# Estimation of Earthquake-Disaster Direct Economic Losses for Industrial Enterprises

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**SUMMARY:**
Earthquake disasters always bring serious economic losses to industrial enterprises, and rapid estimation of direct economic losses of them is significant to post-earthquake reconstruction and recovery work. However, there isn't a general economic estimation method for industrial enterprises until now. Most estimation methods are emphasized on the plants losses by seismologists, other fixed assets, like equipments and vehicles, and inventories are not taken into account. This paper presents a new estimation method according to asset concept in financial accounting. We divided industries into 6 types. Different enterprises under the same industry have same or similar asset structure. Analyzing a lot of balance sheets samples in an industry can get the average ratio of each vulnerable asset to total assets. In the meantime, earthquake-disasters cases in history can provide information about average loss ratio of each vulnerable asset under certain seismic intensity zone. When earthquake disaster happens, we can calculate the direct economic losses for industrial enterprises using above ratios and assets information from statistical yearbooks. This new method will improve accuracy and timeliness of estimation work for industrial enterprises.

*Keywords: earthquake disaster; industrial enterprise; economic loss; rapid estimation*

## 1. INTRODUCTION

After the earthquake disaster, recovery and reconstruction work requires rapid and accurate estimation data of disaster economic losses for making decisions of financial aid to disaster area. And earthquake-disaster economic loss of industrial enterprises takes a big part in entire economic losses. According to a statistical result of Ministry of Industry and Information Technology of the People's Republic of China (MIIT), 14,207 industrial enterprises were affected by Wenchuan earthquake disaster in Sichuan Province, and total direct economic loss of these industrial enterprises was ￥67 billion. Some leading enterprises in Sichuan province, such as China National Erzhong Group Co., Jian Nan Chun Group Co., Ltd., and Dong Fang Turbine Co., LTD., were destroyed seriously by earthquake. The huge economic loss postponed sustainable development of that entire region.

However, during the estimation process of earthquake-disaster direct economic loss for industrial enterprises, there is no generally accepted estimation standard in China. At present, the frequently-used method to estimate economic losses for industrial enterprises is asking enterprises to report their economic loss directly to related department. As some enterprises want to get more financial aid from governments to recovery, their reported result is larger than actual value. So, the final reported result can't provide help to government's work to provide financial allocation to industrial enterprises. And this will also reduce efficiency of capital. Hence, study on making estimation standard of earthquake-disaster direct economic loss for industrial enterprises is very necessary for government and related agencies.

## 2. RESEARCH BACKGROUND

Earthquake-disaster direct economic loss refers to direct economic loss of buildings, equipments, facilities, lifeline engineering and other engineering structures which are caused by ground-shaking and related geologic disasters. Here, the direct economic loss doesn't include indirect economic loss from business-breaking and reduction of sales. At present, there are some search achievements about this topic, such as HAZUS system (U.S.), Heinrich Method, Siman's Calculation Method for accident economic loss and so on. Among above achievements, the most mature one is HAZUS-MH, which estimates the economic loss of buildings and infrastructures and support disaster response and post-disaster recovery work with the help of maps, disaster data processing software. However, this estimation system needs one detailed national assets statistical database which has an industrial enterprises assets sub-database and needs data support from disaster insurance companies. As for as China's estimation work, we don't have a comprehensive assets database throughout the whole country, so this HAZUS-MH system can't work well in China.

Now, China's estimation work of earthquake-disaster direct economic losses is guided under "Post-earthquake field works —Part4: Assessment of direct loss（GB/T 18208.4-2011）"which was firstly issued in 2005 and has its latest edition in 2012. This national benchmark shows how to estimate direct economic losses of buildings, properties and lifeline engineering step by step. And it also tells us the economic losses of enterprises include losses of engineering structure, plants, other buildings and properties within enterprises. Losses of engineering structure, plants, office buildings, and staff departments can be calculated according to GB/T 18208.4-2011, but there isn't one unified method to calculate the losses of equipments, fixtures, inventories and other properties. The national benchmark asks enterprise to report their losses to related government agencies directly. However, this way of estimating economic losses is easily to be affected by enterprises themselves and their reported results are often exaggerated than actual loss value. Another estimation method was proposed by WANG Hui-yan, who used statistical method to estimate losses according to macroeconomic data. But the result is always a rough estimation, and doesn't pay more attention on differences from different types of industries. On the basis of above research achievements, this paper proposes a new idea to estimate economic loss. In this paper, we will analyze relationship between economic loss and different asset item within different industrial enterprises from the perspective of financial accounting. This new method maybe can provide some guide for government agencies to perfect their estimation work after earthquake-disaster.

