

# CREATING A SEISMICALLY RESILIENT SOCIETY

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### Abstract

This paper describes the first part of a study into what affects a community's ability to live with earthquakes. The basic premise of the study is that, important though they are, technical factors are not the only contributors to success in living with earthquakes, and many other factors (social, cultural, political) are also involved. The study so far has done nothing to suggest that this basic premise is false.

The study has been conducted to date by carrying out discussions with the author's friends and colleagues, and by a week spent in Kathmandu 6 months after the April 2015 Nepal earthquake, talking a wide variety of people involved in the earthquake response. Future plans include visits to Christchurch (New Zealand), Los Angeles and Santiago de Chile to carry out similar exercises there. Travel grants have been generously provided by three UK engineering organisations – SECED<sup>1</sup> and EEFIT<sup>2</sup> and the Institution of Civil Engineers R&D enabling fund<sup>3</sup>.

The eventual goal of the study is to assist earthquake engineers in thinking more clearly about how the broader, nontechnical context in which they operate might influence both the technical solutions they develop, and the means of reaching those solutions. The conclusions will be presented by the author at the Institution of Civil Engineers on  $31^{st}$  May 2017 as the  $16^{th}$  Mallet-Milne lecture, organised by SECED, and published as a special issue of the Bulletin of Earthquake Engineering.

Keywords: Earthquake risk reduction, Sendai Framework, Nepal, seismic standards

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## 1. Introduction

This paper gives a preliminary report of an ongoing study into what determines the degree of success with which countries in seismic regions cope with damaging earthquakes. The study starts from the premise that the technical insights of earthquake engineering (my main professional activity of the last 35 years), important though they are, will not by themselves provide the means for success in 'living with earthquakes'; in particular, the study will attempt to discover what recent damaging events have revealed about wider needs for providing a society with earthquake resilience. I spent a week in Kathmandu in the autumn of 2015, discussing these issues with professionals from a wide range of disciplines, and the intention is to repeat this in other regions with different characteristics, including New Zealand, California and Chile. Structural engineers are not best known for lifting their eyes beyond the immediate technical aspects of a problem; the goal of the study is to draw conclusions that might assist them in fitting into a wide picture and making their work more effective in contributing to the reduction of seismic risk. The final report will be presented in London on 31<sup>st</sup> May 2017 as the 16<sup>th</sup> Mallet Milne lecture, a biennial event organised by SECED, the British Branch of the IAEE.

## 2. What sets earthquakes apart from other natural hazards

In my textbook on earthquake engineering [1], I argued that four factors set earthquakes apart from other natural hazards. The factors were:

- i. They occur suddenly and without warning, with the potential to cause huge loss of life and destruction of wealth in a very short space of time.
- ii. The time interval between destructive earthquakes affecting a particular location is often very long, perhaps many generations.
- iii. An earthquake stresses much of the infrastructure that society depends on: superstructures and buried structures, building contents, transport and telecommunication systems, power supplies all are affected.
- iv. Other hazards often follow in the wake of an earthquake, notably landslides, fires and tsunamis.

The sudden, unpredictable and infrequent nature of earthquakes makes for special problems in dealing with them, as does the large number of aspects of human civilisation that they regularly damage. This creates very challenging technical problems, one of the reasons that earthquake engineering is such a fascinating discipline. However, it creates an unusually complex context within which these technical challenges have to be met. The aim of this study is to try and identify some implications for the work of earthquake engineers.

Another question is to consider is the priority that should earthquakes receive on the list of threats to humanity in general and to particular communities. A newspaper article by Kelly, [2], written soon after the Christchurch New Zealand earthquakes, considered the question thus:

"Since records began in 1843, 483 people are recorded as having died in New Zealand as a result of earthquakes. The vast majority of our earthquake fatalities – 447 people – resulted from the two terrible earthquakes in Christchurch in 2011 and Napier in 1931. By comparison, more than twice as many people (1125) died on [New Zealand] roads in the three years from 2008-10."

