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Societal and observational problems in earthquake risk assessments and their delivery to those most at risk

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ABSTRACT

Losses from earthquakes continue to rise despite increasingly sophisticated methods to estimate seismic risk throughout the world. This article discusses five specific reasons why this should be. Loss of life is most pronounced in the developing nations where three factors – poverty, corruption and ignorance – conspire to reduce the effective application of seismic resistant codes. A fourth reason is that in many developing nations the application of seismic resistant construction is inadvertently restricted to wealthy, or civil segments of the community, and is either unobtainable or irrelevant to the most vulnerable segment of the public — the owner/occupiers of substandard dwellings. A fifth flaw in current seismic hazard studies is that sophisticated methodologies to evaluate risk are inappropriate in regions where strain rates are low, and where historical data are short compared to the return time of damaging earthquakes. The scientific community has remained largely unaware of the importance of these impediments to the development and application of appropriate seismic resistant code, and is ill-equipped to address them.

1. Introduction

Despite more than a century of earthquake resistant engineering (Milne, 1891; Tobriner, 2006) and the development of increasingly sophisticated methods to estimate future risks from earthquakes, the past decade has been the most fatal ever if we ignore the 1556 Shanxi earthquake (Fig. 1). Since 2000 AD the world has lost 630,000 people. The cumulative cost of recent earthquakes has exceeded $300 billion, largely due to reconstruction costs in the industrial nations (Fig. 2). The disasters of the past decade may in fact foreshadow yet greater disasters should one or more of the world's megacities suffer a direct hit, similar to those that occurred in Port au Prince, Haiti, or Christchurch NZ.

Several articles have pursued the problems of seismic risks faced by the world's rising populations, concentrated, as they are, largely in cities whose populations have doubled every few decades in the past century (Bilham, 1988, 1995, 2009; Holzer and Savage, in press; Nichols and Beavers, 2008; Nishenko and Barton, 1996). In general these articles note that deaths and costs will continue to rise in the next century, but that extreme events will occur in the large cities of the developing nations, setting new records in terms of death tolls for single earthquakes and costs associated with reconstruction. An unprecedented death-toll exceeding 1 million is now possible in a single earthquake, should it occur near one of the world's megacities (Bilham, 2009).

At the root of the problem faced by the world's cities is that the population now targeted by earthquakes has increased by an order of magnitude in the recurrence interval of a single earthquake at a typical plate boundary. The former villages and towns that earthquakes have visited in the past are now cities and megacities, and the building stock of many of the world's megacities now include fragile buildings, assembled without adequate earthquake resistance.

A recent study by England and Jackson (2011) notes that the largest death toll from earthquakes results not so much from $M>8$ earthquakes, but from relatively modest earthquakes with magnitudes in the range of $7<Mw<7.5$, and specifically from earthquakes in plate interiors. The larger ($M>8$) plate boundary earthquakes in recent years have been expensive but have not resulted in significant loss of life if we exclude the effects of tsunami.

2. Corruption, ignorance and poverty

The building booms of the past four decades have caused the world's cities to increase their stock of buildings often without consideration of earthquake resistance. In many cases the number of buildings has been increased by an order of magnitude. Inevitably many of these buildings, especially in the developing nations, have used inferior materials and methods of assembly and a large number of these buildings are vulnerable to collapse in future earthquakes. It is only after an earthquake that we are likely to learn how poorly they were assembled. The absence of earthquake resistance in these buildings is attributable to several factors, but its prevalence is disappointing given that earthquake resistant construction methods have

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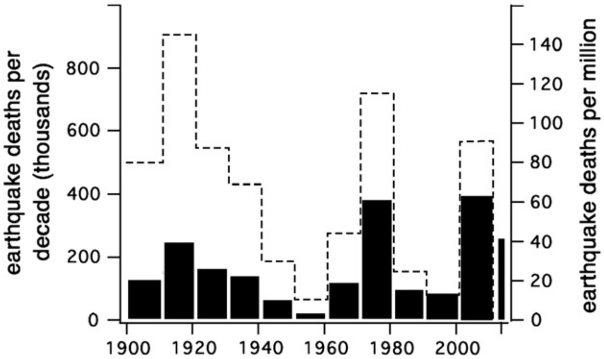

Fig. 1. Deaths per decade from earthquakes since 1900. The dashed line (right axis) is the decadal average normalized to mean global population for that decade.

been adopted by most governments, and implemented by engineers for more than a century.

One startling measure of our failure to prevent deaths from earthquakes is our ability to forecast the death toll anticipated from an earthquake within 30 min of its occurrence, long before news is available from the epicenter. Both the USGS (Wald et al., 2008) and WAPPMER (Wyss et al., 2006) have refined methods to incorporate the magnitude, depth and societal setting of an earthquake, and from these to estimate an empirically determined death-toll and injury-count using building fragility estimates of settlements in the epicentral region. The calculations can be undertaken in within 30 min of an earthquake occurring anywhere in the world, and typically they are accurate to within an order of magnitude of the true death toll.

