Discussion of some issues that may be of interest to Canterbury Earthquakes Royal Commission – E L Blaikie (ME (civil), CPEng.)

1.0 Acceptable Risk (i.e. meaning of the term "safe" in engineering)

In our society tradeoff between perceived life safety risk and perceived benefits is well established. The most obvious example is our motor cars where we pay a heavy price (approx. 300 lives a year) for the convenience of driving our motor cars. Every time we get behind the wheel and turn the key we consciously or unconsciously endorse this tradeoff – and we all do it. When the life safety risk and perceived benefits accrue to the same individual there does not seem to be a problem accepting the tradeoff. However, when the perceived life safety risk accrues to one party and the perceived benefits to another party the tradeoff is usually considered much less acceptable.

When Engineers use the term "safe" they generally use it to convey the same meaning as "acceptable risk" which is dependent on the particular circumstances and the tradeoffs involved. However, when the public use the term "safe" they often use it to convey the absence of risk. Consequently substituting "acceptable risk" for "safe" would have quite different connotations for the public in most situations. For example, post-earthquake "Building Acceptable Risk Assessment " would have quite different connotations for the public when compared with post-earthquake "Building Safety Evaluation". On the other hand these two terms should have much the same meaning for Engineers.

Engineers /seismologists /geophysicists have, with much uncertainty, something to say about earthquake risk (the likelihood and consequences of earthquakes) but can have nothing to say about acceptable risk. Acceptable risk is a subjective value judgment and I believe there is nothing in the training or experience of an Engineer that gives him/her any more insight into what constitutes acceptable risk than the insight available to any other informed citizen.

In my opinion, acceptable risk should only be determined by those exposed to the risk and, where mitigation is possible, those who will need to pay to reduce it. For buildings exposed to earthquakes, these two parties are the building occupants and the building owner. For the purposes of this discussion those in adjacent buildings and who pass by the building and are exposed to the risk, particularity in the case of URM buildings, are included as a component of the building occupants.

However, if the building owners are asked the question "what level of risk is acceptable for the building occupants so that I can continue to collect the rent, pay the mortgage and make a living?" they may respond "as much as it takes". If the building occupier is asked "how much should the building owner pay to reduce the risk to an acceptable level?" they may respond as "as much as it takes to reduce it to zero".

This basic conflict of interests, perhaps exaggerated here to make the point, inevitably makes the determination of acceptable risk a political issue as the conflicting interests of these two groups requires arbitration.

If an engineer is asked to determine if a building is safe in a particular circumstance he/she can only make an evaluation of safety if the acceptable risk for the conditions is defined by some pre-determined standard.

For the design of new buildings it is necessary to have a pre-determined standard that defines acceptable risk. However, for existing buildings it may be acceptable, in some circumstance, for the Engineer (and others) to define the risk and leave it to those exposed to the risk to determine what is the acceptable risk.

2.0 Guidance for engineers (and owners) assessing the seismic performance of buildings in Christchurch issued by the DBH (MoBIE) - June 2012.

Part of this DBH advice relates to who should determine whether a building in Christchurch should be occupied. This advice appears to me, in light of the above discussion on who should determine acceptable risk, to be philosophically flawed.

The essence of the DBH advice appears to be, if CERA or CCC do not require building owners to strengthen their buildings, it is up to the building owner to determine what is acceptable risks for those exposed to the life safety risk associated with their building in future earthquakes. In the Guidelines the role of those exposed to the risk in determining acceptable risk appears to have been only considered as an afterthought.

Although the Guidelines are directed at the current Christchurch situation, in this respect, they have general application across the country.

Since the Christchurch earthquakes, I am aware for the first time in my 40 year career, that market forces are playing a significant role in reducing seismic risk in New Zealand's existing buildings. This indicates to me that principals similar to "disclosure" and "informed consent" could play a much greater role in determining acceptable earthquake risk for existing buildings in New Zealand.

