Earthquake Safety of Housing in Low-Moderate Seismic Regions Worldwide
:: Taking Steps Against Huge Prevalent Risk

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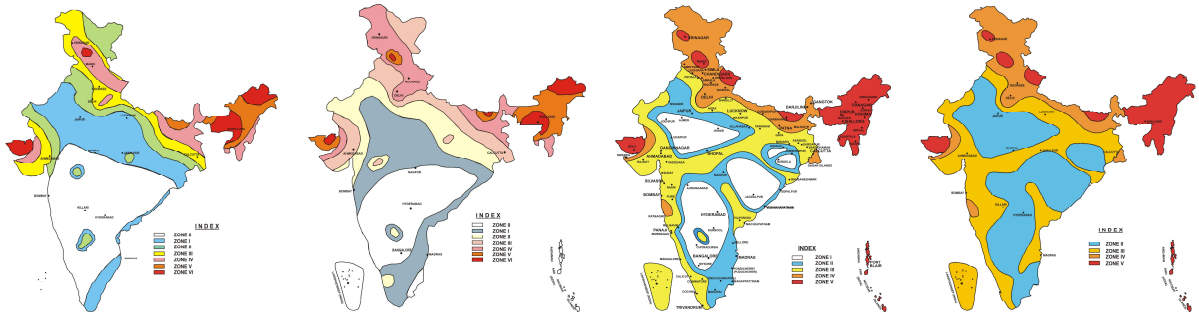
Abstract

World housing is a major contributor to losses, both life and property, during earthquakes. The challenge is grave in areas of low-moderate seismic hazard, because the perception of risk is low and therefore the preparedness is abysmally low or even absent. Many communities in such regions are far from recognizing the problem that safe housing is critical to their sustainable development. These communities need to be supported through a global initiative that is aimed at reducing earthquake risk to housing. Large amount of technical information on earthquake safe constructions is available within the world technical community and also in public domain (www.world-housing.net). But, this information currently is yet to reach communities that are (a) desirous of implementing housing projects, and (b) required to implement safer housing to reduce earthquake risk in future. Interface documents and interface working groups need to play a more proactive role across the world to reduce the earthquake risk to housing. These working groups will have specialized knowledge in providing technically sound and sustainable solutions on making earthquake safe houses across the world. The working groups need to work with governments of concerned countries and provide them guidance on implementing national initiatives on (a) recommended best practices for housing, (b) developing bank of region-specific designs of post-earthquake shelters, (c) cost-effective construction respecting vernacular constructions and locally available materials and skills, and (d) seismic retrofitting technologies for houses based on earthquake risk assessment to different housing types. The paper presents a plan for such a global initiative towards reducing earthquake risk to housing worldwide.

1. Low Seismic Region Experiences in India

The varying geology at different locations in the country implies that the likelihood of damaging earthquakes taking place at different locations is different. Thus, a seismic zone map is required to identify these regions. The seismic zone maps are revised from time to time (Figure 1) as more understanding is gained on the geology, the seismotectonics and the seismic activity in the country (Murty, 2005). The Indian Standards provided the first seismic zone map in 1962, which was later revised in 1966. The first seismic zone map (1962) of Independent India had seven seismic zones, namely *O, I, II, III, IV, V,* and *VI*; *O* was considered non-seismic zone (Figure 1a). The second map (1966) only moved the margins between these zones; the broad features were maintained (Figure 1b).



(a) **(b)** **(c)** **(d)**

Figure 1: Indian Seismic zone maps since 1962: (a) 1962 edition, (1b) 1966 edition, (c) 1984 version, and (d) 2002 edition (Redrawn based on IS:1893-1962, 1966, 1984 and 2002).

Based on the levels of intensities sustained during damaging earthquakes in the interim

period in regions considered to be low seismic areas (e.g., 1967 Koyna and 1969 Bhadrachalam Earthquakes), the 1984 version of the zone map subdivided India into five zones – I, II, III, IV and V (Figure 1c), by merging area under erstwhile zone O to that of zone *I*, and of zone *VI* to that of zone *V* (Table 1). Also, significant changes occurred in the peninsular region along the western and eastern coastal margin, where these 1967 and 1969 earthquakes occurred. The maximum Modified Mercalli (MM) intensity of seismic shaking expected in the resulting five zones were *V or less*, *VI*, *VII*, *VIII*, and *IX and higher*, respectively. Parts of Himalayan boundary in the north and northeast, and the Kachchh area in the west were classified as zone V.