That instant death toll estimates are routine is an admission that earthquake resistance is incomplete and is unavailable for most people especially in the developing nations. Why is this? Of the several factors responsible for the rising death-toll from earthquakes we can identify three within society that prevent the lessons of earthquake engineering from being universally applied: *corruption* in the building industry, an absence of earthquake *education*, and the prevalence of *poverty* in earthquake zones. These three factors often act together, such that their effects cannot easily be separated one from another.

Corruption in the building industry can lead to the issuance of illegal permits or unauthorized inspection certificates at all levels of the construction process. The building industry is one of the largest sectors of the global economy and is particularly alluring to ruthless individuals interested in maximizing profits at the expense of cutting corners in construction guidelines. The concept of "cover-up" is particularly appropriate in the building industry since it is possible to conceal unethical construction at every stage in assembly: inappropriate foundations can be hidden beneath walls, shoddily assembled steel work can be hidden beneath concrete, poorly mixed concrete can be hidden behind paint. The cost of correctly engineered construction means that large profits can be made by contractors willing to risk the use of substandard assembly methods, or weak materials. For specific examples of the processes of corruption the reader is referred to articles by Green (2005), Stansbury (2005), DelMonte and Papagni (2007), Bilham (2009) and Transparency International (2010).

Poverty is both responsible for people constructing buildings from inappropriate materials (adobe, weak concrete, or brittle steel), and for people renting accommodation in buildings assembled by corrupt contractors who have deliberately used inferior construction methods to maximize profits. The world's poor will often build in places that are considered undesirable by earthquake engineers — steep slopes, regions prone to liquefaction, regions prone to flooding and landslides etc.

Ignorance about the earthquake risks in a country can be responsible for home occupants not knowing that earthquake resistance should be considered in their choice of dwelling, but the absence of education is ultimately responsible for weaknesses at several levels of society. Children are not told how to mix concrete in school, these children in adulthood may remain ignorant of the earthquake history of their country because this is rarely taught in school curricula, the future leaders of society remain ignorant of earthquake risks and fail to impose laws on earthquake construction methods, contractors are unable to evaluate the importance of adhering to construction guidelines.

A simple correlation between corruption and *per-capita* income is evident in Fig. 3. Corruption is quantified by the *Transparency International* Corruption Index (see Ambraseys and Bilham, 2011 for the methods adopted). A large Corruption Index value means the country is considered less corrupt (10 means no corruption) and a small index value implies a more corrupt society. The existence of the approximately inverse relationship between income and the level of corruption is presumably linked to the availability and enforcement of regulations in wealthy countries, and if so, one might suspect that wealthy countries are less prone to earthquake disasters because earthquake resistant regulations are always applied. To some extent this is true, but this is clearly not the whole story. In Fig. 3 some countries (below the dashed least-squares regression line) are more corrupt that they should be given their income (e.g. Italy, Greece and Russia). The numerical placement of a country below or above the regression line defines an "expectation index", which can be interpreted as a measure of integrity, or national behavior.

If this "expectation index" is now plotted against national income, with the number of deaths from earthquakes in those countries as a third axis we find that 90% of all earthquake deaths in the past few decades have occurred in poor countries that are more corrupt than expected (Fig. 4). Using this metric, the PRC with an expectation index of +1 (= less corrupt than expected) is one of the few countries where corruption does not appear to contribute specifically to a large death toll. Whether or not corruption is considered the cause of the large number of deaths from earthquakes in the developing nations, an inescapable conclusion is that most deaths from earthquakes occur in countries that are poor.

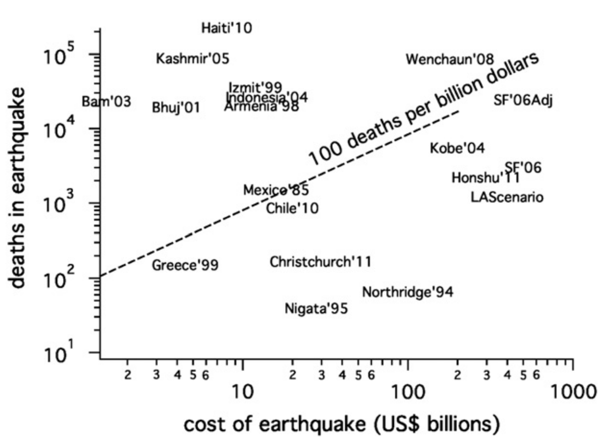

Fig. 2. The reconstruction cost of recent earthquakes is compared to the number of people killed in these earthquakes. The dashed line has a slope of 100 deaths per billion dollars and acts as a divide between countries with low per capita income from those that are wealthy.

3. A bias in the application of earthquake resistance

Thus far I have reviewed the possible contribution of three societal conditions to earthquake disasters: corruption, poverty and education. I now introduce a fourth parameter that amounts to a disconnection between earthquake engineering community and society. The ideas developed in this section are summarized schematically in Fig. 5. There exist few outlets for the application of the results of most state funded