The Mid Niigata Prefecture Earthquake of 2004 was an inland earthquake characterized by damage focused in local and mountainous areas. The damage of road infrastructures is also marked by the characteristics of the local area. In order to prevent or reduce earthquake damage in the future, it is important to clarify the characteristics of the damage level and the road traffic performance in the local and mountainous area, and reflect them in future earthquake prevention measures.

This paper highlights the damage of road embankments and discusses the effects of road closures on local societies, based on related documents and field investigations. The study also quantitatively estimates the damage levels of road infrastructures, road traffic performances in the local and mountainous areas and the relationships between the seismic intensity scale and both damage level and road traffic performance. From these evaluations, new lessons for future earthquake prevention measures have been obtained.

**Key Words**: Mid Niigata Prefecture Earthquake in 2004, road infrastructure, damage factor, damage level, road traffic performance

1. **INTRODUCTION**

The Mid Niigata Prefecture Earthquake of 2004 was an inland earthquake characterized by damage mainly in local and mountainous areas. As for the damage to civil infrastructures, the road infrastructures were also affected by the characteristics at the local area. Settlement of embankments including the approach embankment to bridges, slide failures and slope failures occurred at many locations and resulted in many road-blockages.

After the Earthquake, the need to improve the seismic performance of embankments received attention. Efficient seismic performance is urgently required for the bridges and embankments that make up the road network on local trunk roads, where the density ratio of road network is low and detours are limited, to fortify them in the event of seismic occurrences. This will contribute to smooth assistance and restoration efforts just after an earthquake. For this purpose, it is necessary to clarify the earthquake damage characteristics and traffic performance of road infrastructure in the local and mountainous regions, and make the findings available in advance for future earthquake prevention measures.

This study focuses on and analyzes the damage level of road embankments, the effects of road-blockages and road damage based on data obtained from field investigations and references. It also analyzes the damage level of the road infrastructure...
in the local and mountainous regions and the road traffic performance in those regions. In addition, this study attempts to quantitatively analyze the relationship between the seismic intensity scale and the level of damage to the civil infrastructure and the road traffic performance. As a result, although the data used were obtained just after the earthquake, the level of damage to the road infrastructure and the road traffic performance have been quantitatively evaluated, offering lessons on earthquake prevention measures for the future road infrastructure.1), 2)

2. FIELD INVESTIGATION AND DATA COLLECTION

The authors conducted a three-day investigation, from December 1 to 3, 2004, laying stress on the damage to road infrastructures and the restorations that followed. The investigation covered trunk road lines including national roads R17 and R117, the Kan-etsu Expressway, sites on the line where the Joetsu Shinkansen was derailed, dikes of the Shinnogawa River and Ojiya-city. Since about 40 days had passed since the earthquake occurrence, the investigation focused on understanding the relationship between the damage-form and damage-level of road infrastructures, the progress of restoration and restoration level. The investigation was carried out by collecting information from various media sources and websites of responsible organizations, and by obtaining information offered from related organizations during site investigation. These organizations mentioned above include the Hokuriku Regional Development Bureau of the Ministry of Land, Infrastructure and Transport3)-5), Japan Highway Public Corporation6), East Japan Railway Company7) and Niigata Prefecture8). Data was also offered from the general offices: Nagaoka Road Office and Shinnogawa River Office of the Hokuriku Regional Development Bureau. Furthermore, the original data was obtained during the field investigation. As the data from the above-mentioned organizations were all gathered during the five months after the earthquake (October 2004 to February 2005), and the author’s field investigations were obtained visually, the substance and accuracy of some of the data may be insufficient.

3. DAMAGE LEVEL OF ROAD INFRASTRUCTURE AND TRAFFIC PERFORMANCE OF ROAD

(1) Features of damage and road closures

a) Features of damage to road infrastructure

The features of damage that caused road closures were classified into 6 forms: (i) Settlement or bumps, (ii) Embankment failure, (iii) Slope failure or mudslide, (iv) Bridge damage, (v) Road blocked in advance and (vi) Others. Here, “Settlement or bumps” means damage in which settlement, bumps, or cave-ins are formed, and settlement of an approach embankment to a bridge is included in this category. “Embankment failure” is the damage in which an embankment fails noticeably, accompanied by slide failures. “Slope failure or mudslide” means the damage in which a slope fails, and “Bridge damage” is where a superstructure and/or a substructure of a bridge are damaged. “Road blocked in advance” is a measure taken to block a road in consideration of potential future damage although no actual damage requiring a road closure has occurred. “Others” are those which cannot be classified into the above-mentioned five forms and damage to other structures such as tunnels, snow sheds and so on.