## 3. NEW ESTIMATION METHOD

Under earthquake disasters, ground-shaking leads buildings and structures to move or collapse, and these movement and collapse bring destroy to office supplies, equipments and inventories. As a result, the economic loss of an enterprise is very large. Here, we propose a new method to estimate the total economic loss of industrial enterprises according to asset item of financial accounting. The estimation equation is shown as follow:

$$L = \gamma \sum_{s=1}^{N} \sum_{i=1}^{M} \sum_{j=1}^{Q} P_s(i) \alpha_s(i, j) k_s(i, j) \tag{3.1}$$

In the Eqn. 3.1:

$L$ refers to total economic loss of industrial enterprises after earthquake-disaster

$P$ refers to total assets value of industrial enterprises；

$i$ refers to code of industry, and the total amount of industries is M；

$j$ refers to code of asset item, and the total amount of asset items is Q；

$s$ refers to code of seismic intensity zone, and the total amount of seismic intensity zone is N；

$\alpha_s(i, j)$ refers to the percentage of j asset to total assets in i industry in s intensity zone;

$k_s(i, j)$ refers to loss ratio of j asset in i industry in s intensity zone;
$\gamma$ refers to correction factor.

Enterprises within the same industry have same or similar asset structure, so we can get the average percentage of some asset to total assets for certain industry using balance sheets of a lot of enterprise samples within certain industry. At the meantime, earthquake disaster cases in history and expert experience can provide average loss ratio of certain asset item under different seismic intensity. Hence, when a real earthquake disaster happens, we can estimate direct economic loss of industrial enterprises roughly using Eqn. 3.1, statistic data from some government reports, and basic situation about seismic intensity of destroyed region.

## 4. ILLUSTRATIONS OF PARAMETERS

### 4.1 Total Assets Value of Industrial Enterprises (*P*)

Total assets value of industrial enterprises means the total amount of assets on its balance sheet of enterprises within certain industry. We can get the value of *P* from "Total Asset of Above-Designated-Size Industrial Enterprises by Industrial Sector" on statistical yearbook or related statistic report. Here, what we have to explain is: firstly, this data doesn't include all enterprises. It can only show the total assets value of above- designated-size enterprises, but this data is easily to get and still can represent the basic situation of enterprises. Secondly, to be honest, the data from statistic yearbook is not the latest, and there maybe a difference between *P* value and its actual value. Hence, if there is any latest data about *P* from other sources, we should choose that one to replace the value from old statistic yearbook. This could reduce error of estimation.

Moreover, the total assets value in statistic yearbook is collected according to classification of industries in national economy. This classification method is not the method for us to define *i* in this paper.

### 4.2 Classifications of Industries (I)

According to "National Economical Industry Classification（GB/T4754-2002）", there are 39 industries in China. Different industry has different production process, and needs different equipments, raw material and finished goods. And these facilities and inventory have different vulnerability to earthquake-disaster too. But if we estimate economic loss of all 39 industries within one city or region, the estimation work would be very heavy. Hence, we can put several industries with same or similar vulnerability of facilities to earthquake-disaster into one category. And in this paper, we decided to divide these 39 industries into 6 categories (see Table 1).

