SEISMIC DESIGN DISCUSSION PAPER

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Abstract

There does not appear to have been any seismic guidelines despite the obvious seismic character of Afghanistan. The seismic measures that are being used seem to be of unknown heritage and perhaps of questionable value and hence this discussion paper is to offer a rationalization of seismic design options available to agencies. The focus is for the typical one storey mud/brick house currently in use by agencies and the guidance and recommendations are with this typology in mind.

Figure 1: The “Typical” House

Seismic Options

There are two or maybe three seismic options available as follows:

1) Earth mass walls: this is the commonly used approach.
2) Frames: and in particular steel frames
3) Diagonal braced frames: not generally used but may develop as cost savings approaches are sought.

The counter intuitive aspect of seismic loads is that they change depending on both the material and the structural system used. No other loading has such characteristics.

Seismic loads

The seismic load is usually determined by the following generic relationship:

$$A_h = \frac{\mathrm{Z\,I}\ S_a}{2Rg}$$

(refer to the Indian Standard IS 1893(2002) Criteria for Earthquake Resistant Design of Structures for a fuller commentary)

A_h = Horizontal seismic design coefficient and this factor multiplied by the weight of the house will give the seismic design loads.
Z = Seismic zone factor usually taken from maps provided in codes. However this has been altered to be the Peak Ground Accelerations provided by USGS[1]. These are the basis for the “maximum Considered Earthquake (MCE) and service life of the house. The factor of 2 in the denominator is included to reduce this to the Design Basis Earthquake (DBE). Refer to figure 2

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[1] Preliminary Earthquake Hazard Map of Afghanistan by Oliver S. Boyd, Charles S. Mueller, and Kenneth S. Rukstales Prepared Under the Auspices of the U.S. Agency For International Development page 14

below for values. Note that this has been taken for a 2% chance of exceedance in 50 years and it could be argued that given the service life of these houses and their serviceability requirements that 2% maybe conservative.

I = Building use importance factor and for houses would be 1.0. Higher factors would be used for clinics and infrastructure buildings that would need to be maintained for the post seismic situation. Again it could be argued that this value could be lower and perhaps 0.8; but the large numbers of houses being constructed suggest that 1.0 is perhaps more appropriate.

S_a/g = is average response acceleration and is shown in figure 4 below. It is determined by the natural period of a building (measured in seconds) and the ground conditions. However, for a single storey house such as shown in figure 1 above this factor would be 2.5 (times gravity or "g"). Note that this represents a huge load (refer to appendix A for the back ground material).

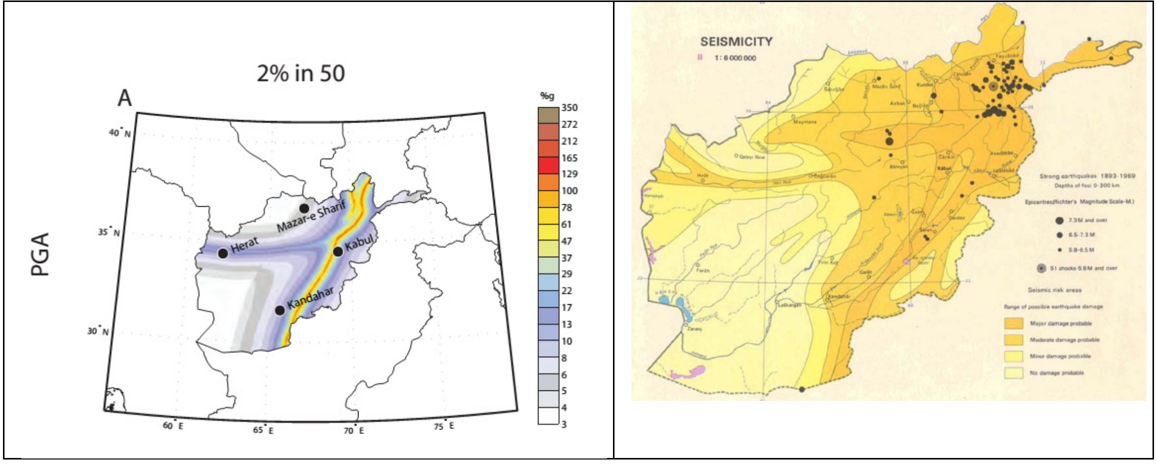
R = is the response reduction factor or ductility and is determined by the material used and the structural system adopted. These are tabulated for the structural systems identified earlier.

This seismic coefficient A_h multiplied by the weight of the building is the seismic load which is then distributed in an inverted triangular manner to represent the ground acceleration nature of the loading. This approach is already simplified which we can further simplify because of the single storey nature of house. This greatly reduces the mathematics and would mean that the seismic shear load at the base of the building (namely the top of the foundations) would be equal to the weight of the building times A_h. And that the over turning load (again at the base of the house) would be the weight to the roof plus half the height of the walls (as a lumped mass acting at the roof level) times the A_h factor. These constitute the seismic loads that the house would realistically need to resist.

Zone Factors

The zone factors seemingly vary throughout Afghanistan and seem to be a narrow band according to the USGS data. However, a wider zoning is suggested by the Atlas figure on the right.

