A PRELIMINARY STUDY ON QUICK ESTIMATING MODEL OF EARTHQUAKE CATASTROPHE -AN EXAMPLE OF PAKISTAN EARTHQUAKE

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Abstract

This paper discusses the mainly affected factors of earthquake catastrophe estimation, including the earthquake parameters (time, magnitude, epicenter, depth), properties and strike of the earthquake fault, the density of population and distribution of economic values, the ability of anti-earthquake level of buildings, the sites and topography conditions, etc.. By the systematical analysis of some recent global strong earthquakes cases and the affected factors for quick estimating of catastrophe, four types of models are suggested, that are, the mountain collision of Himalaya-Tethys, the subduction zone of oceanic plates subducting to continents and islands, normal faults and continent rifts, and transform faults under the ocean floor. The comprehensive mechanisms of catastrophe formation and the possible catastrophe areas or belts are suggested.

Introduction

Since 1994, the projects on urban seismic hazard and losses assessment near 30 cities have been done in China, and also each provincial center on emergency management and decision-making have been established (Chen, 1995, Qu, 1996, 1999, 2003, Feng, 2004). Many developments on risk assessment, emergency management and emergency responses have achieved in the world in recent years (Walker, 2005).The problem for emergency response is how to make quick prediction of potential disaster after the large earthquake occurred, if the large earthquake will result in the catastrophe, especially for rural area. By the systematical analysis of some recent global strong earthquakes cases and the affected factors for quick estimating of catastrophe, four types of models are suggested in this paper.

The Definition of Earthquake Catastrophe and analysis of related factors

The Definition of Earthquake Catastrophe

The mean of earthquake catastrophe is not sure at present. Gao (1997) suggests that the mean of earthquake catastrophe is determined when the casualty is more than 10000, and direct economic losses is more than 10 billions RMB in one case. In each case that has been aids by international city search and rescue teams, the death number is more than 2000 in recent

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years, for example, in Jiji earthquake of Taiwan with magnitude 7.3 in 1999, the death is 2412, and direct economic losses are 10 billion US dollars, Gujarat earthquake in India with magnitude 7.6 in 2001, the death is more than 40000, and direct economic losses are 2.1 billion US dollars, Algeria earthquake with magnitude 6.8 in 2003, the death is 2273, and direct economic losses are 0.5 billion US dollars, Bam earthquake in Iran with magnitude 6.3 in 2003, the death is more than 31000; Gujarat earthquake in India with magnitude 7.6 in 2001(Qu, 2001), the death is more than 40000, and direct economic losses are 2.1 billion US dollars; India ocean earthquake and tsunami with magnitude 9.0 in 2004, the death is more than 30,0000, and direct economic losses are 100 billion US dollars; Pakistan (or South Asia) earthquake with magnitude 7.8 in 2005, the death is more than 8,7000, and direct economic losses are 10 billion US dollars. Based on the cases above, the mean of earthquake catastrophe are: the death people will be over 1000, the direct economic losses will be over 10 billion US dollars.

The Main Affected Factors of Earthquake Catastrophe

The main affected factors of earthquake catastrophe include parameters of earthquake (such as the time of earthquake, magnitude, epicenter, depth of epicenter), and the seismotectonics background and their spatial distribution (normal fault, thrust fault, strike-slip fault or both kinds of faults), the abilities of anti earthquake of buildings, site conditions and social (population) and economic distribution and their density.

Case analysis of recent global strong earthquake

Fast estimating the degree of earthquake damage and giving the decision and advice is very important to emergency relief action startup after a Ms>7.0 earthquake. Quick disaster damage adjustment is affected by lots of factors from the following recent strong earthquake cases.

Magnitude 7.5 – Northern Peru

According to this event details (Talbe1), the inferred results are as followings: Its magnitude is 7.5 and the epicenter is located in the front of eastern Andes foothill where there are several cities with high population, so the earthquake may cause great damage and casualties. The depth released by the United States Geological Survey (USGS) immediately after this earthquake is about 85.4km, which belongs to middle-deep type and may cause a few casualities.But the epicenter is loacated on the east of Andes about 400km from the western coast of the South America (Fig.1), and based on the studies, the Pacific ocean plate underthrusts toward the Puru segment of Andes by the angle of between 20 and 30, we can estimate that its depth is about 150km and will cause less damages in this event. One day after the earthquake, the recaculated depth is 132.3km and two people killed by news report form Puru government.The estimaiton of local depth is crucial to this event which is based on the caculated depth by global seismic stations and local tectonic background.