**Table 1.** Classification of Industrial Enterprises According to Earthquake Vulnerability

| No. | Category | Vulnerability characteristic | Content |
|---|---|---|---|
| 1 | Industries in which secondary disasters are easily to happen | After Earthquake disaster happen, it's easily to result in secondary disasters, such as fire, explosion, corrosion, leakage of toxic substance and so on. | （1）Industries related to chemistry. For example, Petroleum Processing; Coking and Nuclear Fuel Processing; Raw Chemical Materials and Chemical Products; Medical and Pharmaceutical Products; Chemical Fiber; Rubber Products; Plastic Products and other toxic product manufacturing industries. |
| | | | （2）Combustible and explosive products manufacturing industries. For example, Production and Supply of Electric Power and Heat, Production and Supply of Gas. |
| | | | （3）Petroleum and Natural Gas Extraction |
| 2 | Mining and Dressing Industries | Mine structures are different; enterprises usually use large machinery; most inventories are stored in open air and not vulnerable. | Coal Mining and Dressing; Ferrous Metals Mining and Dressing; Nonferrous Metals Mining and Dressing; Nonmetal Minerals Mining and Dressing and other Mining and Dressing industries. |
| 3 | Smelting Industries | Work-in-progress has certain peril; Plant structures are different because smelting processes are different; Raw materials and finished goods are not vulnerable. | Nonmetal Mineral Products; Smelting and Pressing of Ferrous Metals; Smelting and Pressing of Nonferrous Metals; Metal Products industries. |
| 4 | Machinofac-ture Industries | Plants structures are different; equipments and finished goods are not very vulnerable; Some equipment have precision requirement. | Ordinary Machinery Manufacturing; For Special Purposes Equipment Manufacturing; Transport Equipment Manufacturing. |
| 5 | Electrical and Electronic Engineering Industries | Precision requirement is very high, and they are easily to be affected by earthquake. They are vulnerable assets. | Electric Equipment and Machinery; Instruments, Meters, Cultural and Office Machinery; Telecommunication Equipment, Computer and Other Electronic Equipment industries. |
| 6 | Other Industries | Most of these industries are labor-intensive. | Farm Byproducts Processing; Food Production; Beverage Production; Tobacco Processing; Textile Industry; Garments, Shoes and Hats Production; Leather, Furs, Down and Related Products; Timber Processing, Bamboo, Cane, Palm Fiber and Straw Products; Furniture Manufacturing; Papermaking and Paper Products; Printing and Record Medium Reproduction; Cultural, Educational and Sports Goods; Handicraft Articles and Other Manufacture; Reclaiming and Processing of Abandoned Resource and Waste Material; Production and Supply of Tap Water and so on. |

### 4.3 Vulnerable Asset Items

There are many accounts in an industrial enterprise, and each account has its distinctive weight against total assets and has different vulnerability to earthquake-disaster. So the first step we should do is selecting main asset items according to vulnerability to earthquake-disaster to prepare for estimation of economic loss. "Enterprise Accounting Standards (2006)" tells us "current asset" and "non-current asset" are two parts in assets for an enterprise.

In current assets, there are cash and cash equivalents, trading financial assets, notes receivable, accounts receivable, prepayment, interest receivable, dividend receivable, other receivables and so on. The loss of these financial assets has little direct relationship with earthquake-disaster, but has some relevance with its suppliers, customers or other third-parties. The losses about above financial assets mainly calculated in indirect loss, not direct economic loss. Besides, in earthquake disaster, losses of buildings may result in loss of some cash of a company. However, modern enterprises are transforming their cash transactions into bank-related transactions. The amount of cash kept in a company is not too much. So, we will not consider this loss of cash in a company as part of direct economic loss for industrial enterprises.

Inventory in current assets refers to raw materials, work-in-progress, and finished goods of one enterprise in its operating activities. Inventory is physical property, and it always takes a big proportion in current assets. If earthquake happens, ground-shaking and collapse of buildings always result in great loss of inventories. In a word, we should pay more attention on inventory when estimating direct economic loss for industrial enterprises.

Non-current assets within one enterprise mainly include fixed assets, intangible assets, long-term receivables, long-term stock equity investment, investment housing property and so on. Fixed assets have physical form. Other assets are not physical property, and not easily to be destroyed by earthquake-disaster. And they have same characteristics with financial assets which we discussed early, and their loss is indirect economic loss, and they are not our research targets.

Fixed assets loss takes a big part in total economic losses. According to vulnerability of assets, we can divide them into: "buildings (and structures) "and "equipments and devices". Building and structure are vulnerable to earthquake-disaster, and its loss is the most important item. As for as some enterprises with a lot of equipments, such as chemical industrial enterprise, storage tank, reaction vessel and other large equipments always take large proportion in its total assets, we should estimate economic loss taking account of their industry feature and vulnerability. As project material and construction-in-progress have similar vulnerability with fixed assets, we put them into fixed assets category to estimate together.

In a word, assets which are easily to be destroyed by earthquake-disaster are physical assets. So, in this paper we choose buildings (and structure), equipments in fixed assets and inventories in current assets as the research scope (see Figure 1).