Figure 2: [Left] Zone Factor as a % of "g" [Right] seismic zoning from National Atlas of Afghanistan 1977.



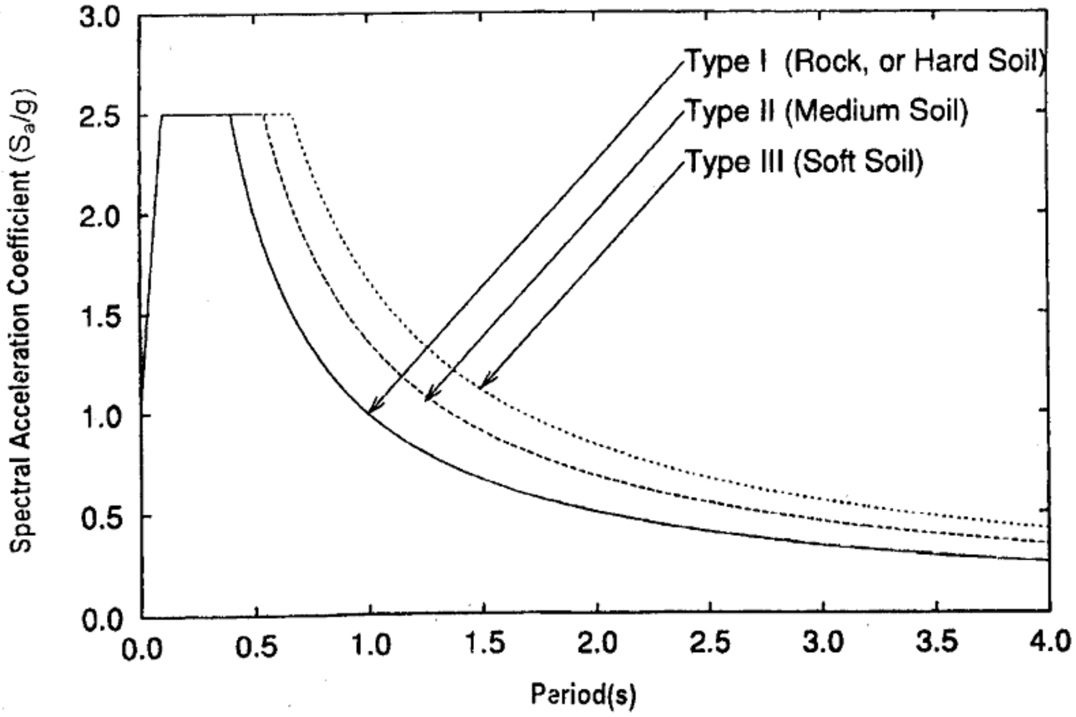
Theses suggest the following ground acceleration:

1) very high hazard zone 4.0 to more than 4.8 m/sec^2 (use say 5 m/sec^2)
2) high hazard zone 2.4 to 4.0 m/sec^2 (use say 4 m/sec^2)
3) moderate hazard zone 0.8 to 2.4 m/sec^2 (use say 2.5 m/sec^2)
4) low hazard zone 0 to 0.8 m/sec^2 (use say 1 m/sec^2)

Average Response Acceleration

Buildings respond dynamically to seismic shaking and the response is shown below in figure 3. As the natural period increases from 0.0 seconds the acceleration of the building dramatically increase to a plateau of 2.5 (times "g") and from around .5 seconds (depending on the type of soil) that will decrease almost as rapidly. Unfortunately, the low rise houses we are concerned with place them on the plateau area. Hence, the average response acceleration is 2.5. This is a large load and is why houses worldwide and in particular the heavy Afghan houses are especially affected. However, on the other hand the large mass is required to keep warm and hence other design approaches need to be developed beyond what happens in other seismically active countries.

Figure 3: Average response Acceleration vs. Building Natural Period (for 5% damping)



Ductility

Ductility is the ability to dissipate seismic energy by being extremely flexible and is largely a function of the material used and the type of structural system selected. It's importance is that the higher the ductility, the lower the design seismic force. However, higher ductility requires stricter construction control and detailing (for joints and connections) whereas lower ductility systems are not as critical. No ductility would be 1, low or limited ductility 1-2, and high ductility 6-8 and the R (ductility) values based on IS 1893(2002) The Indian Earthquake Resistant Standard are as follows:

1) Earth mass walls: this is the commonly used approach: R=1.5
2) Frames: and in particular steel frames: R= 5
3) Diagonal braced frames: not generally used but may develop as cost savings approaches are sought. R=4.0

Ties and Diaphragms

The discussion thus far has developed an approach to determine the seismic loads that a house would need to resist. However, to succeed the houses first needs orthogonal lateral resisting systems (namely in both an X and Y direction) and secondly needs a way to get the loads generated by the mass or weight of the building to those lateral resisting elements. In addition walls particularly if they are load bearing need to be propped for potential “face” loading (perpendicular to the direction of the wall). This requires ties and more often a diaphragm at roof level to transfer these loads. A corrugated roof would be a diaphragm and a timber ceiling would probably be one.