A natural reaction (from an engineer!) might be – "earthquake problem largely solved, concentrate now on road accidents". That probably would not be a response that would go down well among the citizens of Christchurch, still struggling in a number of respects to rebuild their lives and livelihoods. It also would be clearly inapplicable to Port-au-Prince, Haïti, after the tragic devastation of 2010. But if in 2009, you had asked citizens there what priority should be given earthquake protection, they might have stared at you in pitiful amazement: "To *earthquakes*! There hasn't been one here in my time, nor my parents' nor my grandparents'. We struggle every day with constant poverty, poor governance, regular devastation from hurricanes, inadequate schools, hospitals, roads, endemic crime and corruption, large numbers of aid workers telling us how to live our lives … don't talk to me about earthquakes, do something practical to improve my life".



Earthquakes and their effects are almost guaranteed to gain a great deal of media attention. The attention, at any rate in the west, tends to be moderated by the extent to which westerners have been affected. Thus, a few trekkers temporarily stranded in the Himalayas get more attention than the destruction of a mountainous Nepalese village, and holiday makers killed by a tsunami on a Thai beach get more coverage than tens of thousands killed by the same tsunami in Banda Aceh, Indonesia. Possibly, media coverage skews our response to threats to humanity, or possibly the coverage merely reflects what the general public thinks is important, and not what technical experts such as ourselves think. Maybe in the end there is no reliable metric to help us decide what effort should be devoted to living better with earthquakes; that doesn't mean it is not valuable to ask questions about it.

## 3. The role of technology in seismic disaster risk reduction

The 35 years since 1981, when I started practising as an earthquake engineer, have seen stunning technical advances in the discipline. Here is a personal list of some of those advances.

- Complex structural analyses which in 1980 were impracticable using the most powerful computers then available can now be quite easily performed on a laptop costing less than \$300.
- There is a much better understanding of how to achieve ductility in steel and concrete structures.
- Great advances have been made in seismology and seismic hazard assessment, driven partly by the increase in the number of accessible strong ground motion records from a few score to many thousands.
- The technology of seismic isolation, still fresh in 1981, is now widely adopted, and has been proved by a number of large and great earthquakes as highly successful.
- Other technologies also appear to have great promise, including added dampers, unbonded prestressed tendons, and semi-active control.
- New construction materials are having an impact, including high strength and fibre reinforced concrete, and new forms of timber, including cross laminated timber (CLT).

Technology has also played a part in facilitating the response to an earthquake, particularly in the early chaotic stages; another personal list of significant developments follows.

- Analysis of aerial images from satellites, aircraft and drones, perhaps making use of crowd sourcing methods via the Internet, make assessment of damage much more rapid.
- Mobile telecommunications and web-based means of information exchange, such as social media, have revolutionised the ability of players to keep informed and in touch with other.
- Rapid publication of estimates, freely accessible on the Internet, of the likely extent and severity of damage have assisted response planning.
- Development of advance warning systems for the arrival of seismic waves has allowed rapid shutdown of vulnerable systems.

Recent earthquakes disasters might have been far worse without these developments. And yet those same recent earthquakes indicate that by themselves, these advances are not sufficient. The catastrophe in Haïti in 2010 occurred in a country on the doorstep of the most powerful nation on earth, where the presence of foreign aid organisations was already exceptionally large. An undamaged (and seismically isolated) US embassy in the midst of a devastated city, full of destroyed government offices and a large but totally unprepared and shocked foreign aid community form potent symbols of the problem. Technology and preparedness worked in many ways splendidly well in Christchurch New Zealand the following year. Yet this country, a contributor out of all proportion to its size to the development of so many aspects of the modern practice of earthquake engineering, was left with a devastated central business district, and a general (and justified) feeling among the citizens of



Christchurch that things had gone badly wrong. I firmly believe that addressing the problem of how to live with earthquakes requires more than a reliance on technological fixes.