The equivalent of "disclosure" and "informed consent" could be achieved if there was a statutory requirement for building owners to supply all information that they hold relating to a building's earthquake safety to the Local Authority (LA) and for this information to be published on the LA's publically assessable website.

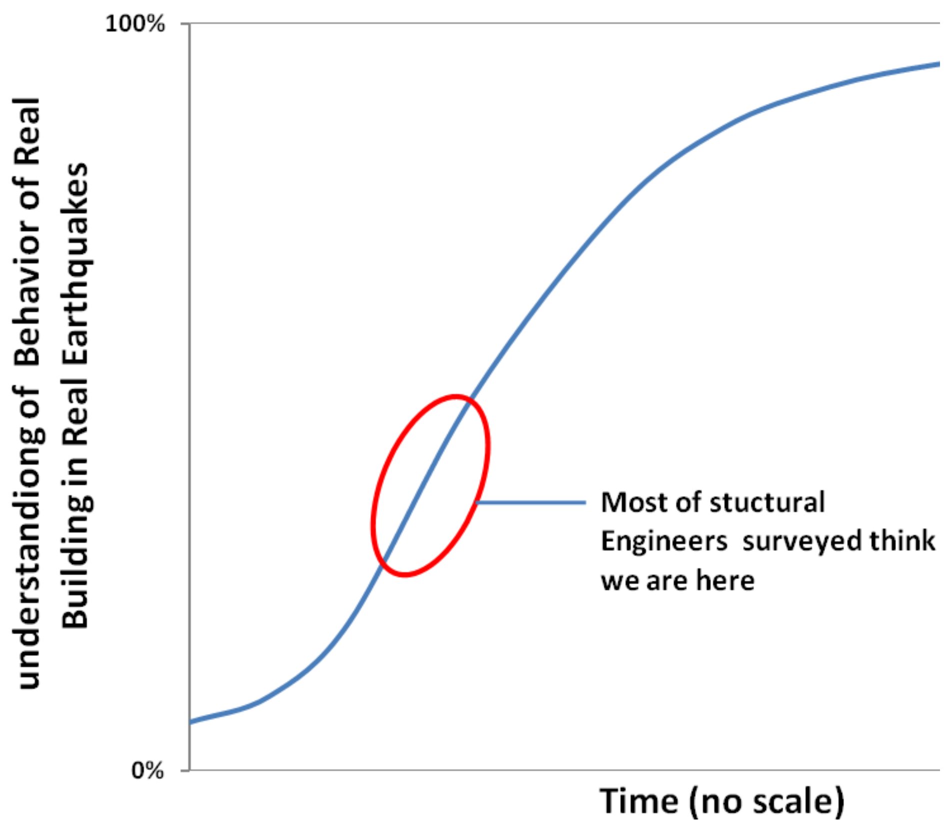
The potential benefits of such a statutory requirement would be to:

- Enable those exposed to the risk to play a greater role in determining acceptable risk. This is considered to be appropriate in a democratic society.
- Expose building owners to market forces encouraging them to have their buildings evaluated and strengthened.
- Enable the standard adopted for earthquake-prone buildings to be left at 33%NBS instead of increasing it to say 67%NBS as some have suggested. This tradeoff would be acceptable because some of the risk is being managed by market forces rather than through the regulatory process.
- Help resolve the conflict that engineers face between their ethical duty to draw to "the attention of those affected to the level and significance of risk associated with the[ir] work" and the requirement "not to disclose confidential information" of a client unless required to by law.
- Provide an incentive for clients to require engineers to develop means to make seismic risk assessments of buildings comprehensible to the general public.
- Make the building safety data on the LA's website available (if backed up) in a post-earthquake emergency and recovery period.

3.0 Informal Survey of Structural Engineers

During the last 6 months I carried out a small informal survey of other structural engineers (about 20) in an endeavor to explore how close practising structural engineers think they are to a complete understanding of how real buildings perform in real earthquakes. This is distinct from their understanding of how modeled buildings behave in modeled earthquakes on which their designs are based.

