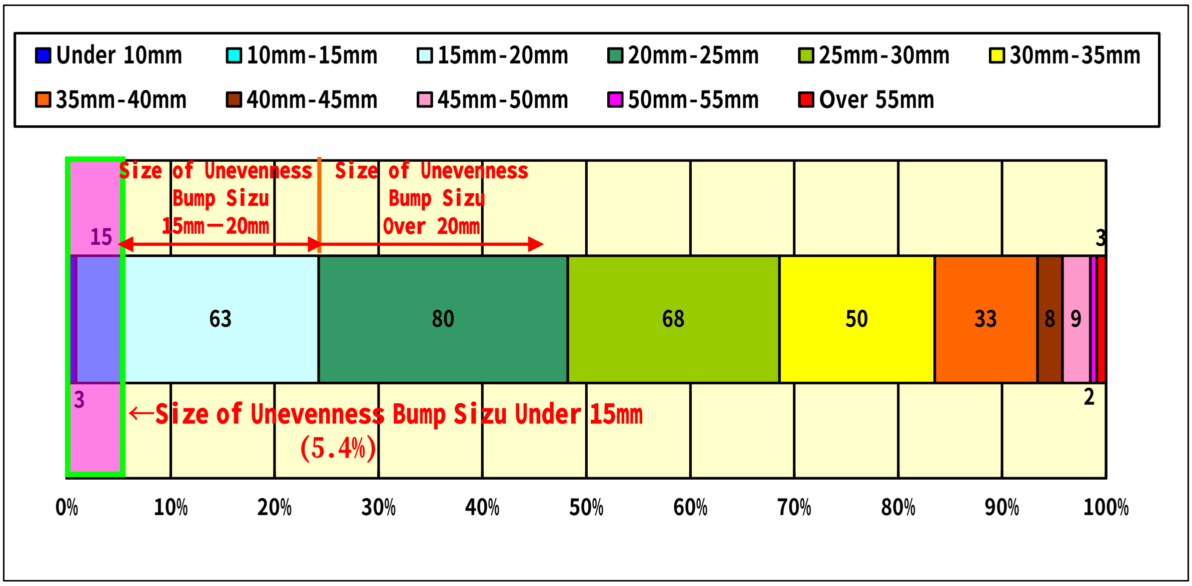


Figure11: 10mIRI Value and Bump Size

The ratio of points, of which 10mIRI was 5.8mm/m and bump size, was 20mm or larger was 76%. The remaining 24% was examined. There the ratio of points with bumps of 15mm or smaller was as small as 5.4%. And the rest, 94.6% had bumps larger than 15mm.

7 CONCLUSION

To find and eliminate ride quality deteriorating bumps is very important. But to determine the bump whether it is larger than repair criterion is very dangerous because it requires level survey on roads with traffic. This paper presents some possibility to use IRI data that can be done without traffic obstruction.

The findings are as follows.

1. The correlation between road user claims with 200mIRI was poor but it was better with 10mIRI. （Table2, 3）
2. It is understandable to locate the road surface with bump size through the use of 10mIRI value.

In the case that the index is 20mm unevenness height as criterion of control level of the bridge joint, the point beyond 5.8mm/m measurement value on 10mIRI is guessed to have some factor like a bump on the road surface.