b) Characteristics of road-blocked points

Seventy-seven blocked points of national roads managed by the Ministry of Land, Infrastructure and Transport (named MLIT hereinafter) and Niigata prefecture were investigated on the damage which were opened to the public through their websites. Fig.1 shows the number of blocked road points and the percentage of each damage form causing the blockage. The epicenter of the earthquake was in a local mountainous region, and therefore most of the damage causes were geotechnical, and especially such cause as settlement or bumps accounted for about 50% of the blocked road points. The second and third most frequently observed forms of damage were slope failures or mudslides, and embankment failures, respectively. The number of blocked road points caused by both settlement or bumps and embankment failures accounted for 60% or more of the total. On the other hand, the number of blocked road points due to bridge damage accounted for only about 7% of the total. This difference can be explained by the advances made in seismic measures
for bridges and the small number of bridges located in the regions where strong ground motion occurred.

(2) Characteristics of damage level to embankment
We investigated severely damaged road embankments to determine their damage levels in a rational manner based on the damage features and their extents.

a) Features of damage to road embankments
The field investigation suggests that the damage to road embankments differed according to the geological features around the embankments and the embankment structures. Photo 1 shows an example of damage at the point of National R117 near Hosojima in Ojiya-city, where the road embankment failed entirely by sliding\(^3\). The embankment located on the sloped ground was constructed neighboring the cut-and-off of the edge of mountain. Moreover, the embankment had a single-sloped cross-section. Photo 2 shows another example, which was very close to the location of Photo 1. The crown of the embankment sank uniformly across its width, and only shoulder and slope of embankment were sledded partially. The embankment had a double-sloped cross-section, and the ground sloped gently in its transverse direction. Furthermore, a stream crossed beneath the embankment in its transverse direction. Photo 3 was taken from the downstream side of the Imogawa-bridge on the Kan-etsu Expressway and shows an example of damage of a relatively small scale, where the backfill embankment behind the abutment settled. The embankment had a double-sloped cross-section in the transverse direction on the flat ground.

According to the field investigation above-mentioned, the various states of the damage to the road embankments are first classified into damage features in either the transverse or longitudinal direction. Damage features in their transverse directions were further classified into those on flat or sloped ground. Damage features on sloped ground were further classified into two types of embankment structures: single-sloped cross-section and double-sloped one. The damage features have been classified according to these types mentioned above. In short, damage features of embankment on flat ground in the transverse direction (TRF: TRansverse direction + Flat ground) was classified as shown in Fig.2 (1). Furthermore, damage features named TRSD (TRansverse direction + Sloped ground + Double-sloped cross-section) and TRSS (TRansverse direction + Sloped ground + Single-sloped cross-section) are classified as shown in Figs.2 (2) and (3), respectively. Damage feature to a certain embankment are not necessarily limited to a unique pattern shown in Fig.2, and several patterns can be combined. The embankments on the cut-and-mounted ground are considered equivalent to the single-sloped cross-section as shown in Fig.2 (3). Furthermore, the longitudinal features of damage to road embankments are classified as shown in Fig.3, based on the relation to the ground formation or other structures such as bridges and transverse structures.
Table 1 shows damage features in transverse and longitudinal directions of road embankments observed in the field investigations. Particularly in mountains, the ground conditions in both transverse and longitudinal directions are complicated, and therefore damage features of road embankments are proper to be classified, combining both Figs. 2 and 3.

b) Correlation between scale of seismic intensity and settlement of road embankments

Bumps on road surfaces remarkably affect road performance. Therefore, the bump height is considered one of the indices to judge the extent of damage to road embankments. The seismic intensities, which the Japan Meteorological Agency (named JMA hereinafter) announces immediately after earthquakes, are an index for measuring the scale of earthquake-induced ground motion and damage on a macro scale.

This study attempts to relate damage extents of the road embankments to JMA seismic intensities. The scale of damage to the road embankments was judged from the height of bump occurred on the road surfaces. Data used for analysis were photographs of damage on directly governed national roads, which were provided by the Nagaoka Road Office. The bump heights on the road surfaces were extrapolated from the photographs, and they were then sorted according to the classification of damage in the longitudinal direction above-mentioned in Fig. 3. The method adopted to estimate seismic intensity is outlined in section 4. (1).

