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Analysis of labor accidents occurring in disaster restoration work following the Great East Japan Earthquake

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ABSTRACT

The Great East Japan Earthquake devastated Japan, and earthquake recovery and restoration work is still ongoing. In connection with such recovery and restoration work, many accidents have been reported in which workers were injured in confined and congested work environments different from those of normal work. In this paper, the trends of labor accidents related to the Great East Japan Earthquake in all industries during a roughly 44 month period after the earthquake are demonstrated. The results of analyses of the trend in the construction industry, which has a higher incidence of labor accidents during earthquake restoration work, are presented. Finally, this report is summarized as the correlation between the casualties caused by "fall to lower level accidents" in the building construction work subsector and damage to buildings.

Introduction

The Tohoku-Pacific Ocean Earthquake, which occurred at 14:46 on March 11, 2011, and the strong aftershocks and tsunami that followed (hereafter referred to as the "Great East Japan Earthquake") devastated Japan, and earthquake recovery and restoration work is still ongoing. In connection with such recovery and restoration work, many accidents have been reported in which workers were injured in confined and congested work environments different from those of normal work.

In this paper, the trend of labor accidents related to the Great East Japan Earthquake in all industries during a roughly 44 month period after the earthquake is demonstrated. The results of our analyses are then the trends in the construction industry, which has a higher incidence of labor accidents during earthquake restoration work. Finally, this paper is summarized as the correlation between the casualties caused by "fall to lower level accidents" in the building construction work subsector and damage to buildings. More detailed analyses are available in the paper by Itoh et al., (2013) and on the website of the National Institute of Occupational Safety and Health, Japan (URL: http://www.jniosh.go.jp/).

Occurrences of labor accidents related to the Great East Japan Earthquake

Labor accidents related to the Great East Japan Earthquake are divided into two categories. One

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is those caused directly by the earthquake (earthquake direct). Another one is those that occurred during earthquake restoration work (earthquake restoration). Their incidence by industry—based on industry classifications used by the Ministry of Health, Labor and Welfare, Japan in its labor accident statistics—are presented in Table 1. Here, numbers in parentheses are fatalities (within each category). The subjects of our analyses are accidents in earthquake restoration work which caused deaths, injuries or sickness resulting in four or more days of absence from work and occurring during a roughly 44-month period following the earthquake and ending on November 30, 2014.

Table 1: Occurrences of labor accidents related to the Great East Japan Earthquake

	Earthquake direct	Earthquake restoration
Manufacturing	806 (340)	40 (3)
Construction	303 (168)	935 (47)
Overland cargo transportation	236 (153)	10 (0)
Other	1,482 (653)	63 (5)
All industries	2,827 (1,314)	1,058 (55)

Data for 2011 to 2013 are final values and data for 2014 are preliminary values up to November 30 (both surveyed by the Ministry of Health, Labor and Welfare, Japan ,http://www.mhlw.go.jp/stf/houdou/2r98520000032ryk.html)

The number of all casualties (deaths and injuries) in all industries caused directly by the Great East Japan Earthquake was 2,827, and the number of deaths among them was 1,314. With regard to fatal accidents in 2011, the manufacturing industry had a share of 17.7% (211 deaths), the construction industry had a share of 30.5% (365), and the land freight transportation industry had a share of 12.9% (154); and these three industries accounted for about 60% of all fatalities. Looking at earthquake restoration work, preliminary figures as of November 30, 2014 indicate that 935 accidents involving fatalities or injuries occurred in the construction industry, which has an overwhelmingly larger number of accidents than other industries. The labor accidents that occurred during earthquake restoration work in the construction industry included 47 fatalities. Since earthquake restoration work involves the restoration and reconstruction of roads and houses damaged or destroyed by the earthquake, labor accidents during earthquake restoration work tend to occur more frequently in the construction industry, which has been pointed out by Itoh et al. (2011). On the other hand, accidents have occurred during earthquake restoration work in other industries as well, although in fewer numbers than in the construction industry. Specifically, the manufacturing and other industries had 3 to 5 fatalities. Figure 1 shows bimonthly numbers of casualties since the earthquake in chronological order and by major industrial classification. It shows that, in all industries, most labor accidents occurred within two months after the earthquake. However, in industries other than construction, labor accidents largely decreased to normal levels within four months after the earthquake. Many accidents in the manufacturing industry occurred during work such as restoring shelves which had been knocked over by the earthquake. It appears that such restoration work that can be completed in a short period of time was largely completed in about four months after the earthquake. In contrast, while accidents in the construction industry have decreased since the immediate aftermath of the earthquake, even after 44 months, at the end of November, 2014, 12 to 15 accidents are occurring every month. That is, the accident number is in a state still higher than the usual value.