Widening the debate beyond the development and use of engineering artefacts such as seismic isolation bearings or the Internet, it is worth considering whether there are approaches drawn from other disciplines that earthquakes engineers could make use of. Spence [3] has suggested that the response of the national and international community to problems of epidemic and endemic disease might have lessons for our field. Could the earthquake problem be 'solved' in the way that could be claimed for smallpox, polio and ebola? Disease clearly has many characteristics distinct from those listed above for earthquakes. However, there is value in an approach co-ordinated through UN agencies, as discussed in the next section, and maybe the response to the recent ebola epidemic in Sierra Leone could yield useful lessons. The importance of community behaviour in overcoming ebola, particularly within the context of a society recovering from a terrible civil war, and the issue of trust (or otherwise) of experts were important in Sierra Leone in the medical context and also (as discussed later) in seismic ones, too. These are issues worth further study.

## 4. UN initiatives on disaster risk reduction

### 4.1 The Sendai Framework

UN (United Nations) based efforts to promote an international approach to disaster risk reduction date back to a predecessor of the 2017 Santiago conference, namely the Eighth World Conference on Earthquake Engineering, which took place in San Francisco in 1984. At this conference, the eminent seismologist Frank Press proposed [4] that the 1990's should be designated by the UN as the International Decade for Natural Hazard (later Disaster) Reduction. In his Mallet Milne lecture of 1989 entitled 'Coping with natural hazards' [5], George Housner, another very eminent earthquake engineer from the United States, reported how the UN had adopted the proposal, requesting every member nation to help implement it. The IDNDR culminated in the Yokohama Accord and was followed by further UN initiatives: the Hyogo Framework and, most recently, the Sendai Framework [6]. This latest initiative defines a strategy for the reduction of both manmade and natural hazards, including, of course, earthquakes. The strategy sets seven global targets for disaster risk reduction, to be achieved by 2030; they are reproduced in the Appendix to this paper. The targets concern a reduction in the deaths and human impact of disasters, a reduction in infrastructure and wider economic losses due to disasters, an increase in the number of countries which have prepared national and local risk reduction strategies and improving the reach of early warning systems and disaster risk information.

### 4.2 Engineers' potential contribution to the Sendai Framework

The scope of the Framework is very broad, covering many aspects of disaster risk reduction beyond those normally considered by engineers, and being primarily directed at the government departments of the 193 countries signing the Framework agreement. The Framework document [6] notes that "there has to be a broader and a more people-centred preventive approach to disaster risk.", and these 'soft', people-centred issues are everywhere emphasised. Thus, stakeholders whose interests must be firmly borne in mind in the design and implementation of policies are listed as including "women, children and youth, persons with disabilities, poor people, migrants, indigenous peoples, volunteers, the community of practitioners and older persons." Success in achieving its goals of disaster risk reduction requires "....the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures....". This is a long list of different factors, in which that relating to engineering comes near the end. Housner's Mallet Milne lecture of 1989 [5] setting out a framework for the earlier IDNDR is in sharp contrast; certainly, it recognised that activities other than technical ones would be needed to achieve the IDNDR's goals, citing the importance of public awareness activities, studies in economics, studying culturally based reactions to disasters, and the involvement of planners and financiers. But these are essentially passing references, and there is little doubt that Housner considered the engineer's role as pivotal to disaster risk reduction.



It is not clear whether *the community of practitioners* referred to by the Framework in the list of stakeholders quoted above includes earthquake engineers, but one would hope this is the case. The Framework strategy certainly refers to the need for technical and scientific measures to reduce risk; it recognises that "a multi hazard approach is needed, with science-based and traditional approaches both having roles to play" which, while hardly a ringing endorsement of the crucial role that engineers might play in reducing the consequences of natural hazards, at least implies they could make a contribution. However, the role of engineers is not much emphasised or discussed, and the term "engineer" does not appear once in the Framework's strategy document [6]. Is this because in a broad strategy document, the sordid details of how to implement policies are not appropriate ("leave it to the engineers, they'll do the necessary if we tell them what's required")? Or is it because policy makers meeting in a grand hotel in Sendai are out of touch with the realities of life in the field, have little idea that engineers might play a role in disaster risk reduction and, as is the case for most of us engineers, are too absorbed in the importance of their own field to recognise the contribution of others? Jo da Silva has written [7]:

"At a strategic level, engineers are notably absent amongst the staff of key decision makers (the World Bank, the UN, bi-lateral donors, governments etc.). Nor do these organisations typically engage experienced engineers or engineering firms as consultants in the early stages of recovery and reconstruction, when their experience is most needed in order to prioritise reinstatement of critical infrastructure, and help develop a road-map for recovery. In the event of a pandemic or a terrorist bomb attack with numerous human casualties, failure to consult medical professionals would be unthinkable. It therefore seems absurd that engineers are not engaged in disasters where there has been considerable loss of infrastructure and thus basic services, and particularly so in an urban context."

#### 4.3 Earthquake engineers and the context they work in

Traditionally, and to the detriment of humanity in disaster-prone areas, engineers have too easily dismissed social scientists and others involved in disciplines other than the 'hard' technical ones as woolly thinkers who should leave the field to those who do the real work of constructing things. We engineers have to become less insular and recognise the broader social, economic and (even!) political context in which we operate, perhaps particularly so in the field of disaster risk reduction. But we also have work to do in persuading other 'stakeholders' of the value of our potential contribution; those we need to persuade are not just decision makers but also the people who potentially or actually suffer from the effects of earthquakes. In a study of informal settlements in Istanbul, made soon after the devastating Turkish earthquakes of 1999, Rebekah Green reports [8] that migrant workers who had built unauthorised housing in the settlements were well aware of the seismic risks. However, they did not turn to professional engineers and contractors for help. This was not just because of the considerable extra cost involved; about half of those interviewed believed that such professional help would not improve seismic safety and that professional engineers were 'profiteers' who charged exorbitant fees. However, the engineering assessment of the unauthorised housing that resulted came to the conclusion that they were seismically very vulnerable, as a result of poor design, detailing, construction methods and materials. The climate of mistrust for technical people spreads much wider than to earthquake engineers; technical experts bringing unwelcome news are widely disbelieved, while when things do go wrong, they are widely blamed. Thus, the overwhelming technical evidence that global warming is occurring and is anthropogenic is in some quarters still dismissed as scare-mongering, while recent flooding in the UK was widely (and in my view unfairly) blamed on incompetent and/or parsimonious engineers failing to carry out routine dredging of rivers [9]. Unfortunately, successful flood defences, and also earthquake resistance designs, are much less likely to hit the headlines. The image problem that engineers have, so long discussed, has real consequences for our ability to help societies live with earthquakes.

Ideally, all the stakeholders and contributors to earthquake disaster risk reduction should respect each other and work harmoniously together to reach solutions. In practice, this may not be so easy. One reason is that experts in any field find it hard to admit they are wrong, and earthquake engineers are no exception. But they are not infallible. The section of Royal Commission report on the Christchurch earthquakes [10] on the collapse of the Pyne Gould building, identifies a number of separate occasions where well qualified engineers



failed to identify weaknesses in that building, which subsequently collapsed with considerable loss of life. Perhaps there is a tendency for engineering experts to be too obsessed with detail to see the bigger picture and spot flaws which others (in my experience, often architects!) pick up straightaway.

Moreover, engineers may suffer from another potential weakness, described by Randolph Langenbach [11]. It concerns the way we are educated. Modern steel and concrete structures are well suited to computer methods of analysis, and this is what structural engineers are trained to do. By contrast, traditional methods of building construction may involve rather complex mixtures of masonry, timber and soil which are not really suitable for this type of analysis. Because we earthquake engineers don't know how to analyse these vernacular buildings, we too easily dismiss them all as inherently highly vulnerable. In many cases, of course, they are; however, as Langenbach [11] shows, a number of traditional forms of construction have evolved which perform very well under earthquake loading. It is important to be open to the possibility that our specialist training may in some cases act as a blinker, and that others – even architects or Kashmiri peasants – might have insights into earthquake resistant design that we 'experts' lack.