Fig. 4 shows the correlation between estimated seismic intensity and bump height for 22 damaged points in the national roads. The figure shows that bump height generally increases with estimated seismic intensity. Comparison for the individual damage forms shows that bumps formed on bridge approaches were greater in number and height than...
those in other locations. Although a bump 40 cm high (at the approach embankment to a bridge) was observed for an estimated seismic intensity of 5 Upper, possible reasons for this anomaly are that the estimated seismic intensity was inaccurate, and the seismic performance of the embankment was low. The forms of bumps are described as "unknown" for many spots because actual situations were not clearly shown in the photographs. Further investigations are needed for these locations.

(3) Features of restoration of road closures

When the road infrastructure is damaged, the impact of road damage on road performance depends on the scale of the damage. This study focuses on road closure as a representative form of serious damage, and the time required for lifting the closure of a location was employed as a measure of the damage there.

a) Features of restoration for each damage form

The durations of closure in the national and prefectural roads were analyzed for different damage forms. Fig.5 shows the change in time (days) of the number of blocked road points for each damage feature. The percentage of the reopened points over the total number of the closed points is shown in Fig.6 as a function of time (days). Closure for a period shorter than a day was counted as a one-day closure. These figures show that the points blocked due to "Settlement or bump" were, though numerous, reopened relatively soon. On the other hand, it took longer to reopen closures due to "Embankment failure" or "Slope failure or mudslide"; about 40% of the points remained closed even after 60 days had passed. The damage due to "Slope failure or mudslide" of the national and prefectural roads was considered to be the most serious in terms of the number of closed points and time needed for repair. The road points blocked due to bridge failure were few and were reopened soon, showing that the impact of bridge failure on road performance in this earthquake was minor.

b) Features of restoration of road of different administrative categories

The durations of closure were analyzed for the 214 fully blocked points at the national roads managed by MLIT, and national roads, main local roads and general roads managed by Niigata Prefecture. Fig.7
Fig. 5 Change in number of road-blocked points with time elapsed for different damage forms

Fig. 6 Change of ratio between the number of closed and reopened points with time elapsed

Fig. 7 Change in number of road-blocked points with time elapsed for different road categories

Fig. 8 Change in ratio of reopened-road points with time elapsed for different road categories

Fig. 9 Change in number of blocked-road points in national roads with time elapsed for different damage forms

shows the change in the number of blocked points with time elapsed for each category, and Fig. 8 shows the change of the percentage of reopened points with time elapsed.

These figures indicate that closure on the few national roads managed by MLIT was lifted first, owing to early emergency measures. Restoration of the prefecture-managed national roads followed. It took longer to reopen the general roads than the national roads, but it is no surprise that emergency restoration was conducted first on roads with the highest priority.

Fig. 9 shows the change with time elapsed in the number of closed points in the MLIT-managed and prefecture-managed national roads for each damage form. As seen in the figure, the national roads were affected more by settlement or bump than slope failure or mudslide, which presumably facilitated early restoration. Reasons why slope failures or mudslides were relatively few may be better protective measures for the slopes or the low density of national roads in the mountainous regions. It is necessary, however, to investigate each damaged points in detail to clarify specific contributing factors. It can be said that emergency restoration for the national roads was promptly implemented, and deterioration of road performance induced by settlement or bumps was severe during the first week after the earthquake.
(4) Features of restoration of different transportation routes

The section between Shiozawa and Nagaoka is at the halfway point between Tokyo and Niigata, where the old and new Joetsu railroad lines, Kan-etsu Expressway and National R17 run approximately in parallel. In this study, to show the importance of the early restoration of main roads, this section was divided into five links at four major intermediate nodes: Minami-Uonuma, Uonuma, Kawaguchi and Ojiya. The progress of restoration of performance by each transportation authority was then compared in each link.

a) Comparison of transportation routes

The status of reopening of each link in each transportation route during the 30 days after the earthquake is shown in Fig.10. Table 2 shows the actual points of each route corresponding to the nodes mentioned above. If a single blocked point was found in a link, the whole link was regarded as blocked. The "day just after the earthquake" in the figure is defined as midnight October 24, 2004, and days elapsed are calculated based on this time.