Magnitude 7.6 - Pakistan

According to this event details (Talbe1), the inferred results are as followings: Its magnitude is 7.8 and the epicenter is located in the front of Himalaya foothills. The depth is about 10-15km. We can infer that this earthquake occur on the main boundary thrusts (MBT) where the historical earthquakes had caused great damages and casualties (Fig.2). Additionally, the earthquake happened in the scenic spots of northern Pakistan where lots of cities and villages are distributed with dense population, so this event can cause huge damages; Disaster news from Internet and Media come more from Islamabad and surrounding area where the tremble is felt obviously. But there is little news about extensive damage after 3 hours, the north Pakistan has little report after 2 hours which may be due to traffic and communication

interruption, forming the "blind stage" of devastated earthquake. Based on the above analysis, we give the great disaster relief advice after 2.5 hours.

Table 1 Case analysis of recent global strong earthquake and fast related disaster assessments

Region	Date-time Local	Magnitude Ms	Location		Depth km	Fault type	population	damage
			latitude	Longitude				
Northern Peru	05, 09,26,18:55	7.6	5.657°S	76.4 W	132.3	subducted zone	more	light
Pakistan	05, 10, 08, 08:50	7.8	34.4N	73.6W	10-15	Thrust fault	more	catastrophe
Congo-Tanzani	05,12, 05, 14:19	7.0	6.1S	29.7E	10	Rift-normal fault	more	light
East of the south Sandwich islands	06, 1, 2, 7:10	7.5	60.8S	21.4W	Not clear	Transform fault	no	no
Mozambique	006 2, 23, 0:29	7.5	21.1S	33.2E	10	Rift-normal fault	less	light

Fig.1 Plate tectonic map of Peru 7.6 earthquake

Fig.2 Disaster information map of Pakistan Earthquake
Real line involved: part damaged area, dotted line involved: no disaster reported area

Because the earthquake mechanic fault is in the front of Himalaya front thrust belt with north-west verging hanging wall and 20-40°angle of dip. According to the past damage distribution of the earthquake induced by thrust faults, the macro-epicenter and micro-epicenter are different, so we infer that the macro-epicenter should lie in north-west of micro-epicenter. The inferred results are approved by relief action and disaster evaluation after this event.

2.3 Magnitude 6.8 – Lake Tanganyika region, Congo-Tanzania

According to this event details (Talbe1), the inferred results are as followings: Its magnitude is 7.0 and the epicenter is located in the Lake Tanganyika region. The depth of epicenter is about 10km and shallow earthquake affecting Congo, Tanzania, Kenya, Zambia and Burundi, so this event may cause great disaster. The earthquake occurred in the East African rift system with a serious of normal faults. The earthquake generated faults may be on the east normal faults of the rift dipping to the west. The west Lake Tanganyika region and nearby cities may be the heavy disaster area. Because the Kalemie city is 50km away from the epicenter, the inferred intensity is near VII VIII (pic.3) (based on the estimation of intensity) and will have some loss. On the basis of analyzing the building earthquake resist, the casualties may be little. We concluded that there were no great losses and this conclusion was verified by local newspaper after 2 days, only 7 persons were killed by this earthquake in the Kalemie city.

Magnitude 7.4 –East of the South Sandwich Islands

According to this event details (Talbe1), the inferred results are as followings: The earthquake occurred on the east of the south Sandwich island of south Atlantic Ocean which is the transform faults affected region under the Atlantic and Pacific Ocean floor. The earthquake generating tectonic should be large scale transform faults forming the arcade islands such as

Bird island and Edward Prince island (Fig.4). Although the sea water is deep, the transform faults have strike slip characters and little vertical rupture displacement, so the hazard of tsunami is little. Because the surrounding islands are far away from the epicenter (about 300-500km), we infer that there should be little losses from this earthquake.

Fig.3 Map of earthquake epicenter of Democratic Republic affected of the Congo and Tanzania area

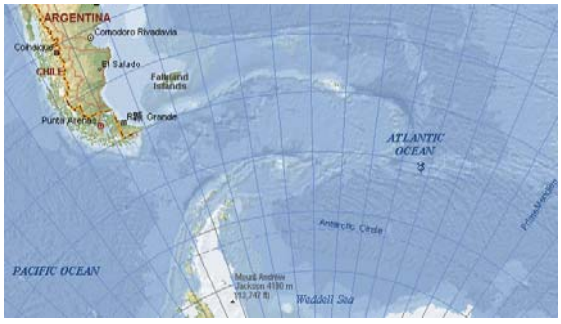

Fig.4 Sea floor topographic map of earthquake

Preliminary establishment of quick estimating model of earthquake catastrophe

From the above analysis of strong earthquake cases, the different disaster damages can be caused by the same magnitude earthquake with different depth, epicenter, time and social economic situations. Such as the Ms 7.6 earthquake which caused great loss in the North Pakistan but little damage in the Peru and South Atlantic ocean area. On the conditions of close magnitude and depth, different epicenter and fault type cause different losses such as the great losses in the Pakistan while little losses in the Kago-Tanzania. On the same conditions of seafloor earthquakes, the tsunami occurred in the Indian Ocean and caused great casualties while less loss in the South Atlantic Ocean. On the basis of the above analysis, quick estimating models of earthquake catastrophe are classified as followings:

Mountain collision type of Himalaya-Tethys

This type is thrusting or continental strike-slip faults as earthquake generating structure which runs cross Pyrenean, Alps, Atlas, Mediterranean Sea, Zagros and Pamir-Himalaya earthquake belts from west to east. Most earthquakes belong to shallow earthquake except the middle depth earthquake in the Pamir and occur in the mountain ranges or its front where lots of developing countries have poor earthquake resist buildings and dense population. The micro-epicenter and macro-epicenter have different locations. When the magnitude is more than 7.0 and depth is between 5 and 30km with dense population, the great losses are along the fault strike or hanging wall such as 1999 Turkey Ismit earthquake, 2003 Algeria earthquake, 2003 Iran Bam earthquake and 2005 South Asian earthquake.

Subduction zone type of oceanic plates subducting to continents and islands

This type is mainly include the earthquake generated subduction zones surrounding Pacific and India Oceans, include subduction seismic zones surrounding Pacific (Andes, Cordillera mountains, Alaska, Aleutian island, Japan-Nansei Shoto, Taiwan, Philippine, Papua-New Guinea, Tonga and New Zealand et al) and Indonesia, Banda Sea Arc, many times earthquake generated tsunamis occurred in history. Due to the subducting angles are different in different parts of Pacific and India Oceans, so to determined the depth of epicenter depends on the subducting angles is very important, and then to consider if the epicenter located in the high dense population area. Historical records show that Japan, Alaska, and North American countries will has less damage when the earthquake magnitude near or less 7.5 occurred, but

the Indonesia, Philippine, Papua-New Guinea, Tonga and South American countries will have huge damages in the same conditions (earthquake magnitude near or less 7.5).

Normal faults and continent rifts

The seismic structure is normal faults, normal slip faults and rift in areas of this type, such as the East Africa Rift and the North China Rift Valley. Because the source depth is usually shallower than 20Km in such plain area and cities distributed with high dense population. Strong earthquake can cause catastrophe, such as the Tangshan earthquake Disaster that happened in China in 1976.

Transform faults under the ocean floor

Seismic structure in areas of this type is large scale transform faults. Ordinarily, earthquake occurring in such area will not induce catastrophe, such as the Richter magnitude 7.5 earthquake that occurred in the South Atlantic Ocean. A Richter magnitude 8.7 earthquake that occurred in the Northwest Atlantic Ocean induced a tsunami that caused more than 50,000 fatalities in Portugal and Spain in 1755.

Comprehensive analyses of affected factors for quick estimating of catastrophe

Above analysis results following relationship between the affected factors and the catastrophe intensity:

Disaster Degree = Magnitude * Depth * Fault type
Disaster losses = Disaster degree * Population density * Vulnerability

In generally, catastrophe will quite likely occur in the land area if the earthquake magnitude is larger than 7.0, the source depth is shallower than 30Km, and the epicenter is in urban area, and the disaster happens in developing country or territory.

If the earthquake magnitude is larger than 7.0, the source depth is shallower than 30Km, the depth of the water in the epicenter area is deeper than 4000m, a tsunami will quite likely happen and induce a catastrophe in the sea area. Otherwise, if not all the factors meet above condition, a catastrophe probably will not happen.

Conclusion

This paper discusses the mainly affected factors of earthquake catastrophe estimation, including the earthquake parameters (time, magnitude, epicenter, depth), properties and strike of the earthquake fault, the density of population and distribution of economic values, the ability of anti-earthquake level of buildings, the sites and topography conditions, etc.

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The comprehensive mechanisms of catastrophe formation and the possible catastrophe areas or belts are suggested.

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Dr. QU Guosheng, Prof. and Chief Engineering, National Earthquake Response Support Service, China Earthquake Administration. He has applied his research achievements to the prevention and mitigation of seismic hazards in China and achieved breakthrough progress in such fields as urban disaster emergency management, the application of geographical information systems (GIS) and remote sensing (RS), three-dimensional underground structure modeling for urban areas, exploration of active tectonics, regional seismotectonics and petroleum structural geology. Qu is also an instructor of doctorate candidates in the Institute of Geology, CEA.In 2005, he participate the South Asia Earthquake search and rescue action in Pakistan as a team member of CISAR.

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