## 5. Political aspects and the limitations imposed by political systems

Clearly, the effectiveness of its national and local government to plan, implement and monitor measures promoting earthquake preparedness and resilience are crucial to a country's ability to live successfully with earthquakes. Emergency response plans, public training exercises, land use planning, building controls, strengthening of existing infrastructure and provision of new resilient infrastructure are all vital. Generally, engineers play a part in all these activities, but not a leading role. How do engineers need to adapt their role under circumstances where the civil authorities are weak or non-existent? Is the government role more effective when legitimised by consensual, democratic political processes, and if so, how should engineers respond when that process rejects the rational, evidence based solutions they propose? Or is it better within this context to have an authoritarian, technocratic system of government, which imposes the 'best' solutions? As is clear from Rebekah Green's study [8] cited earlier of informal building in Istanbul, there are issues in balancing the needs of different sectors of society – in this case, those of poor migrant workers for immediate shelter against wider concerns for seismic safety in a great international city – in which engineers will inevitably find themselves involved.

### 5. The development of technical communities

This paper has presented arguments that the wider community within which engineers operate is important for their effectiveness, but the way in which engineers organise their own specialist communities is important too. Christchurch New Zealand had access to a lively earthquake engineering society, a university which was internationally leading in earthquake engineering and a widely respected (and applied) seismic standard. Port-au-Prince in Haïti had none of these things. Although there was great suffering in Christchurch when the earthquake struck, it was nowhere near the scale in Port-au-Prince, and the efforts, dating back half a century, of New Zealand earthquake engineers to develop a very strong community surely played a key role in this difference. Sharing knowledge and ideas, and fostering the development of strong communities of earthquake engineers by bringing them together from all over the world – this of course is fundamental to the aims of the IAEE which organises this conference. But perhaps we have been insufficiently sensitive to the ways in which wider cultural and political factors influence the development of technical communities. Perhaps there is more we could do as an international community to help national specialist communities develop.

### 6. Engineering standards and the spread of knowledge

The hard pressed structural engineer working to meet the latest deadlines for the design of a building may be tempted to believe that successful earthquake resistant design is merely a matter of ensuring compliance with the applicable seismic standard. Of course, there are many examples of code compliant structures which have performed dreadfully in earthquakes; steel moment frame connection details and the Northridge California earthquake of 1995 come immediately to mind. But this does not detract from the value of engineering

standards; they are vital means of spreading the consensus of current knowledge about best practice. The problem comes when they are seen as a set of rules which have to be obeyed by the structures themselves as well as engineers, rather than as a (possibly fallible) consensus on minimum standards to ensure satisfactory earthquake performance. A key finding of the Weightman report [12] into the disaster at the Fukushima nuclear power station, written by Her Majesty's Chief Inspector of the UK's Nuclear Installations at that time, was that the regulatory system which governed Japanese nuclear power stations relied too much on prescriptive measures. Weightman advocated a system in which performance standards are set rather than specifying prescriptive rules which have to be complied with. In Weightman's preferred solution, how nuclear power plant operators choose to demonstrate to the regulator that the required performance is achieved is left largely up to them; they can choose the means but not the ends. Of course, tried and tested means have their place in standards, because they save the designer time and should give some assurance of good performance. Also, the resulting calculations are much easier for others to check! However, ultimately it is the ends that are important, and the means given in codes may not achieve them in all circumstances.

Another issue for seismic standards concerns their level of complexity. Is the same level of sophistication required for a skyscraper in Los Angeles as for a two storey house in Nepal? Clearly, the answer is no, and so standards should self-evidently be context specific. But is a standard that has some chance of being usable in mountainous areas of Nepal better than one too sophisticated to be of use, even if the simple standard provides a level of protection much lower than would be acceptable in Los Angeles? In simple terms, is aiming to improve earthquake protection from 10% to 50% acceptable if the alternative of aiming for 90% protection results in a set of rules that are unlikely to be applied in practice? And if it does, would a rural population after a damaging earthquake accept that adoption of the simple rules has greatly improved matters, even if some code compliant buildings performed rather badly and killed or injured their inhabitants? As mentioned in the next section, these are live issues for Nepal, where the seismic code was drawn up with the needs of rural users very firmly in mind.

