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Probability analysis of setback distance based on structural damage near earthquake-fault-rupture

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Abstract. The probabilistic analysis method is the inevitable result of the development of engineering seismic science and adapts to the current level of people's understanding. This paper systematically summarizes the seismic damage of the engineering structures near the surface rupture zone of strong earthquakes in Yushu earthquake, Wenchuan earthquake and Jiji earthquake in recent years. According to the quantitative relationship between building damage index and distance, probability analysis results of the setback distance is given. This result is easy to popularize and apply, and lays a foundation for probabilistic risk analysis of buildings close to the surface rupture zone of strong earthquakes.

1. Introduction

The surface rupture of strong earthquake is also called the ground fracture or dislocation of strong earthquake. It is the ground deformation formed when the seismogenic fault moves suddenly and releases elastic strain energy to produce strong earthquake. It is strictly controlled by the seismogenic fault, and the exposed position, spreading direction and mechanical properties are consistent with the seismogenic fault.

The damage, destruction or collapse of the engineering structure caused by strong earthquake surface rupture is called the earthquake damage of the engineering structure under the surface rupture, referred to as the structure damage. Structural damage refers to the vicinity of the surface rupture, that is, within a certain distance of the engineering structure because of its damage, such as collapse, severe damage, moderate damage or loss of some functions. In fact, this is the problem of the avoidance distance of engineering structure, and the distance from the strong earthquake rupture zone (trace line) to the engineering structure, namely the setback distance.

From the perspective of development, the recognition of the severity of structural damage caused by surface rupture has gone through two stages. In the first stage, the process of the less emphasis gradually developed to the second stage of special attention, especially in recent years with the strong earthquake and surface rupture and structural damage of many devastating occurrence, baptism and improve the people especially scientists in this aspect of the cognitive level.

Predecessors' research, however, is actually at the surface rupture width on the quantitative study and rarely conducts the investigation and research on the structural damage caused by the surface rupture zone, which is near the surface rupture has been conducted on its engineering structure analysis. This analysis and research can more accurately reflect the security of the structure under the evasive distance between the surface rupture and the engineering structure. Therefore, it can be seen that further analysis of the setback distance relationship between surface rupture and its adjacent engineering structure is an urgent and difficult task in the field of current strong earthquake surface rupture evaluation.



Based on the earthquake damage of engineering structures near surface rupture zones such as Yushu earthquake, Wenchuan earthquake and Taiwan Jiji earthquake, the preliminary results of engineering structure setback distance considering probability risk are given in this paper.

2. Structures Seismic damage analysis near Yushu earthquake rupture zone

On April 14, 2010, an Ms7.1 earthquake occurred on the Ganzi-Yushu fault section. The rupture zone is about 30-40km in length, and each main rupture fault is composed of a series of ruptured geese. The rupture is a left-lateral strike-slip property, and the maximum slip-slip displacement is located on the north main rupture, about 1.8 m [1-2].

In this paper, the author on April 18, 2010 conducted a seismic damage investigation on buildings along the surface rupture trace in the VIII degree zone, along the surface rupture trace (north west about 290°) from the point of G0 to point the G7. In the rupture area with a linear distance of about 22km, 72 buildings (structures) such as villages and monasteries along the active fault were investigated to find out the damage from the distance of the active fault, and according to the relevant standard specifications [3], the earthquake damage index of each single house is provided more detailed information for the quantitative study of the distance between the building and active faults rupture.

Combined with the above investigation analysis, the relationship between the seismic damage index and the setback distance of the hollow brick structure along the rupture trace can be seen in Figure 1 and Figure 2. It can be seen from the figure that with the increase of the distance from the surface rupture (S), the seismic damage index (I) of the hollow brick structure is greatly reduced; if the hollow brick structure is more than 50m away from the surface fracture trace, it is basically in line with the principle of "big earthquake does not fall". If the damage can be repaired under medium level (that is, the damage index is 0.4-0.5), the distance from the fracture trace should be at least 150m.

