A research on improving seismic performance of non-engineered adobe buildings in Afghanistan

Davoud Sultani

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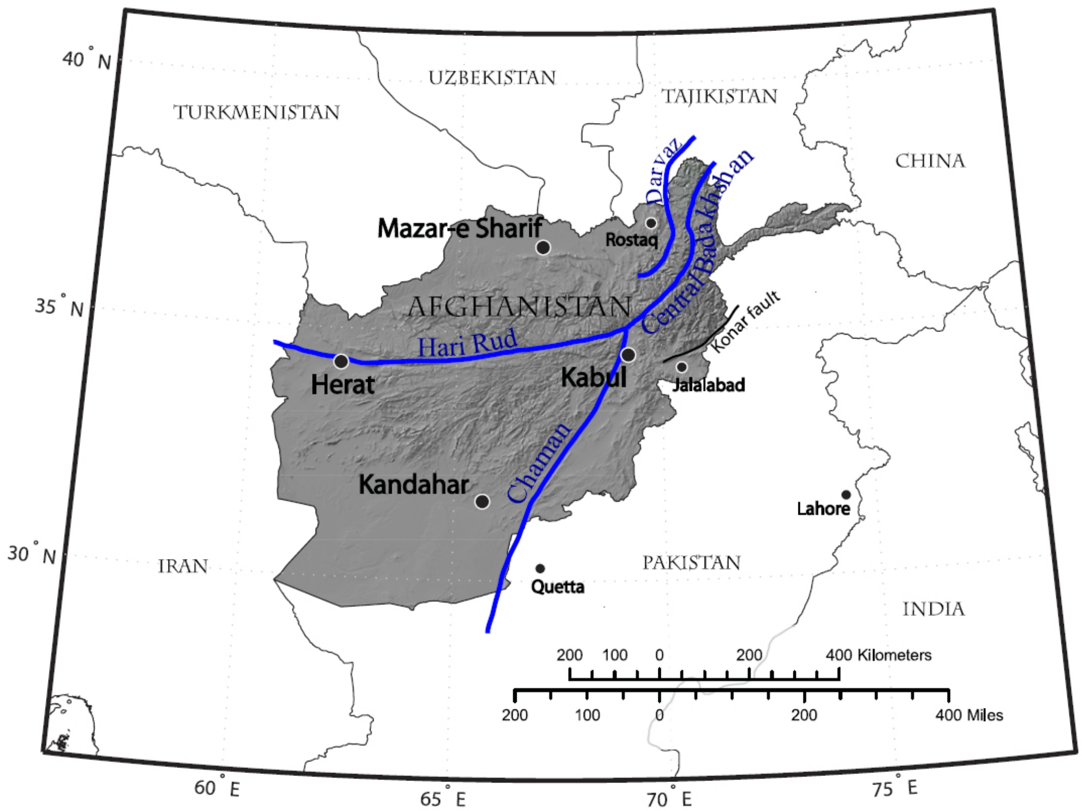
I would like to express my gratitude to all of them. Without their passionate participation and input, this research could not have been successfully conducted:

- Grahame Hunter – Architect, founder of Afghan Earth Works
- Karel Terwel - Structural engineer CiTG faculty TU Delft
- Joop den Uijl - Earthquake researcher in CiTG faculty TU Delft and Pontifical Catholic University of Peru
- Joop Paul - Professor of Structural Design at the Faculty of Architecture and the Built Environment TU Delft
- Masood Rafi - Chairman Department of Earthquake Engineering NED University of Engineering and Technology, Karachi

Problem description - Earthquake and Afghanistan

The same geologic uplift that has caused the formation of highest mountain peaks in the world including the Himalayan, the Karakoram, the Pamir and the Hindu Kush range (with Noshaq peak at 7492 meters being the highest in Afghanistan(Wikipedia, 2015)), the northward motion of the Indian and Arabian tectonic plates against the Eurasian plate, according to U.S. Geological Survey is behind the "12,728 earthquakes that occurred from the second millennium B.C. to December 2004" (Dewey, 2006)



Afghanistan's main fault lines (Boyd, Mueller & Rukstales, 2007)