### 6. Some findings and observations from Kathmandu

### 6.1 A shortage of fuel in Kathmandu

In October 2015, 6 months after a magnitude 7.8  $M_w$  earthquake had killed 8,000 people in the country and caused much ongoing suffering and disruption, I visited Kathmandu, capital of Nepal. The main damage had occurred outside the capital, and it was easy to spend time travelling through it without noticing any signs of earthquake damage. However, the most striking finding was that the main current concern of those working and living in Kathmandu was not earthquake recovery but how difficult it was to get hold of fuel for their cars. Significantly, this had nothing to do with earthquake damage of petrochemical facilities, but it was directly linked to the earthquake, as is now explained.

In the period 1996 to 2006, there was a bloody civil war in Nepal, which killed 15,000 people (nearly twice the number in the 2015 earthquake) and left many deep scars. The road to establishing a civil administration required the adoption of a new constitution, and after many years of debate, it was only the shock of the 2015 earthquake which persuaded all parties, for the sake of national survival, to reach a constitutional settlement. Interestingly, this had been drawn up to exploit the valuable water resources of the country and so one wonders whether civil engineers had been involved. Himalayan snow melts provide water for irrigation and hydroelectric power; therefore, the provincial boundaries of the new constitution were drawn up to maximise this resource. Water flows perpendicular to contours and so the provincial boundaries did the same, running north to south down from the Himalayan mountains to the plains along the Indian border.

However, that is not the way the human divisions work in Nepal; mountain people are very different from those of the plains, so the cultural and ethnic boundaries run *along* the contours in an east-west direction. As a result, the new constitution was not popular with the people of the plains, who found themselves in the minority in all the new provinces, rather having a province drawn up on ethnic lines in which they could dominate. They demanded a change to the constitution, and with support from their (ethnically similar) neighbours in India, imposed a blockade at the Nepalese-Indian border crossing which formed the only effective land route for supplies into Kathmandu. The result was a severe shortage of fuel in Kathmandu which was so evident during my visit.





Thus a direct link existed between the constitutional settlement after a devastating civil war, the 2015 earthquake and the fuel shortage in the capital that was causing its major headache when I arrived. If nothing else, this suggests that earthquake engineers, at any rate in Nepal, cannot work in a technical vacuum, free from cultural, social and political influence.

#### 6.2 Some observations from Kathmandu about living with earthquakes

My reason for visiting Nepal was to conduct the first stage of the enquiry described in this paper. Over the period of a week, I talked to about two dozen professionals in a number of different fields – half Nepalese and half expatriates – about what lessons might be drawn from the event for how to live with earthquakes. In future stages of the enquiry, I hope to conduct similar exercises in Christchurch New Zealand, Santiago de Chile and Los Angeles. Some pointers from my discussions in Kathmandu are as follows

#### 6.2.1 National versus community response

There was a widespread feeling that the civil authorities had not dealt as effectively as they might with the immediate aftermath of the earthquake. Perhaps this is not surprising, given the political uncertainty at the time and some impressive efforts by central government departments to record damage and also design and supply prefabricated housing is, under the circumstances, an impressive achievement. But it was widely felt that the solution, at any rate to earthquake resilience in the remote mountainous and rural areas that had been most damaged. lay not in relying on central government but in the development of community based capability and responses. A remarkable development in Nepal has been the establishment of the Nepalese Society for Earthquake Technology, NSET, founded in 1993 by Amod Dixit and still led by him. Working at a community level has been fundamental to NSET's approach, with firstly community awareness and secondly human capacity (particularly the availability of local craftsman) seen as the two essential pillars of earthquake resilience without which the third pillar, namely governance – i.e. ensuring that regulations are followed – will not be effective.