The figure below indicates the results of the survey. The curve in the figure speculates how the understanding that structural engineers have of how real buildings behave in real earthquakes might vary with time.



Prior to the 1931 Napier earthquake, buildings in New Zealand generally had no earthquake design input and the starting point forf seismic engineering in NZ would be somewhere near the start of the curve. The time interval when most URM buildings were built would mainly occur in the time period before the start of the curve.

Near the top of the curve, at a time probably not less than 50 years (assuming an engineering Einstein) and probably not more than 500 years into the future (assuming no future dark age), structural engineers might be approaching a complete understanding of how real building behave in real earthquakes. For those with a legal background this would probably be around the same time that Parliament makes perfect laws and everyone understands them.

I asked structural engineers where they thought the profession was currently on this curve (as distinct from where they thought they were on the curve). The lowest response I received was at the 10% level and the highest was at the 80% level but most of the engineers thought we were somewhere in the range 30 to 50% of complete understanding as indicated in the figure.

When structural engineers are asked to design a building to resist earthquakes or assess a building for risk from earthquake, they don't say "come back and see me in 50 to 500 years when I have a more complete understanding of how buildings behave in earthquakes". They tend to look around for what is known and what can be readily be researched and get on with it. This is part of a "can do" culture that is so ingrained and so universal that most structural engineers probably don't recognize it as a culture. The built component of our current civilization depends on this culture and we all share in the benefits and risks. I guess this is a plea for public understanding of where structural engineers find themselves now and for the foreseeable future.

Looking back at early seismic designs of buildings from the 1930's as I have done, and thinking about how far we have come in understanding the behavior of buildings in earthquakes, it seems to me there will be many unknown unknowns, things we have not even begun to think about, between our current position on the above learning curve and a complete understanding of the seismic behavior of buildings. Currently, when it comes to seismic engineering, the only certainty is that nothing is certain.

Although, by definition, we can't know the effect of these unknown unknowns, I think we can guess at their net effect. From my observations, it would appear that our current seismic design and assessment procedures are highly conservative. The impression I have is that, in almost every case I am aware of, structural engineers have struggled to explain not the damage, but the lack of damage that buildings and other structures sustained in the Canterbury earthquakes. This would appear to still hold true when probable strengths and pushover type analyses (or inelastic time history analyses) are used to eliminate most of the sources of over-strength in a building as an explanation. It is likely that the shaking intensity that buildings were subjected to in the Christchurch CBD, considering only the critical frequency range and direction for an individual building, varied by a factor of about 3. This variability of ground shaking intensity could explain the good performance of an individual building but it cannot explain the better performance of the CBD buildings considered as a whole.

The target for acceptable risk of building collapse is not defined explicitly in the New Zealand earthquake Loading Standard (NZS1170.5). However, a figure in the commentary suggests that, for the collapse limit state, about a 20% chance of collapse in a 2500 year return period event is to be expected. Based on the assessed seismic hazard in 2010, it would appear that the (spectral) shaking intensity that occurred in the February aftershock was approximately a 2500 year event (but of short duration). If the target for acceptable risk had been realized in this aftershock, 20% of all the buildings designed to 100%NBS would have collapsed. However, in the February event only two of the more modern buildings with capacities probably less than 50%NBS (especially if evaluated on the same dependable capacity basis) collapsed. When allowance is made for the effects of errors and omissions that are inevitable in the design and construction of all significant buildings this suggests that there is much about the collapse behavior of buildings in earthquakes yet to be learnt.

It appears likely that even URM buildings in the CBD achieved a performance that was not too dissimilar to the target for acceptable risk for collapse implicit in the earthquake Loading Standard at the time. This performance was achieved without assistance from structural engineers (apart from some strengthening) and could be considered as an affront to structural engineers. These buildings appear to have far more seismic resistance than our current assessment procedures indicate. However, this resistance is probably highly variable and not yet predictable for an individual building.