This figure shows that the railways took longer than the roads to reopen links. This means that transportation was highly dependent on road traffic in the early stage after the earthquake.

b) Comparison of the Kan-etsu Expressway and National R17

In order to assess the influence of the damage level of roads, we tried to evaluate quantitatively the effect by road closure and reopening at the Kan-etsu Expressway and National R17, using an index defined as the usual traffic volume in a certain link divided by that of the all links concerned. The index means the degree of relative effects of damage and degree of restoration in each link on the performance

![Fig.10 Condition of restored links for different transportation routes](image)

| Location | Transportation method | Joetsu line | Joetsu Shinkansen | Kan-etsu Expressway | National R17 |
|----------|-----------------------|-------------|------------------|-------------------|-------------|
| Shiozawa | Shiozawa-ekimae station | Ishiuchi IC | Ishiuchi IC | Ishiuchi IC | Ishiuchi IC |
| Minami-Uonuma | Uonuma | Kamaguchi | Ojiya | Kawaguchi | Ojiya |
| Uonuma | Kamaguchi | Ojiya | Nagaoka | Nagaoka | Nagaoka |
| Kawaguchi | Ojiya | Nagaoka | Nagaoka | Nagaoka | Nagaoka |
| Ojiya | Nagaoka | Nagaoka | Nagaoka | Nagaoka | Nagaoka |

Table 2 Corresponding nodes in different transportation routes
of the entire road network comprising all the links.
Removal of all blockages in a link was regarded as restoration of normal road performance of the link, and the recovered traffic volume at that time point was assumed to be equal to the usual traffic volume. As for one-lane blockage, the traffic volume was also regarded as the usual one considering the small impact on the road network.

The traffic volume in this analysis was identified as the 12-hour traffic volume of the road traffic census of FY1999. The usual traffic volumes used in the links of the Kan-etsu Expressway and National R17 are shown in Table 3. Data for National R17 were collected at points closest to the administrative boundary of each municipality in order to minimize the effect of the traffic volume only within each municipality.

On National R17 and the Kan-etsu Expressway, the change in degree of restoration of road performance with time represented by the index is shown in Fig.11. This figure shows that the road performance of National R17 was restored earlier than that of the Kan-etsu Expressway. This result indicates that National R17 had fewer links with road closure and the links seriously affected by closure were restored more quickly, since the index defined above is greater for roads which have more unblocked links or in which links with large traffic volumes are restored sooner.

4. CORRELATION BETWEEN SEISMIC INTENSITY SCALE AND DAMAGE LEVEL TO CIVIL ENGINEERING STRUCTURES AND ROAD PERFORMANCE

The seismic intensity announced by the Japan Meteorological Agency is an effective index for estimating the scale of seismic ground motion and possible damage on a macroscopic basis. The seismic intensity scale can thus be possibly used for rough estimation of damage to roads and other civil engineering structures and for determining the necessity of maintaining activities such as patrolling. The current seismic intensity scale, however, does not take civil engineering structures into account. Therefore, this study attempts to correlate quantitatively seismic intensity with the level of damage to road infrastructure. Then it will possible to utilize the seismic intensity scale for managing the road infrastructure when an earthquake occurs.

(1) Estimation of seismic intensity at damaged points
The seismic intensities at damaged points were estimated by comparing the location information of each damaged point with a seismic intensity distribution map for the main shock, available at the website of the Mid Niigata Prefecture Earthquake Restoration and Revival GIS Project, overlaid on a topographical map.

The length of each road was measured for each estimated seismic intensity on a map with a scale of 1/25,000, using the distance measuring function on the website. The function allows measurement of distances between plotted points and distances along roads were obtained by plotting points at distances of 100 to 400 m. An average of three measurements was calculated for each distance. Since road lengths in each region vary with an estimated seismic intensity, a “road closure ratio” per kilometer was calculated by dividing the number of road blocked points by the length of the road located in each region of a given seismic intensity.

![Figure 11](image_url)
(2) Road closure ratio and seismic intensity on national roads

a) Road closure ratio and seismic intensity

Table 4 shows the number of blocked points and road lengths for each estimated seismic intensity. Fig. 12 shows the correlation between the road closure ratio for national roads and seismic intensity for different damage forms based on overall road closure after the earthquake, which is also shown in Table 5. These results show that the road closure ratios for regions with seismic intensities of 5 Lower, 5 Upper, 6 Lower and 6 Upper or 7 are 0.003, 0.030, 0.105 and 0.291 points/km, respectively; that is, the road closure ratio increases with estimated seismic intensity.

