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EARTHQUAKE EFFECTS: THE IMPACT ON BUILDINGS AND ENVIRONMENT

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Abstract

The direct shaking effects as damage or collapse of buildings, bridges, elevated roads, railways, water towers, water treatment facilities, utility lines, pipelines, electrical generating facilities and transformer stations, are not the only hazard associated with earthquakes, other secondary effects, that are caused by earthquakes, most often a result of strong shaking, such as landslides, soil liquefaction, fires, floods etc. have also played an important role in destruction produced by earthquakes. These effects mean short-term (immediate) or long-term impacts. Depending on the vulnerability of the affected community, large numbers of people may be homeless in the aftermath of an earthquake. The estimating of all hazards is very important in order to get how are changed the life and the environment after an earthquake. The paper present some aspects related to this subject, what are some effects of earthquakes on the natural and built environments, why do buildings collapse in earthquakes, how we can make buildings more resistant to earthquakes etc.

Keywords: *earthquake, vulnerability, damage, strengthening works*

1. INTRODUCTION

Earthquake damages depend on what area is hit. If an unpopulated area is struck, there will not be loss of life or property, but there will be only some effects on environment. If it hits a big city, there may be many injuries and very severe damages.

The negative effects of earthquakes include, but are not limited to, the following: shaking and ground rupture, landslides, fires, soil liquefaction, floods, tsunami, human impacts etc.

Over time, it was found that the real dangers to people are being crushed in direct shaking effects as collapsing building and then what is very important from some secondary effects as drowning in a flood caused by a broken dam or levee, getting buried under a landslide, or being burned in a fire.

Usually, earthquake fatalities are dominated by shaking-related causes, while secondary effect-induced fatalities are dominated by landslide deaths. From the earthquake records, the fire and liquefaction tend to contribute more to structural and financial losses rather than fatalities.

2. WHAT EFFECT DID THE EARTHQUAKE HAVE ON THE BUILDINGS AND LIFELINE SYSTEMS?

2.1. How earthquakes affect buildings

For economic reasons, building codes permit buildings to be damaged by the infrequent severe earthquakes that may affect them, but prevent collapse and endangerment of life safety. For buildings that house important functions essential to post-earthquake recovery, including hospitals, fire stations, and emergency communications centres etc., all codes adopt more conservative criteria that are intended to minimize the risk that the buildings would be so severely damaged they could not be used for their intended function.

Failure of the ground and soil beneath buildings is also a major cause of damage.

Several important characteristics of buildings affect different the performance during an earthquake (Figure 1):

- *natural period* - it becomes a problem if the period of the ground is the same as that of a building on the ground
- *damping* - connections of non-structural elements such as partitions, ceilings, and exterior walls can dampen a building‘s vibration
- *ductility* - using materials, primarily steel, the structure will bend or deform before it will fail
- *stiffness* - less rigid building elements have a greater capacity to absorb several cycles of ground motion before failure, in contrast to stiff elements, which may fail abruptly and shatter suddenly during an earthquake
- *drift* – some limits are often imposed on drift so a building is not designed to be so flexible that the resulting drift or swaying during an earthquake causes excessive damage; if the level of drift is too high, a building may pound into the one next to it
- *building configuration* - determines the ways in which seismic forces are distributed throughout the building (an L, T, H-shaped building will experience increased stress at the point where the wings of the building meet; torsion forces on these buildings can cause one wing to rotate around the other)
- *soft-story* - creates a discontinuity of strength and stiffness; the first floor is the most highly loaded, so a soft-story to the first floor possibly causing column failure or can cause the building to collapse

a. b.

c.

Figure 1. Negative performance during an earthquake due to some characteristics of buildings (a. pounding between two buildings because large drifts [1]; b. soft-story [2]; c. Lizeanu building, Bucharest – soft storey effect - March, 4, 1977, ICCPDC-INCERC photos)

2.2. How Earthquakes Affect Lifeline Systems - Transportation lifelines, Water distribution systems, Natural gas systems, Electric power systems, Sewer and wastewater systems etc.

The extensive damage and disruption to lifeline systems appear as deformed rail lines, tilted container cranes, and cracked wharf piles, catastrophic collapse of major bridge structures (which can led to a significant loss of life, and a big total repair cost, traffic delays and delays in the transportation of goods vital to the economy), cracking of distribution systems pipes etc. (Figure 2- b. this was particularly likely where the road crossed areas of softer, wetter ground, where the shaking was stronger and lasted longer; c. below one intersection a subway station collapsed, leaving the road above to sink unpredictably for months until it could be excavated)

a. b. c.