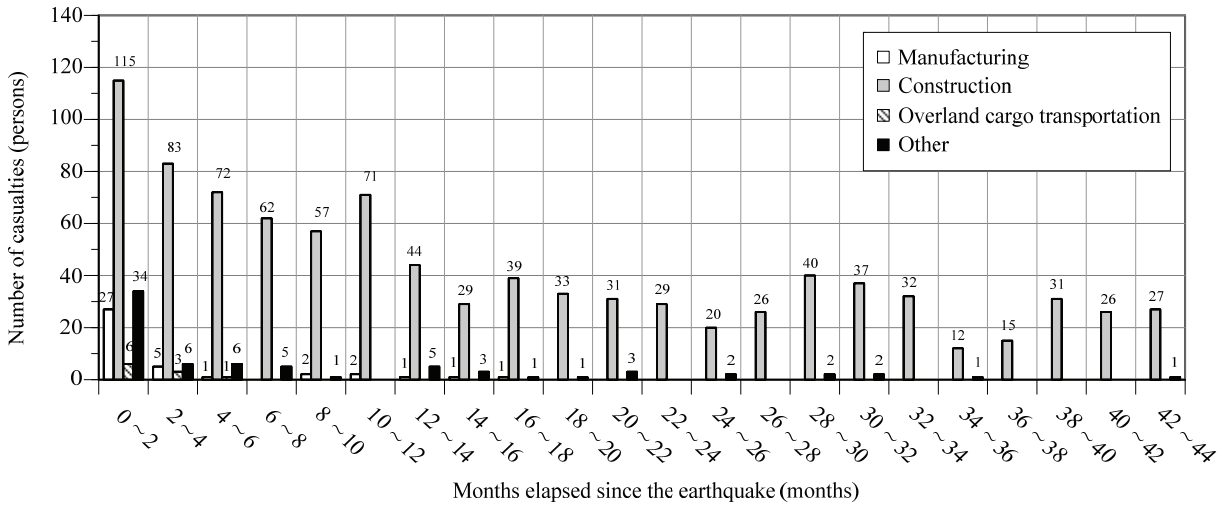

Figure 1: Number of casualties by months elapsed since the Great East Japan Earthquake (major industry classification)

In the sections below, analyses focusing on labor accidents during earthquake restoration work in the construction industry are investigated.

Occurrences of labor accidents during earthquake restoration work in the construction industry following the Great East Japan Earthquake

Study subjects and analyzed data

The subjects of this study are accidents in the construction industry which caused deaths or injuries requiring an absence of four or more days and occurring during a roughly 44-month period from the Great East Japan Earthquake (March 11, 2011) to November 30, 2014. The data of subject accidents for 2011 to 2013 are final values, but the data for 2014 are preliminary values as of November 30, 2014 (published on December 17, 2014). The number of subject accidents was 385 for 2011 (of which 21 were fatal), 246 for 2012 (of which 9 were fatal), 188 for 2013 (of which 11 were fatal), and 116 for 2014 (of which 6 were fatal), with a total of 935 accidents (of which 47 were fatal). The main analytical data items include the date of occurrence, location (prefecture), industry of the business where the accident occurred, and the type of accident.