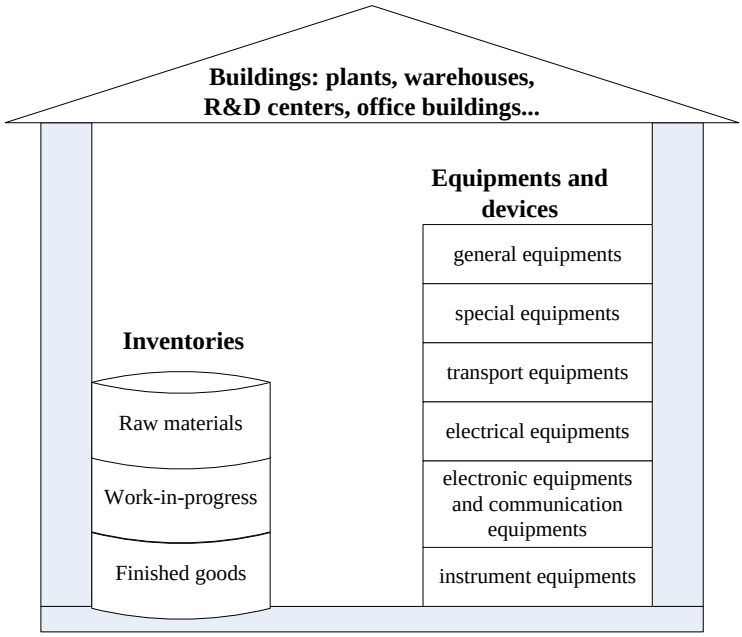


**Figure 1.** Vulnerable accounting items in industrial enterprises

### 4.4 Seismic Intensity Zone （S）

Seismic intensity is used to describe the destroy level of earthquake to a region. Seismic focal depth, stratigraphic structure, epicentral distance, anti-seismic grade of buildings will affect seismic intensity. There are 12 grades of seismic intensity in China, and we divide seismic zones according to national standard "Chinese Seismic Intensity Scale (GB/T 17742－2008)". When we use Eqn. 3.1 to calculate the direct economic loss, we can use intensity zone data provided by national earthquake filed team.

### 4.5 Asset Structure of Vulnerable Asset for Certain Industry （$\alpha_s$）

Enterprises in one industry have same or similar asset structure of some asset item. It means the proportion of certain asset item against to total assets is same or similar, such as inventory, fixed assets and other physical assets. Asset structure of vulnerable asset depends on type of industry, so we can obtain average of $\alpha_s$ from analyses of enough samples in the same industry. With the development and innovation of production process, equipments and facilities of certain industry will update rapidly, so the statistic data of $\alpha_s$ should update timely.

### 4.6 Loss Ratio of Vulnerable Asset Item （$k_s$）

Loss ratio refers to the ratio of economic loss of certain asset to its total value of that asset. The most accurate method to determine loss ratio of one industry is investigating asset loss situation of industrial enterprises in disaster area after earthquake-disaster. If there are too many enterprises, we can also use sampling survey. But this way always take too much time to do, and can't give timely support for government's decision on financial aid. Hence, we want to use data from historical earthquake cases and expert's advice as reference. When we take data from historical cases, we should try our best to choose loss ratio from historical cases with same seismic intensity as in actual disaster zone. If there is difficulty to acquire loss ratio from same seismic intensity zone, we can select data from zones which has similar economic development and social condition. We divide loss ratios of vulnerable asset into 2 types: loss ratio of buildings (and structures), loss ratio of equipments, and loss ratio of inventories.

*4.6.1 Loss Ratio of Buildings (And Structures)*

For there is one mature national standard for estimation of buildings (and structures), we will still use loss ratio from that standard (GB/T 18208.4-2011). At first, buildings are divided into 5 types from the perspective of their destroy level: basically intact, slightly damaged, moderately damaged, severely damaged，collapsed. Considering about types of buildings (and structures) and actual situation of civil engineering, we can choose reasonable loss ratio from table 2.