NSET had been in existence for over 20 years when the 2015 earthquake struck. How effective was it proved to be under this test? Community based disaster risk management did work in Nepal in 2015, I was told, but government did not engage with it, because it didn't fit into the normal government channels. NSET's own assessment was one of partial success; their programmes had made a real difference in the limited number of local areas where it had a strong presence, particularly for the seismic retrofit of schools. It would be valuable to have some independent assessment of NSET's effect. The importance of an organisation with a strong technical base combined with deep cultural understanding and knowledge of the area in which it works seems beyond doubt, and NSET's value may lie as much in its function as a model for other countries, as in what it has actually achieved for the citizens of Nepal. One clear lesson from 2015 is that the time needed to develop such organisations to the point where they have a pervasive influence must be measured in decades rather than years.

#### 6.2.2 The importance of local skills and of cultural behaviour

A significant challenge to reconstruction after the earthquake, and a barrier to achieving a 'build back better' result (dismissed by one knowledgeable local actor as just a slogan) was reported as the lack of good carpenters and masons at village level. Many Nepalese with good construction skills have gone to work in Dohar and other parts of the Middle East, and their foreign remittances are vital to the Nepalese economy. At village level, young workers without such skills tend to seek work by internal migration to the cities, which adds to the problem. What is to be done? Training programmes are of course part of the answer, but one observation was that the effort and resource put into training for the construction industry was in inverse proportion to need. Thus, far more skilled construction workers are required than qualified engineers and architects, but most of the money goes into providing higher education facilities.

Another interesting observation came from an architect involved in recovery programmes in Nepal after the 2015 earthquake, in Bhuj after the 2001 Gujarat earthquake and in southern India after the tsunami of 2004. The Gujaratis, according to this witness, are enterprising risk takers, geared to getting things done. Therefore, when the cement promised for earthquake reconstruction by the Indian government didn't arrive, they procured it themselves; 'build back now' was much more important to them than 'build back better' and reconstruction



proceeded quickly, albeit with somewhat dubious qualities of seismic resistance. The southern Indians, by contrast, were much more concerned with achieving social justice and welfare, and reconstruction proceeded far more slowly while these issues were resolved; however, proofing against future tsunami losses appeared to be quite successful. The point here is that it is vital to understand the social and cultural setting if reconstruction is to be successful. "Earthquakes are a political, social and cultural problem – not a technical one" I was told, and while as an engineer I don't wholly accept that statement, it has considerable force.

### 6.2.3 The comparative resilience of Nepalese mountain dwellers and Los Angelinos

Life is always difficult for Nepalese living in rural areas, and for them, other aspects of survival may take precedence over provision of earthquake resistant buildings. But the very difficulties of everyday life in the Himalayas make them likely to be better at coping with exceptional post-earthquake conditions than the inhabitants of Los Angeles. Earthquake resilience therefore depends not just on the physical resilience of infrastructure and the built environment, but on the cultural make up of the communities involved.

#### 6.2.4 The Nepalese code

Of course, there is always a need to examine whether a local code needs adjustment after a damaging earthquake and this was recognised in Nepal. The Nepalese code is unusual in that it gives prominence to basic rules of thumb for simple rural buildings. These basic rules are intended to give partial rather than full seismic protection, in the hope that they might be more widely understood and adopted than more complex and comprehensive ones. The consensus seemed to be that the simple rules should stay in the code, although it is not clear the extent to which they had been effective in reducing damage in 2015. There was felt to be a need for new rules to cover high rise construction in the capital, a relatively recent phenomenon not envisaged when the code was drawn up a quarter of a century ago. However, failings in the building code were not seen as contributing significantly to the scale of the disaster.