Occurrences of death or injury accidents by months elapsed

Figure 2 shows the numbers of casualties that occurred during earthquake restoration work in each of the middle classifications of the construction industry (civil engineering work, building construction work, and other construction work) by months elapsed since the earthquake in units of two months. In the building construction work subsector, 73 accidents occurred during the first two months following the earthquake, and subsequently the number has trended down with cyclical increases and decreases. In contrast, in the civil engineering work subsector, the rate of occurrence since the earthquake has been 6 to 24 accidents every two months. The same analysis of the Niigata Chuetsu Earthquake showed that the building construction work subsector had the highest number of casualties immediately after the earthquake, while the civil engineering work

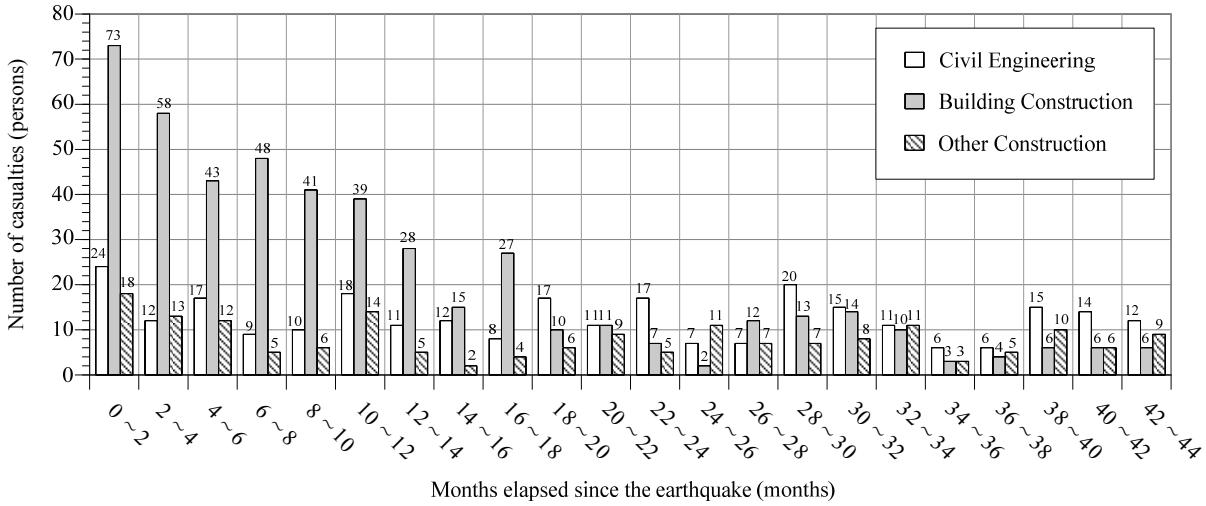

Figure 3: Number of casualties by months elapsed since the Great East Japan Earthquake (middle industry classification within the construction industry)

subsector recorded the largest numbers between 6 and 18 months after the earthquake, indicating that different subsectors had different periods of concentrated occurrences (Itoh et al., 2011). The data for the 44 months following the Great East Japan Earthquake show similar patterns including the fact that the largest number of accidents occurred in the building construction work subsector immediately after the earthquake. With regard to the civil engineering work subsector, it appears that a certain number of accidents are occurring even now because earthquake restoration work has been delayed by the large-scale damage caused by the tsunami, etc.

Probability of labor accident occurrence in earthquake restoration work depending on damage caused by the earthquake – verification

Timing and trend of labor accidents during earthquake restoration work in the building construction work subsector

With regard to the probability of labor accident occurrence during disaster restoration work in the building construction work subsector, Itoh et al. (2011) focused on several subsectors (small classifications) and presented a conceptual diagram of the severity of damage (minor to severe) and the time required for restoration. Figure 4 is a conceptual diagram of the severity of damage to a wooden house and the time required for the restoration work. In the case of a wooden house, minor damage such as fallen roof tiles are restored by deploying plastic sheets for protection immediately following the earthquake before replacing the roof tiles. In this case, the house is restored to its original state in a few days to a few weeks. However, if the house is partially or completely destroyed, it takes a long time as the house needs to be demolished and in some cases the land needs to be improved before the new house can be built. In other words, the figure conceptually shows that areas with minor damage will be restored to their state before the earthquake in a relatively short period of time after the earthquake, while areas with severe damage will need more time for recovery and restoration as social infrastructure planning and other factors need to be considered.