**Table 2.** Loss ratio of buildings (%)

| Types | Destroy level | | | | |
|---|---|---|---|---|---|
| | Basically Intact | Slightly Damaged | Moderately Damaged | Severely Damaged | Collapsed |
| Reinforced concrete buildings, masonry buildings | 0-5 | 6-15 | 16-45 | 46-80 | 81-100 |
| **Industrial plant** | 0-4 | 5-16 | 17-45 | 46-80 | 81-100 |
| Town bungalow, rural buildings | 0-5 | 6-15 | 16-40 | 41-70 | 71-100 |

Source：GB/T 18208.4-2011

*4.6.2 Loss Ratio of Equipments*

Different industry requires different equipments and devices, and their vulnerability to earthquake is different. If we give every loss ratio for each type facilities in different industry, the work is too hard to finish. So, firstly, we analyze the feature of facilities in different industry, and find that although the equipments and devices are different in different industries, the differences are mainly showed in special devices in certain industry. And then, according to the features of devices, we divided facilities for estimation work into 6 types: special equipments, general equipments, transport equipments, electrical equipments, electronic equipments and communication equipments, and instrument equipments. After acquiring enough samples about equipments and devices destroy, we can calculate the average of certain facility's loss to its total value.

*4.6.3 Loss Ratio of Inventories*

Inventories are physical properties for enterprise. Their existing states are different when they at different step of production cycle. When earthquake disaster happens, inventories are easily to be affected by ground-shaking and collapse of buildings. Hence, the place to lay them is one key influencing factor of loss. For the data of loss ratio of inventories, we can use the same method of that for equipments. But the premise is collecting and analyzing enough and detailed earthquake cases in history.

### 4.7 Correction Factor（Γ）

$\gamma$ is a correction factor. When we determining value for each parameter in Eqn. 3.1, the process maybe affected by external interference. So expert can adjust it according to their rich experiences.

## 5. CASE STUDY

In this paper, we choose "Smelting and Pressing of Ferrous Metals industry" of Category 2 under Wenchuan earthquake disaster in China as our case to explain how to use above new method to estimate direct economic losses. Other industry has the same estimation process.

### 5.1 Basic Information

Ms8.0 Wenchuan earthquake happened in Wenchuan County of Sichuan Province on 12, May, 2008. After the earthquake disaster, production facilities of Smelting and Pressing of Ferrous Metals industry are destroyed seriously, and all enterprises had to close their business. And among those enterprises, Pangang Group Changcheng Special Steel Co. Ltd., Pangang Group Chengdu Steel Co., Ltd., and Sichuan Bluestar Machinery Co., Ltd. are affected more seriously.

### 5.2 Estimation Process

*P*: The exact total assets value of whole industry in this region is very hard to obtain, but we can find its value at the time point which is near to 12th May, 2008. From the statistic yearbook of Sichuan Province of 2008, we found that there are 354 state-owned and above-designated-size enterprises of Smelting and Pressing of Ferrous Metals industry in Sichuan Province until the end of 2007, and the total assets value is 98,534 million yuan.

*j*: Considering about characteristics of Smelting and Pressing of Ferrous Metals industry, we choose inventory, building, special equipment, and transport equipment as estimation asset item, so the value of *j* is 4.

*s*: We can see the seismic intensity information from filed team's investigation work. And Smelting and Pressing of Ferrous Metals industry enterprises in this case mainly located in Ⅷ seismic intensity zone.

$\alpha_s(i, j)$: In order to get vulnerable asset structure of Smelting and Pressing of Ferrous Metals industry, we choose 16 listed company in this industry as samples. After calculation of related data from their balance sheets, the asset structure of above 4 asset items is shown in table 3.