Table 1: Indian Seismic zones reduced with each recent revision, owing to increased perception of seismic threat.

Year of Release of Zone Maps			
1962	*1966*	*1984*	*2002*
0	0		
I	I	I	
II	II	II	II
III	III	III	III
IV	IV	VI	IV
V	V	V	V
VI	VI		

Public uproar following the 1993 Killari (Maharashtra, Central India) earthquake that occurred in the erstwhile seismic zone I, with about 8,000 fatalities, again raised questions on the validity of the seismic zone map in peninsular India. The 2001 Bhuj earthquake in the most severe seismic zone V of the country caused about 13,805 fatalities. These two events in particular pressured the Bureau of Indian Standards to revise the seismic zone map again in 2002 (Figure 1d); it now has only four seismic zones – II, III, IV and V. The areas falling in seismic zone I in the 1970 version of the map are merged with those of seismic zone II. Also, the seismic zone map in the peninsular region has been modified. Madras now comes in seismic zone III as against in zone II in the 1970 version of the map. This 2002 seismic zone map is not the final word on the seismic hazard of the country, and hence there can be no sense of complacency in this regard.

2. Fatalities versus Economic Setback

In countries (like India) where seismic design is not practiced in general, each earthquake is expected to cause both large fatalities and huge economic setback. For instance, the M7.7 Bhuj earthquake in 2001 resulted in 13,805 deaths, over 167,000 injured, 215,255 houses collapsed and 928,369 houses damaged (Murty *et al*, 2005). The economic setback is slated at US$5 billion (Jain *et al*, 2002). Urbanization in India is rising at an alarming rate, but the built environment is not commensurate with the prevalent seismic hazard. And, with time, the disaster is expected to be bigger because effectively very few earthquake-resistant constructions are being built across the country even today. On the other hand, in countries where structural design has matured with formal processes in place, the losses are more in terms of contents of buildings. For instance, in Australia, even small events caused major economic set back, *e.g.*, the M5.6 Newcastle (NSW) earthquake of 28 December 1989 killed 13, but affected Aus$1.5 billion economic setback, and the M5.4 Ellalong (NSW) earthquake of 8 August 1994 resulted in Aus$40 million setback. With increasing urbanization and formalism in construction, the finishes (non-structural elements) are becoming increasingly expensive. But, such countries (with matured engineering practices) are very few across the world. A majority of countries fall into the former category. Even in Australia, where earthquakes are not ruled out in most of the land area (UWA, 2007), some basic earthquake resistant features may be built in, at least in housing construction.

3. Earthquake Safety of Houses Worldwide

One can broadly categorise countries into three sets, namely

- Group I countries (e.g., Japan, USA, and New Zealand) that have formal systems to regulate housing construction;
- Group II countries (e.g., India, and Nepal) that know what needs to be done but don't have collective wisdom to regulate housing construction; and
- Group III countries that are far from recognising that safe housing critical to sustainable development.

To present a scenario of Group II countries, the earthquake safety related experiences from India are recalled.

India became independent in 1947 and has about 1.1 billon population. India is a seismically active country and about ~60% India's land area is under the threat of moderate-to-severe seismic shaking. What is alarming is that even though construction standards exist, mechanisms are not in place to ensure their compliance. Even worse is the fact that the earthquake safety related subjects were not taught in any college until 2003; even after 2003, only the few government colleges in one of the states (namely Gujarat that experienced a major earthquake in 2001) mandated the inclusion of earthquake resistant design and construction in the curriculum. Added to this is the fact that the urban areas in India are growing at an alarming pace. They cities and towns are magnets for millions of citizens from rural India, and becoming attracting reservoirs of skills and engines for the productivity & economic growth of the country. By 2020, the urban areas are expected to account for 40% of the population and to contribute 70% of the GDP of the nation. Further, the already acute shortage of housing with more than 25 million units needed to be built annually for the next 10 years is further enhanced by the housing losses caused by the natural calamities. With water supply, sanitation and other urban infrastructure becoming scarce, legal and institutional reform have not kept pace with the population explosion. Regulations to control land use, occupancy and ownership are still at a not in place. With this as the backdrop, the real estate boom underway in the nation comes at a time where there are insufficient checks on quality of professional services rendered.