#### 6.2.5 Resilience of the hospital sector in Kathmandu

Flagship Project 1 of the Nepal Risk Reduction Consortium was set up to address seismic risk reduction in schools and hospitals. The Consortium consists of a number of international and national agencies, co-ordinated by the UN, and had been in existence for about 5 years at the time of the 2015 earthquake. The UK government's Department for International Development undertook to fund some projects in hospital risk reduction, although these were not complete at the time of the earthquake. The effectiveness of the Consortium's programme in the light of Nepal's ability to cope with the 2015 earthquake merits study, and this will be pursued as part of the project reported here, particularly in relation to hospitals. Are large international consortia the best way to channel hundreds of millions of dollars into improving seismic resistance, or do they prove to be too remote and bureaucratic to make a real difference? One of my interviewees told me that foreign aid meant that money was not the main issue for the recovery phase in Nepal, but that the political problems of coordination and organisation were. Perhaps smaller NGOs working at a community level can bypass these problems in a way that big consortia find very difficult.

One part of the infrastructure which survived the earthquake well was the mobile phone network, which continued to operate satisfactorily immediately after the earthquake. This had significant implications for the hospital sector. A senior doctor responsible for running the largest Kathmandu hospital told me that the ability to communicate and coordinate by mobile with colleagues in other hospitals was vital to maintaining the capital's hospital system at an acceptable level in the post-earthquake period. This is a clear achievement resulting from a recent technological advance (albeit not one for which structural engineers had the primary responsibility) and one that apparently carries no cultural or social baggage. The reasons why the mobile network in this case withstood the earthquake would be well worth investigating further.

It is interesting to note that one of the biggest problems of the doctor I interviewed did not arise from technical failures arising from the earthquake; rather, it was having to cope with the many foreign doctors who wanted to come and help. There were far more than he needed, except those with the expertise in really short supply, which was trauma surgery.



6.2.6 Predicted earthquake losses in Kathmandu

In 2001, a report for the UN Centre for Regional Development [13] estimated that Kathmandu was the city with the highest vulnerability to earthquakes in the world. It was estimated that the 475 year return period earthquake motions would cause around 70,000 deaths. Similar warnings of Kathmandu's seismic vulnerability were published elsewhere. There was good reason to suppose that a large earthquake would cause a lot of damage. The recent rapid growth in the city has resulted in much sub-standard construction. Moreover, rescue efforts would be hampered by a number of factors: the narrow streets of many parts of the city, the limited overland supply routes, the small capacity and potential vulnerability of the airport and the possibility of widespread liquefaction.

In the event, the 2015 earthquake caused 8,000 deaths, mainly outside the capital, much lower than feared. The earthquake was centred well to the north and the focus was relatively deep, so the intensity of shaking in Kathmandu may have been considerably less than was assumed in the 2001 report referred to previously. The previous large earthquake of 1934 was shallower and to the south of the city and was likely to have caused much more damaging motions. If there were a repeat of the 1934 event, a possibility that seismologists predict as likely sometime in the future, then the level of shaking in Kathmandu might be much higher, and the consequences much more serious. However, in the meantime, there appeared to be a widespread perception in Kathmandu that there is on the whole not too much cause for concern about the built environment, and that the experts predicting disaster were exaggerating its scale. Consequentially, there is a fear that complacency has set in and the drive to improve earthquake resilience in Kathmandu may weaken as a result.

## 7. Concluding remarks

The paper was written well before the end of this study of how technical and non-technical factors interrelate to produce success or failure in living with earthquakes. At this stage, many more questions have been raised than conclusions reached. The ultimate aim is to assist earthquake engineers in thinking more clearly about how the context in which they operate should influence the technical solutions that it is our job to develop, and the ways in which we go about doing so. My research so far has done nothing to dissuade me of the view that to be fully effective, our profession must somehow lift itself out of its technical comfort zone and consider the broad context of society in which it operates.

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### **Appendix – The global targets of the United Nation's Sendai Framework [6]**

- (a) Substantially reduce global disaster mortality by 2030, aiming to lower the average per 100,000 global mortality rate in the decade 2020–2030 compared to the period 2005–2015;
- (b) Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 in the decade 2020–2030 compared to the period 2005–2015;
- (c) Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030;
- (d) Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030;
- (e) Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020;
- (f) Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of the present Framework by 2030;
- (g) Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030.