Regarding damage forms, road closure in the areas with a seismic intensity of 6 Lower or lower was largely due to settlement or bumps causing relatively minor damage. The road closure due to the serious damage caused by embankment failure or slope failure or mudslide was more frequent in areas with an estimated seismic intensity of 6 Upper or 7. The road closure ratios due to embankment damage of both settlement or bumps and embankment failure are 0.0, 0.018, 0.081 and 0.160 points/km for seismic intensities of 5 Lower, 5 Upper, 6 Lower and 6 Upper or 7, respectively, accounting for the largest part of road closure. In addition, the road closure ratios due to slope failures or mudslides are 0.0, 0.003, 0.012 and 0.110 points/km for seismic intensities of 5 Lower, 5 Upper, 6 Lower and 6 Upper or 7, respectively. On the other hand, the road closure due to bridge damage is seen in areas with a seismic intensity of 6 Lower or higher, but the frequency is low.

b) Change with time of road closure ratio and seismic intensity

In order to investigate the state of restoration of road performance of national roads in areas with different seismic intensities, the change of the road closure ratio with time for each seismic intensity has been summarized in Fig. 13 and also in Table 5. The zero point of the time axis indicates the midnight of October 24, 2004. This figure shows that for areas with a seismic intensity of 6 Upper or 7, the road closure ratio at 3, 10, and 30 days after the earthquake was 0.218, 0.102 and 0.095 points/km, respectively. The result shows that the closure ratio decreases with time elapsed. The few cases where the ratio increases with time probably reflect the fact that road closure was delayed because the damage couldn’t be assessed just after the earthquake, or some points were additionally blocked due to aftershocks. On the other hand, the “road reopening ratio” was calculated by subtracting the road closure ratio from 1. Fig. 14 shows the change of the road reopening ratio with time elapsed.
(3) Road closure ratio for damage estimation

Many conventional scales for estimating damage to road infrastructure do not take into account the degradation of road performance or the time required for restoration. This study reviews these factors and proposes a more realistic scale for estimating damage to road infrastructure based on changes of road closure ratios with time described in (2) a) and

Table 5 Road closure ratios for national roads (segments/km)

| Seismic Intensity | 5 Lower | 5 Upper | 6 Lower | 6 Upper or 7 |
|-------------------|---------|---------|---------|--------------|
| Over all          | 0.003   | 0.030   | 0.105   | 0.291        |
| After 3days       | 0.003   | 0.006   | 0.065   | 0.218        |
| After 10days      | 0       | 0       | 0.028   | 0.102        |
| After 30days      | 0       | 0.003   | 0.016   | 0.095        |

(2) Damage to road embankment

| Seismic Intensity | 5 Lower | 5 Upper | 6 Lower | 6 Upper or 7 |
|-------------------|---------|---------|---------|--------------|
| Over all          | 0       | 0.018   | 0.081   | 0.160        |
| After 3days       | 0       | 0.003   | 0.048   | 0.109        |
| After 10days      | 0       | 0       | 0.024   | 0.036        |
| After 30days      | 0       | 0       | 0.012   | 0.036        |

(3) Damage to slopes

| Seismic Intensity | 5 Lower | 5 Upper | 6 Lower | 6 Upper or 7 |
|-------------------|---------|---------|---------|--------------|
| Over all          | 0       | 0.003   | 0.012   | 0.110        |
| After 3days       | 0       | 0       | 0.012   | 0.080        |
| After 10days      | 0       | 0       | 0.004   | 0.058        |
| After 30days      | 0       | 0.003   | 0.004   | 0.051        |