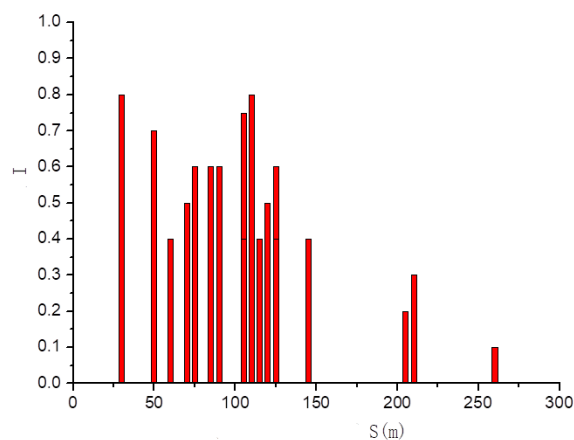


Figure 1. Damage Index of Hollow Brick Structure on rupture trace

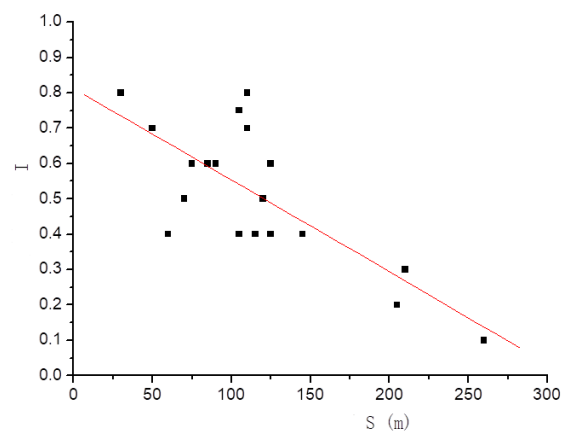


Figure 2. Scatter plot of setback distance and damage index of hollow brick structure

3. Structures Seismic damage analysis near Wenchuan earthquake rupture zone

The M8.0 earthquake in Wenchuan in 2008 made the middle part of Longmenshan nappe tectonic belt strike NE, dip NW, and the Beichuan-Yingxiu fault with dextral strike-slip component and the Guanxian-Jiangyou fault occur surface rupture at the same time, forming three synseismic surface rupture zones. The surface rupture zone of Wenchuan earthquake has very distinct characteristics in surface rupture type, rupture width, geometric structure and coseismic displacement distribution, etc. It is the most complex surface rupture structure, the longest rupture length, and an internal slip-type mega-earthquake thrust and dextral strike-slip component [4].

The fault nature of the Wenchuan earthquake and the factors of site conditions and engineering structure types provide valuable first-hand data on the impacts of seismic damage and damage forms on the surface rupture setback area, providing a scientific basis for the study of setback distance.

Table 1. Seismic damage index of buildings from surface rupture distance in Wenchuan earthquake