About 96.5% of India's construction is of non-engineered type with little or no engineering input, and the rest is made of reinforced concrete. Even this ~3.5% of so called engineered structures showed extreme vulnerability to earthquake shaking during the past two decades in the country. Unfortunately, the number of practicing professionals formally trained in earthquake safety related subjects is very small, and a number of projects are being implemented without sufficient expertise in earthquake resistant design and construction. Standards exist for earthquake-resistant design of structures but are not used in most building projects, sometimes because of lack of understanding amongst designers. Even the available standards have many loopholes and designers exploit them to reduce cost of construction. These strategies result in different levels of safety built into buildings. The local governments have insufficient checks on technical quality as the municipal offices not equipped to monitor technical quality; many of them do not have civil engineers to scrutinize the building designs. With no system in place for ensuring conformation, there is an indiscriminate issue of permits to construct. Scenarios similar to the above are prevalent in many countries in Group II and III. Hence, a major seismic safety initiative is required in all these countries.

3.1 The Earthquake Safety Problem

Earthquakes do not kill people; seismically unsafe buildings do. Primarily, the earthquake safety problem is a structural safety problem, and hence a technology problem. The key deficiency is in the practice & management of earthquake-resistant technology. Organisations, agencies, and/or individuals with no technology background that are steering these projects have been ineffective. Architects & Engineers are not playing a responsible role; they are offering sub-standard technical services leading to UNSAFE constructions.

In Group II and III countries, under a large earthquake, the loss of life is high and loss of housing is colossal. For instance, in the 2005 Kashmir (M7.6) Earthquake, the loss of life was over 87,000 and over 3.5 million persons were displaced. On the other hand, even in small earthquake, the loss of life is significant, and the loss of housing is staggering. For instance, in the 2006 Jogyakarta Indonesia (M6.3) Earthquake, the loss of life was around 6,000 and over 1.5 million persons were displaced. In these Group II & III countries, in every earthquake, housing sector is the most affected. For example, in the 2001 Bhuj India (M7.7) Earthquake, over 230,000 units had to be reconstructed and over 950,000 units strengthened. In addition, there are a number of challenges that these countries are still faced with. These include: assessing of damages to houses, undertaking seismic retrofit of damaged houses, constructing new earthquake-resistant houses (either replacement units or additional units).

3.2 International Experience from Past Earthquakes

In Group I countries, in the early 1900's, there were high human fatalities and high economic losses. But, by early 2000's, the human fatalities were systematically eliminated by improved construction standards; each stakeholder has been clarified of his/her role and thereby bringing in a community ownership of ensuring earthquake safety. Of course, the high economic loss due to damages/loss to the built environment is still a challenge for these countries. On the other hand, in Group II & III countries, the high human fatalities and high economic losses in early 1900's have not been corrected and even today they continue to have the same trend. Deaths due to building collapses are COMPLETELY AVOIDABLE, and this needs to be a major focus for Group II & III countries in all future projects.

Scientific knowledge is growing worldwide on how to protect houses during earthquakes. In countries that managed to convert this knowledge into practice, new structures have performed better than older ones, when codes are updated regularly. For instance, in the 1995 Kobe Earthquake (Japan), the buildings built by the older standard performed poorly, while those built as per the newer standard performed very well. On the contrary, in countries that are not updating the building standards, even the newer buildings are being built with technologies that are known to be creating unsafe buildings. Some countries in Asia come under this category.

Another vital lesson learnt from international experience is that existing structures built by the older standards need to be and can be successfully retrofitted. The process is expensive but is needed at least for public buildings. Also, such technologies must be disseminated freely to encourage private agencies to undertake seismic retrofitting projects.

In Group I countries, professionals with background in earthquake-resistant technology (e.g., Architects and Engineers) lead/steer earthquake safety implementation programs. Such an experience is not available in Group II & III countries, where often uninformed bureaucrats lead such activities; this trend needs to be reversed.

4. Strategies Towards Ensuring Earthquake Safety of Housing Worldwide

World housing is a major contributor to losses, both life and property, during earthquakes. Communities across the world can be grouped into three sets: (a) those that are far from recognizing the problem that safe housing is critical to their sustainable development, (b) those that know what needs to be done but don't have the collective wisdom to regulate housing constructions; and (c) those that have formal systems to regulate housing constructions. The latter two sets of communities need to be supported through a global initiative that is aimed at reducing earthquake risk to world housing.