Table 6 Correlation between seismic intensity and damage to road infrastructure

| Seismic intensity | Damage to road infrastructure |
|-------------------|------------------------------|
| 0-4               | Damage that doesn’t cause trouble to traffic. |
| 5 Lower           | Damage causing road-blocked points rarely occurs. Possible slope failure in mountainous regions may require traffic restrictions in advance. |
| 5 Upper           | Settlement or bumps may form on road surfaces, however most do not cause serious problems with traffic. Bumps may be generated at bridge approaches and interfaces with c-boxes, and traffic may be interrupted by a bump if damage is serious. Substructure of bridges may be damaged, but there is no impact on traffic. Falling rocks in mountainous regions may impose traffic restrictions. A road-blocked point is generated approximately every 30 km. Emergency restoration often requires less than 2-3 days. |
| 6 Lower           | Settlement or bumps can be observed at many spots on road surfaces. A lot of bumps are found at bridge approaches and interfaces with of c-boxes, which may cause traffic closure. Most bumps are 30 cm or lower in height. Road embankment failures, accompanied by slides, may occur, causing traffic closure. Substructure of bridges may be damaged, which may cause traffic closure. Frequent falling rocks occur in mountainous regions and mudslides or slope failures may be occurred. A road-blocked point is generated approximately every 10 km. Emergency restoration for half of this damage requires less than a week. However, it may also require two months or longer in mountainous regions. |
| 6 Upper or 7      | Settlement or bumps are seen at most places on road surfaces. Bumps appear in most bridge approaches and the interfaces with c-boxes, which may cause traffic closure. Many bumps are 30 cm or more in height. Road embankment failures accompanied by slides occur frequently. Even substructures of bridges with high seismic performance are likely to be damaged in many spots, which often causes traffic closure. The concrete retaining wall of tunnels may separate and fall. Frequent mudslides or slope failures occur in mountainous regions. Traffic is blocked approximately every 10 km. Emergency measures restore half of damaged spots within 10 days. However, restoration may take two months or longer at many points, mainly in mountainous regions. |

5. CORRELATION BETWEEN THE JAPAN METEOROLOGICAL AGENCY’S SEISMIC INTENSITY SCALE AND DAMAGE TO ROAD

No comments related to damage to road infrastructure can be found in the Japan Meteorological Agency’s table of seismic intensity scale. Results of this study described above were used to correlate the seismic intensity scale with expected road infrastructure damage as summarized in Table 6 for the site conditions: the local and mountainous regions and earthquake level: Magnitude of about 7 or seismic intensity scales of 6 Upper or 7, similar to those of the Mid Niigata Earthquake in 2004. The
seismic intensity scales considered are 4 or less, 5 Lower, 5 Upper, 6 Lower and 6 Upper or 7. As shown in this Table, earthquakes with the seismic intensity scales of more than 5 Lower cause damage to road infrastructure severely.

The Table describes quantitatively the road closure ratios, bump heights, and numbers of days for restoration to represent damage as specifically as possible. The Table allows evaluation of damage to road infrastructure based on the seismic intensity scale available easily and immediately just after an earthquake.

6. SUMMARY

The results of this study provide the following lessons regarding the level of damage to road infrastructure and road performance resulting from the Mid Niigata Earthquake in 2004.

(1) Sixty percent or more of the damage leading to road closure was attributed to settlement or bumps or embankment failure. Less than 20% of damage was attributed to slope failure or mudslide, and less than 7% to bridge damage. Most of great damages connected to road closures were resulted in the damage of road embankments.

(2) Damage features of road embankments can be conveniently classified by combination of categories which were obtained by describing the situation in the transverse and longitudinal directions, the former being divided according to flat or sloped ground, and the latter being further divided according to single-cross-section or double-sloped one.

(3) Road traffic tended to be restored sooner than rail traffic. Therefore, transportation at an early stage of restoration is highly dependent on road traffic.

(4) In order to prevent excessive deterioration of the entire road network just after an earthquake, it is necessary to set an adequate and well balanced earthquake-resistance level for each of the road infrastructure components not only bridges but also embankments and so on.

(5) In local mountainous regions, seismic countermeasures for road embankments and slopes are needed to maintain road performance. For this purpose, new effective and economical construction methods should be developed in addition to practical application of conventional methods.

(6) A clear relation between seismic intensity scale and road closure ratio has been shown. The three parts of Table 5 are proposed to estimate the road closure ratio and its change with time elapsed for each seismic intensity for all damage forms, embankment damage and slope damage, respectively.

(7) To estimate damage to road infrastructure easily and immediately based on seismic intensity information just after an earthquake, the relationship between JMA seismic intensity scale and the damage to road infrastructure and road performance for site conditions and earthquake level similar to those of the Mid Niigata Earthquake in 2004 was presented in Table 6.

Since the data collected and analyzed in this study were all obtained just after the earthquake, their amount and accuracy may be insufficient. Therefore, it is necessary to improve the accuracy of data in the future.

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