Building name near the fault	Setback diatance(m)	Damage index	structure type	Macro description	Source of literature
Wangjiakan, Guangou, Bailu Town Shuangyang	10-20	1.0	Many brick and wood structures	Complete collapse	[7]
Villagers'House in Tongji Town	30-40	0.2	2 storey building	The courtyard wall falls down, the exterior looks good, the preliminary judgment is tenable	[7]
Ma Liangmin's Home in Shuangyang Village, Tongji	0	1.0	Brick wood structure	Complete collapse, kitchen stove sinking	[7]
Beichuan Hotel	47	0.8	Frame structure	The 1 layer collapses.	This article
Dongjia of Shenxi Valley in Hongkou Town	36	0.2	2 storey building	In 2006, there were no obvious cracks in the surface walls and slabs.	[7]
New Building by the River in Yingxiu Town	20	0.7	6 layers brick concrete structure	2 layers crushed, other layers did not collapse and migration occurred	This article
Bailu Town Middle School Building 1	10-20	0.55	4 layers brick concrete structure	Serious damage to the main body	[6]
Bailu Town Middle School Building 2	10-20	0.1	3 layers brick concrete structure	It's just a crack in the wall.	[6]
Bailu Town Residence	10	0.7	Brick wood structure	Serious damage, roof rafters falling	[6]
Bailu Town Middle School Building 3	30	1.0	Brick houses	collapse	This article
Xiaoyudong Town House 1	27	1.0	3-storey bottom frame masonry	collapse	[5]
Xiaoyudong Town House 2	100	0.6	3-storey bottom frame masonry	Serious damage	[5]
Xiaoyudong Town House 3	220	0.4	3-storey bottom frame masonry	Moderate damage	This article
Xiaoyudong Town House 4	150	0.1	3-storey bottom frame masonry	Slight damage	[5]
Hongkou Bajiao Temple House	10	0.9	brick concrete structure	collapse	[7]
Beichuan County Building 1	80	1.0	bottom frame masonry	collapse	This article
Beichuan County Building 2	60	0.8	Academic Building	tilt	This article
Beichuan County Building 3	50	1.0	Academic Building	collapse	This article
Beichuan County Building 4	50	0.7	High-rise residential buildings	partial damage	This article
Beichuan County Building 5	35	0.5	6 layers brick concrete structure	partial damage	This article
Beichuan County Building 6	34	0.45	6 layers brick concrete structure	partial damage	This article
Beichuan County Building 7	30	0.9	2 layers brick concrete structure	damage	This article
Beichuan County Building 8	20	0.4	2 layers brick concrete structure	partial damage	This article

This paper analyzes the related contents that can reflect the structural damage along the surface rupture: (1) structural damage results investigated by Jisheng Zhao et al. (2) structural damage data compiled by Qing Zhou et al.; (3) structural damage results investigated in this paper. Due to the limitations of the relationship between surface rupture and structural damage in Wenchuan earthquake given by predecessors, this paper sorted out the engineering structural damage at a certain distance from

the rupture line of Wenchuan earthquake. According to the structural damage index and fault trace distance (setback distance from the house) the principle of relationship quantification is summarized in Table 1.

4. Structures Seismic damage analysis near Taiwan Jiji earthquake rupture zone

In 1999, Taiwan Jiji M8.0 earthquake produced a strong earthquake surface rupture zone along the Chechengpu thrust fault nearly north-south, with a total length of about 100 km [8].

Taiwan's Fengtian Lin[9] used the earthquake investigation team composed of 21 academic and professional units led by Ministry of the Interior Construction Planning Administration (ACP) to provide investigation data on the damage of buildings around Chegongpu fault surface rupture. A plot of the spatial relationship between the surface and its adjacent buildings damage is shown in Figure 3-6.

In this paper, it is believed that Fengtian Lin's analysis using the investigation data on the fault rupture trace and adjacent vicinity is objective and detailed, and the method of destroying (destruction) rate is actually an analysis method similar to the idea of analytical method of single structure seismic damage index.