4.1 The Proposal

Large amount of technical information on earthquake safe constructions is available within the technical community worldwide (Brzev & Greene, 2004, Brzev et al, 2004), and also in public domain (e.g., visit the *World Housing Encyclopedia* website www.world-housing.net). But, this information currently is yet to reach communities that are (a) desirous of implementing housing

projects, and (b) required to implement safer housing to reduce earthquake risk in future. Hence, interface documents and interface working groups across the world need to play a more proactive role to take the available know-how on making houses safe from earthquakes and thereby reduce the global earthquake risk to housing. These working groups will have specialized knowledge in providing technically sound and sustainable solutions on making earthquake safe houses across the world. The working groups need to work with governments of concerned countries and provide them guidance on implementing national initiatives on (a) recommended best practices for housing, (b) developing bank of region-specific designs of post-earthquake shelters, (c) cost-effective construction respecting vernacular constructions and locally available materials and skills, and (d) seismic retrofitting technologies for houses based on earthquake risk assessment to different housing types.

A *Global Housing Earthquake Safety Network* is required to formally plan strategies for transferring technical information on safety of houses during earthquake available worldwide (but within the technical communities) to earthquake-prone countries (Figure 2).

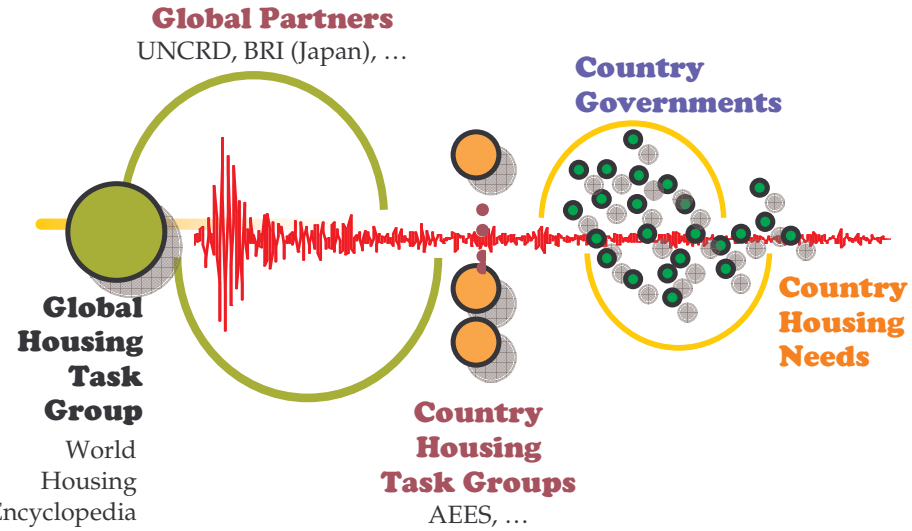


Figure 2: *Global Housing Earthquake Safety Network:* Global and country housing task groups need to be formed with professionals concerned about earthquake safety of houses. Interactions between these international and national task groups are essential to take advantage of know-how available globally, and thereby to empower local governments and communities to implement initiatives for ensuring earthquake safety of houses.

The players in such a global network would be:

- *a Global Housing Task Group*: It is an international network of professionals having specialised knowledge in earthquake resistant housing technologies and international experience. Fortunately, the *Editorial Board* of the *World Housing Encyclopedia (WHE)* has the requisite expertise and experience, and can volunteer to take responsibility of the *Global Housing Task Group*;
- *Global Housing Partners*: It is a network of international agencies with access to country governments particularly in countries with high seismic vulnerability of built environment and to international funding on development projects in such countries. UNDP, UNCRD and BRI (Japan) are some examples multi-lateral agencies with such a profile.
- *a Country Housing Task Group in each country*: It is a national network of professionals with good knowledge of issues related to national housing. This task group will champion housing earthquake safety needs in each country by liaisoning with *Global Housing Task Group* to receive advantage of globally available technology and by lobbying with governments, agencies & organisations to ensure earthquake safety in all housing projects implemented in the country. AEES can be an effective agency in Australia; and

- *a Country Housing Network in each country*: It is the collection of all governments in the country and of other building related professionals in the country from governmental and non-governmental agencies.