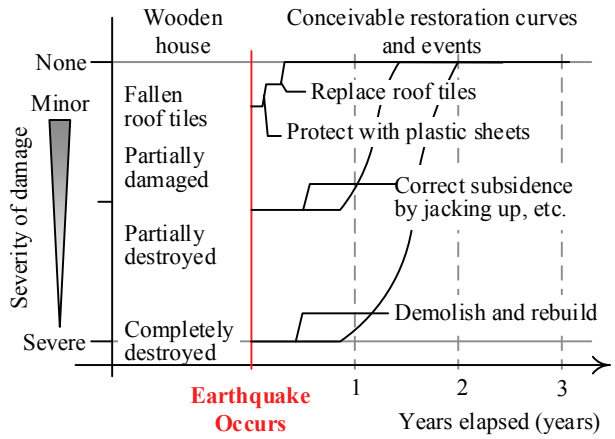

Figure 4: Conceptual diagram of restoration curves and events in disaster restoration work on a wooden house depending on the severity of earthquake damage (Itoh et al., 2011)

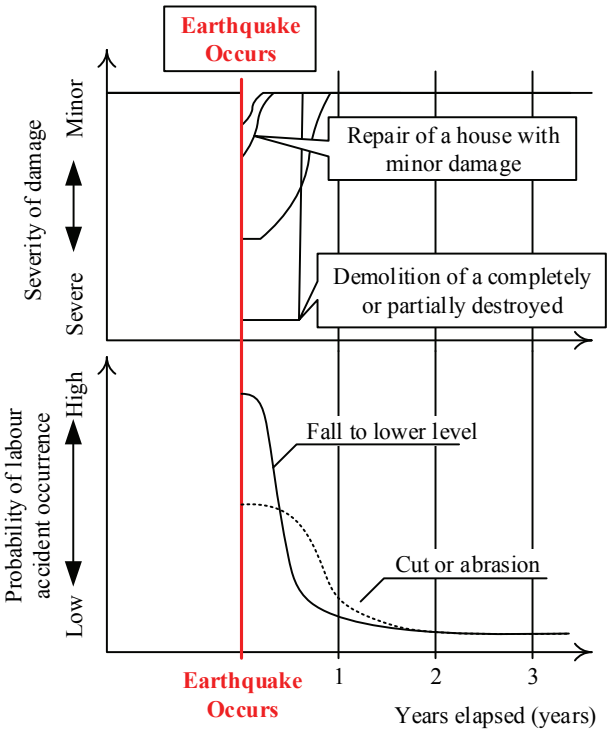

Figure 5: Conceptual diagram of restoration curves derived from typical tasks in the building work subsector and probability of labor accident occurrence (Itoh et al., 2011)

Figure 5 is a conceptual diagram showing the restoration curves, derived from typical tasks in the building construction work subsector, and the probability of labor accident occurrence. A building with minor damage in an area where damage is minor or non-existent is essential for daily life and is located in the periphery of the affected areas where goods and materials can be supplied, so it is restored to its original state immediately after the earthquake. In such an area with minor damage, disaster restoration work begins immediately after the earthquake, resulting in many “fall to lower level” accidents caused by, for example, ladders placed in unstable places

or people falling off roofs of partially destroyed wooden houses. In addition, attention needs to be paid to "cut or abrasion" accidents during demolition work on partially or completely destroyed houses, and these accidents occur at different timings. We looked at the data to see if these concepts, shown in Figure 5, are applicable to earthquake restoration work in general.