Figure 2. a. Railroad Damage [3]; b. from a report by J.-P. Bardet at USC and others at Gifu Univ.; Large sections of the main Hanshin Expressway toppled over [4]; c. from a report by J.-P. Bardet at USC and others at Gifu Univ. [4]

3. WHAT EFFECT DID THE EARTHQUAKE HAVE ON THE ENVIRONMENT?

The different types of seismic waves produce several different effects on the natural environment that also can cause tremendous damage to the built environment (buildings, transportation lines and structures, communications lines, and utilities). The negative effects of earthquakes include landslides, soil liquefaction, floods, fires, tsunami, and human impacts.

3.1. How earthquakes produce landslides and liquefaction

Occasionally large landslides can be triggered by earthquakes. Careful consideration should be made before place a building in a location that could be affected by a landslide. During an earthquake, a landslide can block the exits to the firehouse, and, while the fire equipment will be blocked inside, the town will suffer from fires caused by the earthquake (Figures 3, 4, 5).

Figure 3. a. Landslide produced by earthquake - Conchita, 1995 [5]; b. Landslide produced by earthquake - El Salvador, 2001 [6] c. Landslides produced by Anchorage earthquake near a school building - Alaska, 1964 [7]

Figure 4. Damage due to soil liquefaction and permanent settlement [8]

Strong ground motion during an earthquake can cause water-saturated, unconsolidated soil to act more like a dense fluid than a solid; this process is called liquefaction. Liquefaction occurs when a material of solid consistency is transformed, with increased water pressure, in to a liquefied state. Water saturated, granular sediments such as silts, sands, and gravel that are free of clay particles are susceptible to liquefaction. If the soil beneath it suddenly behaved like a liquid, a building would happen to shift, tilt, rupture, or collapse.

Figure 5. It is showed how buildings can topple when soil assumes the properties of a liquid and loses its bearing capacity [8]

Ground Failure

Strong ground motion is also the primary cause of damages to the ground and soil upon which, or in which, people must build. These damages to the soil and ground can take a variety of forms: cracking and fissuring and weakening, sinking, settlement and surface fault displacement.

One of the most important types of ground failure is known as liquefaction. Liquefaction takes place when loosely packed, water-logged sediments at or near the ground surface lose their strength in response to strong ground shaking. Liquefaction occurring beneath buildings and other structures can cause major damage during earthquakes.

Ground Sliding

Strong ground motion is also the primary cause of damages to the ground and soil upon which, or in which, people must build. These damages to the soil and ground can take a variety of forms: cracking and fissuring and weakening, sinking, settlement and surface fault displacement.

Ground Tilting

Sometimes, due to earthquake, there is tilting action in the ground. This causes plain land to tilt, causing excessive stresses on buildings, resulting in damage to buildings.

Differential Settlement

If a structure is built upon soil which is not homogeneous, then there is differential settlement, with some part of the structure sinking more than other. This induces excessive stresses and causes cracking.

3.2. How earthquakes produce floods

An earthquake can rupture (break) dams or levees along a river. The water from the river or the reservoir would then flood the area, damaging buildings and maybe sweeping away or drowning people.

Figure 6. a. A tsunami floods over the breakwater protecting the coastal city of Miyako – Japan 2011 [9]; b. Earthquake-related failure of the breakwater in the Navlakhi port in 2001[10]

3.3. How earthquakes produce fires

The fires produced by earthquakes can be started by broken gas lines and power lines, or tipped over wood or coal stoves. It will be a serious problem if the water lines that feed the fire hydrants are missed or broken (Figure 7).

a. *b.*

Figure 7. a. School building after a fire produced by earthquake in 2004, India [11]; b. The destruction of lifelines and utilities made it impossible for fire-fighters to reach fires started by broken gas lines. Large sections of the city burned, greatly contributing to the loss of life [12];

3.4. How earthquakes produce faults

We saw in the previous unit that ruptures along fault planes or zones sometimes reach the surface. If a building stands on a fault line, little can be done to protect it during an earthquake. It is extremely important to select sites for new buildings that are away from known fault surface traces (Figure 8).