Significant synergy can be achieved through the above network, wherein the strengths of each group are being leveraged by the other, for a single cause - ensuring safer housing in each community worldwide.

4.2 Roles of Stakeholders

The key role of the *Global Housing Task Group* would be to collect best available worldwide knowledge on earthquake safety of housing and share with the *Country Housing Task Groups*. Each *Country Housing Task Group*, in turn, will work with governments and professionals within their countries to better inform and help improve the technical quality of house construction in each country. In brief, the key role of the *Country Housing Task Groups* is to run The *Last Technical Mile* for their country, guide their governments on minimum acceptable norms for ensuring earthquake safety in housing projects, and provide technical know-how to organisations & agencies that require specialised knowledge on earthquake safety. The *Country Housing Task Groups* would have to work on a number of fronts within the country. These fronts could include:

- *New Housing Projects:* Often, the number of such projects is too many and it will be difficult for the *Country Housing Task Groups* to participate in all of them. However, they can offer guidance to all projects by (i) providing policy and strategy, (ii) recommending best global practices, (iii) emphasising the required technology for ensuring cost-effective earthquake-resistant constructions, (iv) improving and preserving vernacular constructions, and (v) improvising on use of locally available materials and skills.
- *Seismic Retrofitting for different housing types:* Understandably, with limited manpower and limited resources (both technical and financial), each country will have a limited number of these projects. Often, funds are available for undertaking these projects, but the pressing need is technical solutions, and technical human resources. The *Country Housing Task Groups* can provide the necessary know-how for the same.
- *Re-building (replacement) housing:* Most governments are often under tremendous pressure to undertake reconstruction in a very short time frame. Hence, this activity is implemented under intense political pressure and instant solutions are being sought by governments to provide housing alternatives. The *Country Housing Task Groups* can do the needful by hand-holding governments in such projects.
- *Region-specific post-EQ shelter designs:* After most earthquakes (even smaller ones), making post-earthquake shelters is the first requirement in countries with high seismic vulnerability of the built environment. Most governments are often not prepared to meet this challenge after the event. The *Country Housing Task Groups* can participate with governments prior to the occurrence of earthquakes to plan and stockpile the technology, skill-manpower and raw material for construction of such shelters in a short period.

The *Global Housing Partners* have a critical role to play as a pressure group to impress upon the country governments to initiate housing projects with earthquake safety component embedded in them in the short run, and to develop national plans for ensuring earthquake safety of housing in the long-run. Since they also contribute financial resources to each of such countries, this would be a workable strategy as experienced from the past projects of such agencies that successfully implanted newer initiatives some of which were eventually internalized by the countries.

To get the above *Global Housing Earthquake Safety Network* underway, the *Global Housing Task Group* can take the first step. A document of best practices can be developed based on prevalent housing development strategies in countries that managed to reduce loss of life during earthquakes. Such a document should be circulated amongst governments, organisations and institutes related to housing safety in earthquake-affected countries. Such documents will provide clarity on (a) the approaches adopted for regulating construction of houses, (b) the classification of

houses into Engineered, Pre-engineered (or Prescriptive) & Non-Engineered Houses based on the level of seismic vulnerability of these housing types, (c) Licensing and Certification processes employed to control the quality of technical eservices rendered by architects, engineers, and artisans, and (d) possible construction technologies employed for housing along with their strengths and challenges.

5. Closing Comments

In many Group II countries, now there is strong will at highest political level. But, such a will is found wanting in the persons implementing housing safety projects. The buildings industry has become a major source for black money. In instances, even the underworld is involved. This adds a new constraint in some of these countries. Also, the technologists are way behind in providing the required support to the national needs. They are too few in number even in Group II & III countries with HIGH earthquake hazard, *e.g.,* India. Self-regulation of the quality of professional services is not seen as a need. This needs to be realized at the earliest.

Common man not yet taking ownership of the problem; this is also attributed to the very low awareness of prevalent earthquake risk. Clearly, there is a need to step up education at all levels from the technical education (involving Faculty Members and Curriculum) to Waking up communities (involving Awareness and Preparedness drives). Some modest beginnings have been made in these countries, but the general ethos needs a major impetus. Here, the Global Technical Community must step in to do some hand holding. The countries must set modest goals initially, with time targets, achieve them and build confidence. Earthquake safety agenda must be placed on a slow-upward ramp; it affects each one of us…

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