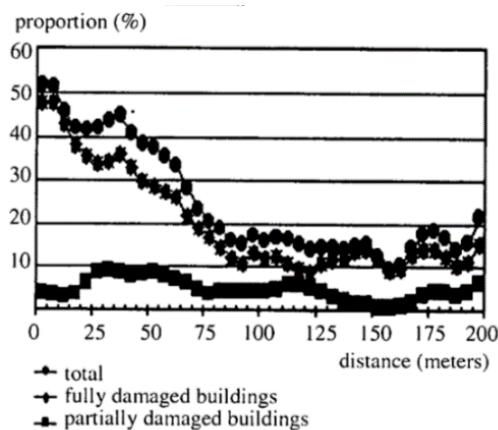


Figure 3. Proportion of damaged buildings in village area

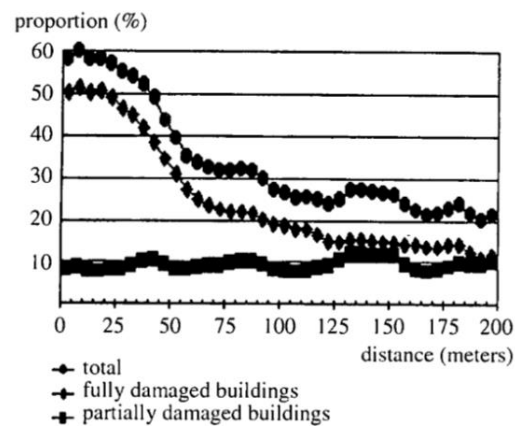


Figure 4. Proportion of damaged buildings in urban area

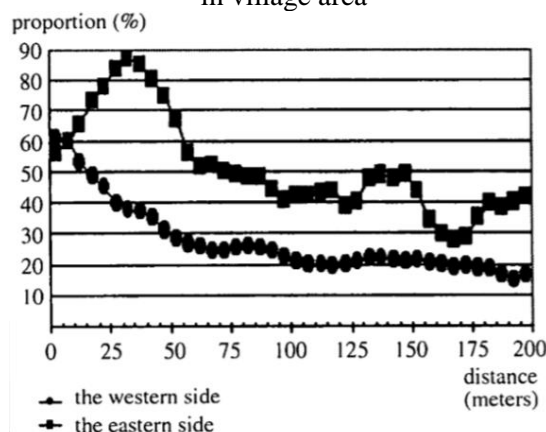


Figure 5. Proportion of damaged buildings on both sides along the fault rupture trace in village area

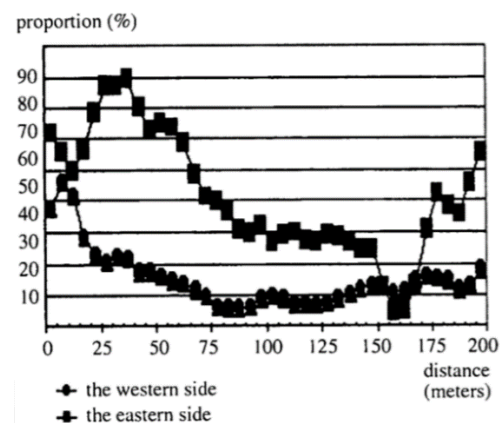


Figure 6. Proportion of damaged buildings on both sides along the fault rupture trace in urban area

5. Setback distance probability analysis

Combined with the comprehensive statistical analysis of the collapse of buildings at a certain distance along the rupture trace of Yushu earthquake, Wenchuan earthquake and Jiji earthquake, table 2 can be given.

Table 2. Probability of structural collapse under different setback distances

Setback distance	$S > 150$	$150 \geq S \geq 100$	$100 > S \geq 50$	$50 > S \geq 25$	$S < 25$
Probability assignment (%)	10	20	35	55	75

Note: if the building is in the upper panel, the probability assignment in the table will increase by 20%.

It can be seen from the table that : (1) the seismic damage situation of the engineering structure is serious if the setback distance is within 50m, and the probability risk of collapse or severe damage is basically over 50%, especially if the avoidance distance is within 25m, which is basically an area that is difficult to be solved by engineering seismic measures; (2) from 50m to 150m, the seismic damage of the engineering structure is mainly medium damage with a probability risk of 20-35%, which can be solved by some reasonable measures of anti-fault-rupture structure; (3) the setback distance is more than 150m, which is basically a minor failure, and this distance may not be caused by the surface rupture effect of strong earthquakes, that is, it can be solved in accordance with the relevant seismic design specifications. (4) buildings located on the upper panel of active fault, the probability of avoidance distance will increase, increasing by about 20%.

Based on the above analysis, the probability analysis and evaluation of the setback distance of engineering structures adjacent to the surface rupture of strong earthquakes are in line with the current research level of engineering earthquake science, and it is also the general requirement of engineering seismic fortification. Therefore, it is an inevitable result of the development of scientific knowledge that probability evaluation method replaces the macroscopic qualitative evaluation method.

Acknowledgments

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