Figure 8. Ground failure near the building school, Duzce -1999 (INCERC photo)

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3.5. How earthquakes produce tsunamis

During an earthquake, seismic waves can produce powerful ocean waves. These waves tend to be very deep, with long distance between the peaks. In deep water there may be no noticeable evidence of the tsunami at the surface. However, when the wave enters shallow waters, the energy is forced to the surface and produces a tall wave that travels at high speed and moves far inland. Seaside communities are usually ravaged twice—first, when the water crashes in from the sea and, second, when the water recedes and carries loose objects out to sea. Though tsunamis are not as common as earthquakes, they can cause much more damage.

Figure 9. The effect of a tsunami from March 11, 2011 Japan [13]

3.6. How earthquakes can induce a disasters chain

The formation of the disaster chain requires certain conditions and a certain correlation between the disasters. The disaster chains induced by an earthquake can cause great destruction and costing many lives so it's very important to analyze their patterns and spatial distribution in order to prevent possible disaster consequences. A model of such a chain of disasters assumes also the calculation of occurrence probabilities of all disasters which could appear.

A possible disasters chain is presented in Figure 10.

According with scheme presented in Figure 10, total effects F, can be computed applying the following expression

$$F = f(s_i,\ x_i) + f(s_i,\ r_i) + f(x_i,\ y_i) + f(s_i,\ x_i,\ r_i) + f(s_i,\ x_i,\ y_i) + f(s_i,\ y_i,\ r_i) + f(s_i,\ r_i,\ y_i) \quad (1)$$

where, *Initial cause* $= f(s_i)$; *Direct effect on natural environment* $= f(s_i,\ x_i)$; *Direct effect on built environment* $f(s_i, r_i)$; *Secondary effects* $= f(x_i,\ y_i)$; *Effect 1* $= f(s_i,\ x_i,\ r_i)$; *Effect 2* $= f(s_i,\ x_i,\ y_i)$; *Effect 3* $= f(x_i,\ y_i,\ r_i)$; *Effect 4* $= f(s_i,\ r_i,\ y_i)$; s_i – *seismic movement;* x_i – *slope gradient, lithology, elevation;* r_i – *seismic response of the buildings, bridges, etc.;* y_i – *existing a flood prediction or warning system for fire*

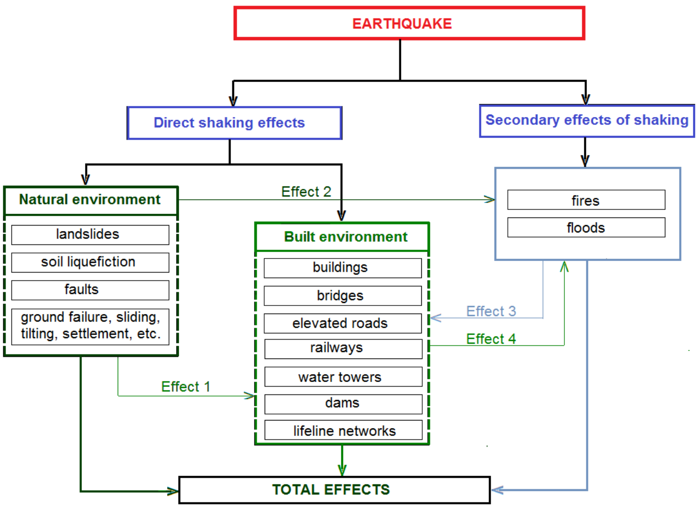

Figure10. A possible disasters chain, with a conditional probabilities analysis

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4. CONCLUSIONS

Buildings aren't the only things to fail under the stresses of seismic waves. Often unstable regions of hillsides or mountains fail. In addition to the obvious hazard posed by large landslides, even non-lethal slides can cause problems when they block highways they can be inconvenient or cause problems for emergency and rescue operations. There are maps for seismic risk, for landslide features which delineate potential slope-stability problem areas, in condition of earthquake incidence or not, all these would be important for a common disaster preparedness plan. Knowing more about the direct or indirect effects of earthquakes helps us to understand the mitigation steps that must be taken to protect a community from a seismic event.

The presented images in this study show the effects on the built environment as a result of the occurrence of earthquakes and they can be found in the civil engineering university programs, although most of them are taken from other earthquakes produced in recent decades.

Based on this study can draw lessons and adapted for Vrancea earthquake characteristics and then can be entered into the university curricula as design examples of works from civil engineering and built environmental protection field.

To remember is that if a future Vrancea earthquake, the data should be collected in a short time because they can lose over time by intervention to restore the environmental equilibrium.

Taking into account that the seismic events occur at intervals of a few decades, we can not afford to lose all the seismic data that can be used after in the research and design field, as well as educational material in the university.

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