Relationship between damage to buildings and "fall to lower level" accidents in the building construction work subsector

Itoh et al. (2013) reported "fall to lower level" accidents in the building construction work subsector in some prefectures, sequenced by months for a period of 1.5 years from the earthquake. Looking at the changes in the number of casualties (deaths or injuries) caused by "fall to lower level" accidents, in the first two months following the earthquake, Ibaraki prefecture recorded the highest number (15 incidents), but in the subsequent 2-4 month period, Miyagi prefecture had the highest number with 16 incidents, indicating that accidents occurred at different timings in different prefectures. With regard to damages to buildings, the number of completely destroyed buildings was 2,620 in Ibaraki and 85,331 in Miyagi (about 35 times that of Ibaraki), and the number of partially destroyed buildings was 24,158 in Ibaraki and 151,768 in Miyagi (about 6 times that of Ibaraki), showing large disparities. However, the number of partially damaged buildings was 183,675 in Ibaraki and 224,124 in Miyagi (about 1.2 times that of Ibaraki), both at a similar level. From these data, we can surmise that the death or injury accidents caused by "fall to lower level" in the building construction work subsector were affected by the volume of work associated with repairs or emergency restoration work on partially damaged buildings immediately after the earthquake. The death or injury accidents caused by "fall to lower level" accidents in the building construction work subsector are closely related to restoration work of partially damaged buildings. Therefore, this paper focus on the relationship between damage to buildings (partially damaged) and "fall to lower level" accidents in the building construction work subsector through analysis. Figure 6 plots the number of deaths and injuries caused by "fall to lower level" accidents in 16 prefectures where buildings sustained damage (partially damaged). Here, the black circles near the origin (0,0) represent 10 prefectures: Aomori, Saitama and Tokyo which had one casualty by "fall to lower level"

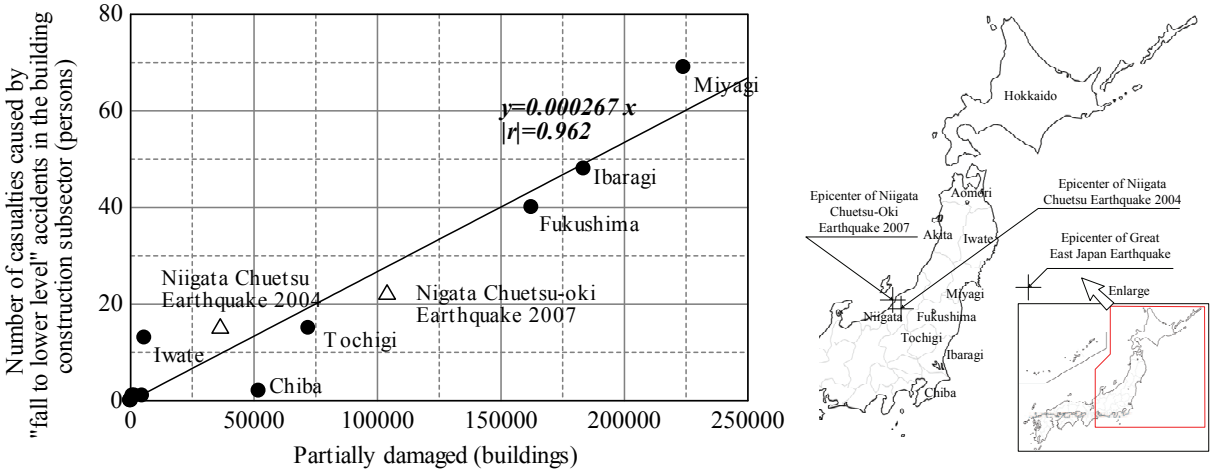

Figure 6: Relationship between damage to buildings (partially damaged) and the number of casualties caused by "fall to lower level" in the building construction work subsector

accidents and Hokkaido, Akita, Gunma, Kanagawa, Niigata, Nagano and Shizuoka which had none. Furthermore, we added the data of Niigata prefecture following the Niigata Chuetsu Earthquake 2004 and the Niigata Chuetsu-Oki Earthquake 2007. When Iwate and Chiba prefectures are removed from this plot, it becomes clear that the number of partially damaged buildings and the number of casualties are in a linear relationship in which when one increases the other does too, and the relationship can be expressed as this equation:

$$y = (2.67 \times 10^{-4}) \times x \tag{1}$$

Here, x denotes the damage to buildings (number of partially damaged buildings) and y denotes the number of casualties caused by "fall to lower level" accidents in the building construction work subsector (number of individuals). The correlation coefficient of Equation (1), even with the data for Iwate and Chiba included, is 0.962, which indicates a high correlation. In terms of outliers, the data of Chiba prefecture were affected by the fact that partially damaged houses included those damaged by liquefaction in coastal and marshy areas including the cities of Urayasu and Katori, and many of them had nothing to do with "fall to lower level" accidents. In Chiba prefecture, the earthquake caused varying degrees of ground uplift, slumping, and liquefaction. A significant number of buildings need to be lifted to allow their foundations to be replaced following the earthquake. During building repair work jacking up foundations, many labor accidents, in which feet were caught or compressed by the foundations or jacks, etc., occurred. On the other hand, in the case of Iwate prefecture, half of the damaged buildings were hotels and fishery facilities, and the data did not fit well with the number of partially damaged buildings which otherwise represent damaged houses.

With regard to damage to buildings, the Central Disaster Prevention Council of the Cabinet Office is making predictions of damage which may be caused by future major earthquakes (URL: http://www.bousai.go.jp/jishin/index.html). The insight gained by this study can be used to understand, broadly and in advance, which areas are likely to have more labor accidents after an earthquake, and to focus labor accident prevention efforts on those areas following a mega earthquake.

Conclusions

This paper found the occurrences of labor accidents following the Great East Japan Earthquake by examining the data of death or injury accidents during a roughly 44-month period following the earthquake, and analyzed the characteristics of labor accidents in earthquake restoration work and the relationship between regional earthquake damage and accidents. The main results of this paper are described as follows.

1. It was confirmed that most labor accidents in earthquake restoration work following the Great East Japan Earthquake occurred in the construction industry, which had already been known. However, when damage is severe, attention needs to be paid to accidents in manufacturing and other industries within four months following the earthquake.
2. From the analysis of death or injury accidents sequenced by months elapsed in units of two months, it was found that the building construction work subsector had the largest number of death or injury accidents occurring immediately after the earthquake, while in the civil engineering work subsector 6 to 24 accidents have been continually occurring every two months.

3. With regard to the number of casualties caused by “fall to lower level” accidents and the number of partially damaged buildings, the data of prefectures affected by the Great East Japan Earthquake and the data of past earthquakes was plotted, and a correlation was found between them. This shows that, by using damage predictions for a major earthquake, one can understand, broadly and in advance, which areas are likely to have more labor accidents after an earthquake, and this insight can be used to focus labor accident prevention efforts on such areas.

This report presents the results of detailed analyses of labor accidents that occurred during earthquake restoration work in the 44-month period following the earthquake. As we can see from these figures, the recovery and restoration from the earthquake is far from complete, and earthquake restoration work in severely damaged areas is just beginning. Moving forward, we will continue to study the characteristics of labor accidents during earthquake restoration work in the affected areas. In addition, several accidents (including fall to lower level from roofs) during decontamination work associated with the radioactive fallout of TEPCO’s Fukushima Daiichi Nuclear Power Plant have been reported, and we plan to look into these accidents from a different perspective than those for past disasters.

Acknowledgments

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References

Itoh K., Noda M., Kikkawa N., Hori T., Tamate S. Toyosawa Y., Suemasa N. *Analysis of labour accidents occurring in disaster restoration work following the Niigata Chuetsu Earthquake (2004) and the Niigata Chuetsu-oki Earthquake (2007), Journal of Japan Society of Civil Engineers, Ser. F6 (Safety Problem), 67, (1), 27-40, 2011. (In Japanese)*

Itoh K., Takanashi S., Hori T., Hino Y., Kikkawa N., Takahashi H., Ohdo K., Tamate S., Toyosawa Y. *Analysis of labour accidents occurring in disaster restoration work following the Great East Japan Earthquake, Journal of Japan Society of Civil Engineers, Ser. F6 (Safety Problem), 69, (1), 32-45, 2013. (In Japanese)*