**Table 3.** Asset Structure of Ferrous Metal Smelting and Calendaring Industry

| Enterprise | Inventory | Buildings | Special Equipments | Transport Equipments | Total |
|---|---|---|---|---|---|
| Anyang Iron and Steel Inc. | 24.00% | 9.71% | 28.10% | 0.18% | 61.99% |
| Changjiang Precision steel Inc. | 40.01% | 10.37% | 4.19% | 0.28% | 54.85% |
| Fangda Special Steel Technology | 19.04% | 10.66% | 16.17% | 6.93% | 52.80% |
| Fushun Special Steel Co., Ltd. | 27.55% | 8.29% | 19.29% | 0.27% | 55.40% |
| Gansu Jiuquan Iron and & steel | 21.55% | 12.93% | 26.09% | 0.27% | 60.84% |
| Guangzhou Iron &Steel | 46.01% | 3.53% | 19.17% | 0.18% | 68.89% |
| Hangzhou Iron and Stell Inc. | 18.40% | 9.80% | 19.92% | 0.03% | 48.15% |
| Jinan Iron & steel Co., Ltd. | 19.51% | 10.67% | 35.68% | 0.17% | 66.03% |
| Laiwu Steel Corporation | 18.80% | 22.86% | 36.83% | 0.02% | 78.51% |
| Lingyuan Iron & steel Co., Ltd. | 27.58% | 14.05% | 29.21% | 0.27% | 71.11% |
| Liuzhou Iron & steel Co., Ltd. | 37.85% | 23.94% | 22.17% | 0.00% | 83.96% |
| Angang Steel Company Limited | 17.94% | 19.53% | 29.95% | 0.11% | 67.53% |
| Inner Mongolia BaoTou Steel | 26.18% | 7.94% | 30.99% | 0.13% | 65.24% |
| Nanjing Iron & steel Co., Ltd. | 16.82% | 19.48% | 24.69% | 0.08% | 61.07% |
| Wuhan Iron & steel Co., Ltd. | 15.29% | 8.75% | 57.46% | 0.29% | 81.79% |
| Zhejiang Hangxiao Steel Structure | 38.15% | 14.60% | 11.13% | 0.34% | 64.22% |
| Average | 25.92% | 12.94% | 25.69% | 0.60% | 65.15% |

With above data, we calculated vulnerable asset value before earthquake disaster: the value of inventories is 25,540 million yuan（98,534*25.92%）,the value of buildings is 12,750 million yuan, the

value of special equipments is 25, 313 million yuan, and the value of transport equipment is 591 million yuan.

$k_s(i, j)$: Until now, earthquake has passed for a long time, and destroys and losses information of enterprises which was collected at that time was not very sufficient. Earthquake filed team experts just gave us a value range for each loss ratio (table 4). And we had to choose reasonable value for each loss ratio roughly by our subjective experience. The values of loss ratio of above 4 asset items are 8%, 30%, 4% and 8% respectively.

**Table 4.** Loss Ratios of Assets in Ferrous Metal Smelting and Calendaring Industry

| Asset item | inventory | building | Special equipment | Transport equipment |
|---|---|---|---|---|
| Loss ratio（%） | 2~20 | 5~70 | 5~50 | 5~25 |

Finally, we put above value for each parameter into Eqn. 3.1, and get the final result is:

$$L = 25{,}540 \times 8\% + 12{,}750 \times 30\% + 25{,}313 \times 4\% + 591 \times 8\% = 6928 \qquad (5.1)$$

The final estimation result is 6928 million yuan, and the actual reported economic loss of Smelting and Pressing of Ferrous Metals industry enterprises is 6891 million yuan. The little gap between 2 results shows that the new estimation method in this paper can reflect the basic information of direct economic loss of industrial enterprises after earthquake disaster, and we can use it in future estimation work.

## 6. CONCLUSIONS

The amount of industrial enterprises, especially large and medium-sized enterprises in China is increasing every year. And some of them are located in Ⅵor above Ⅶzone. With the expanding of industrial enterprises, the direct economic loss will become more and more seriously if earthquake disaster attacks them. This paper proposed a new method to estimate direct economic loss resulted by earthquake-disaster from the perspective of financial accounting. This method allows experts to get a rapid rough estimation about the effect of earthquake-disasters to industrial enterprises, to the economy of a city, a region or a country. And this new idea also can provide some help to related government agencies.

The innovation of this method in this paper is using balance sheet, which shows basic financial situation of a company for estimation. Each company is required to prepare balance sheet every year, so related data is easily to acquire for estimation. This can provide convenience to estimation work and save much time for it. Although this method is easy to operate theoretically, there are disadvantages of it, such as difficulty in collecting enough historical earthquake data, relying too much on experts' subjective judgment and so on. And we will try our best to study on how to perfect this method in the future.

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**REFERENCES**

Direct economic losses of approximately 14,000 enterprises in Wenchuan earthquake is ￥67 billion, *Fortune World* **2008(6)**: 12-21.

Post-earthquake field works—Part4: Assessment of direct loss (GB/T 18208.4-2011). Beijing: Chinese Standards Publishing House，**2005**.