Transitional Houses

The loads used for the seismic weight determination should be for any future planned transition. For example if the walls are initially light weight with the intention of them being constructed of heavier material later than the seismic weight should be based on the heavier load. In a similar way if the house is supplied with a corrugated steel roof with the intention of it being a thick mud roof later that that should be included in the load calculation.

Conclusion

This then gives a procedure for readily determining seismic loads that a house will need to resist. It is interesting to note that nearly 9,000 people in Afghanistan died as a result of earthquakes between 1948 and 2006. This is higher than flooding or landslides and hence cannot (and should not) be put aside. But beyond the issue of compliance it also opens up the opportunity for innovation through the use of local materials and traditional practices as well as specific ductility approaches.

Appendix A: The Peak Ground Acceleration.

The natural periods of vibration (measured in seconds) can be estimated from

$T = 0.09 \times h/\sqrt{d}$

T= natural period of vibration in seconds
h = building height
d = building width along the direction of the earthquake shaking

Hence, for a 3 storey building with a storey height of 3.5 metres and a base of 9 metres would have a period of around T= 0.3 sec and would experience a seismic acceleration of 2.5x PGA. In approximate terms each floor of a building represents 0.1 seconds of natural period. Consequently, t shelters would be in the 0.1 second range and like the worked example above would be subjected to 2.5x PGA and thus the building acceleration values included in table 1 above. Hence, the t shelter significantly increases the seismic loading that arrives via the ground to it's foundations.

Appendix B: Recent earthquakes in Afghanistan.

These records suggest that from 1948-2006 that approximately 9,000 people died as a result of earthquakes. This means that earthquakes cause more fatalities than flooding but as is often the case flooding impacts on more people.

S.N.	Date	Epicenter location	M_s	Intensity of damage
1	11/08/2006	Tajikistan, nearby Badakhshan province	4.7	No significant damages.
2	25/03/2002	Nahrin district of Baghlan Province	6.0, 5.1, 5.8	Nearly 1200 people were killed.
3	03/03/2002	Hindu Kush region	7.2	32 houses destroyed; 20 person injured, 6 person killed.
4	03/01/2002	Takhar Province	6.3	No report of damages and casualties.
5	30/05/1998	NE Afghanistan	6.5	Killed nealry 4000 people; injured many thousands in the districts of Badakhshan and Takhar.
6	04/02/1998	Rustaq area, Takahr Province	5.9	Killed nearly 2300 people, 800 injured; 8100 houses were destroyed, nearly 8000 people homeless.
7	12/01/1986	Shock was strongly felt in Kabul.	5.5	Record not available
8	03/07/1984	Takhar Province	5.2	Record not available
9	07/12/1983	Takhar Province	4.6	Record not available
10	16/12/1982	NE Afghanistan, strongly felt and damaged in Baghlan Province	6.5	Destructive earthquake; killed nearly 450 people, destroyed 7000 houses, injured nearly 3000 houses in Baghlan, serious damage and loss of life in coal mines in the province.
11	13/06/1981	Between Samangan and Jozjan Provinces	5.4	Large number of people were killed but not
12	19/03/1976	NE Afghanistan	5.5	Killed some 50 people, damaged nearly 1000 houses in Samangan Province.
13	24/06/1972	Nearby Takhar Province	6.4	Killed nearly 20 people, few hundred houses collapsed.
14	12/09/1962	Available macroseismic information is not sufficient to locate the epicenter area but suppeosed to be close to Takhar Province.	6.0	Record not available.
15	16/09/1956	Logar district near to the border with Pakistan, NE Afghanistan	6.7	Sketchy information, number of houses collapsed and few people were killed, landslide and snow-avalanches in Hindu Kush range.
16	09/06/1956	Bamyan district.	7.4	Small villages totally destroyed, Yakwalang district heavily damaged with loss of life, triggered landslide and rockfalls, an estimated 100,000 m^3 of limestone and marls slid down damming the upper valley of the Kamar river holding back 8 million m^3 of water for four days. The dam gave way on 14th June. It swept away the settlements drowning about 350 people. Great panic in adjoining district
17	28/01/1948	Balkh in NE of Afghanistan	6.5	Killed number of people and domestic animals, old houses and shops were destroyed, dome and towers of shrine buildings fell down, widely felt in Kabul as well.
18	05/07/1935	Border of Afghanistan and Uzbekistan	NA	Insignificant damages in Mazar-e-Sarif, Sari-e-Pul.
19	01/01/1911	Northern Afghanistan	7.1	Relatively large earthquake in northern Afghanistan, maximum damages in Feyzabad and Kalan. In Kalan, 60 houses collapsed, killed 240 people, 70 houses were destroyed. In Feyzabad, houses were ruined with fatalities. The shock was rather strong at Shuburghan, Termez and Mazar-e-Shharif.
20	07/07/1909	Somewhere in Badakhshan Province, it consists of two events; one shallow and another deep. Followed by several after shocks.	Appr. 7.5	Serious damages at the south of Amu River at Badakhshan Province, also rockfalls and landslides.