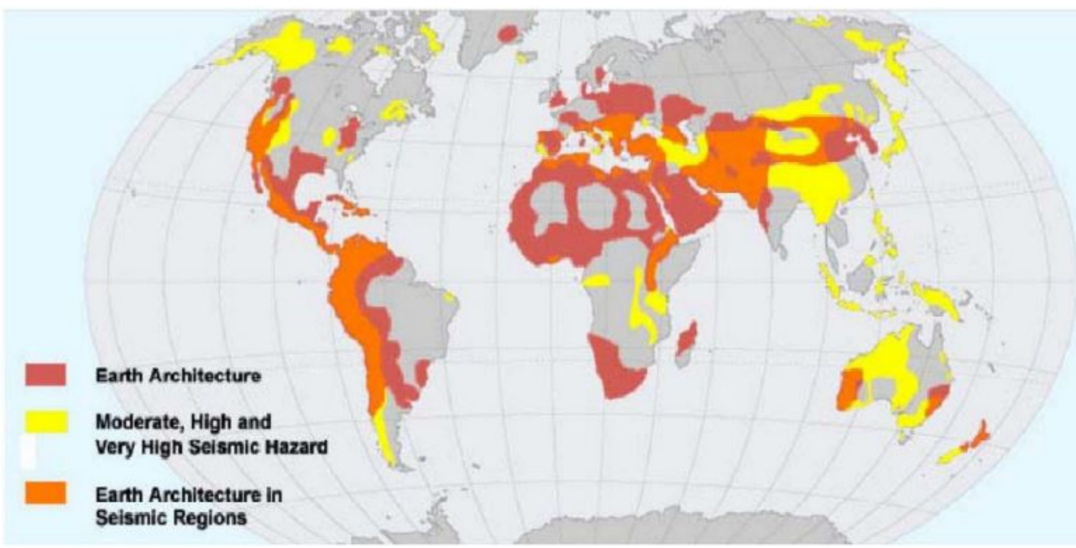
Above image is a simplified tectonic map of Afghanistan, showing four main fault zones. These faults and hundreds of others not shown are zones of weakness in the Earth's crust that could be susceptible to movement and earthquakes. For a more detailed version check Appendix b.

This presence of active seismic source regions leaves Afghanistan highly vulnerable to earthquakes. Many of the important cities of Afghanistan including the capital city Kabul, are located in moderate to severe seismic hazard zones and many of the prevalent construction practices and building typology in rural areas are extremely vulnerable to earthquake hazards. With a considerable portion of population living or working in earthen construction, there's a need for research on ways of improving earthen buildings against earthquakes.

Focus on adobe

Possibly mankind's first building materials, earth has been in continuous use in various guises throughout history and on every continent. Of the many distinct ways in which earth has been used to construct shelters, adobe may be the simplest; blocks of earth produced manually by throwing wet earth into a formwork, sometimes called mud bricks or sun-dried earth blocks. Adobe is one of the oldest and most widely used building materials dating back to 8000 B.C. (Houben & Guillard, 1994).

The use of adobe is very common in many of the world's most hazard-prone regions, such as Latin America, Africa, the Indian subcontinent and other parts of Asia, the Middle East and Southern Europe, as shown below:



Correlation between earthen architecture and high seismic activity areas (Pollak, 2009)

Approximately 3 billion people live or work in earthen buildings (Rael, 2009). Approximately 50% of population in developing countries, including a majority of the rural population and at least 20% of the urban population, live in earthen dwellings (Houben & Guillaud, 1994). For example in India, according to the 2001 Census, 30% of all buildings are made out of earth which translates to roughly 73 million houses inhabited by more than 300 million people. (Blondet et al, 2010)

There are several obvious explanations for adobe's popularity. It is a cheap, easily available construction material, often manufactured by locals. Adobe structures are generally made by their owners, because the construction practice is simple and does not require additional resources. Skilled technicians (engineers and architects) are generally not involved in this type of construction. In addition to its low cost and simple construction technology, adobe construction has other advantages, such as excellent thermal and acoustic properties.

Typical adobe houses around the world (World Housing Encyclopedia, 2009)

a) El Salvador

b) Argentina

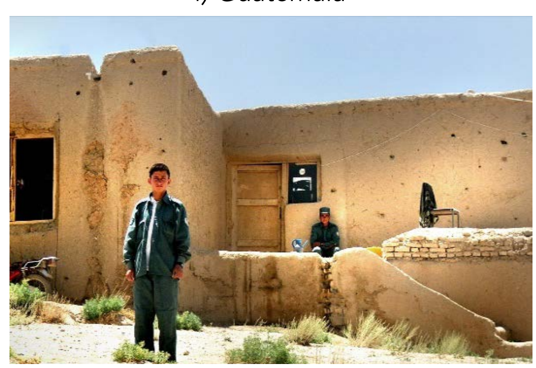
c) India

d) Iran

e) Peru

f) Guatemala

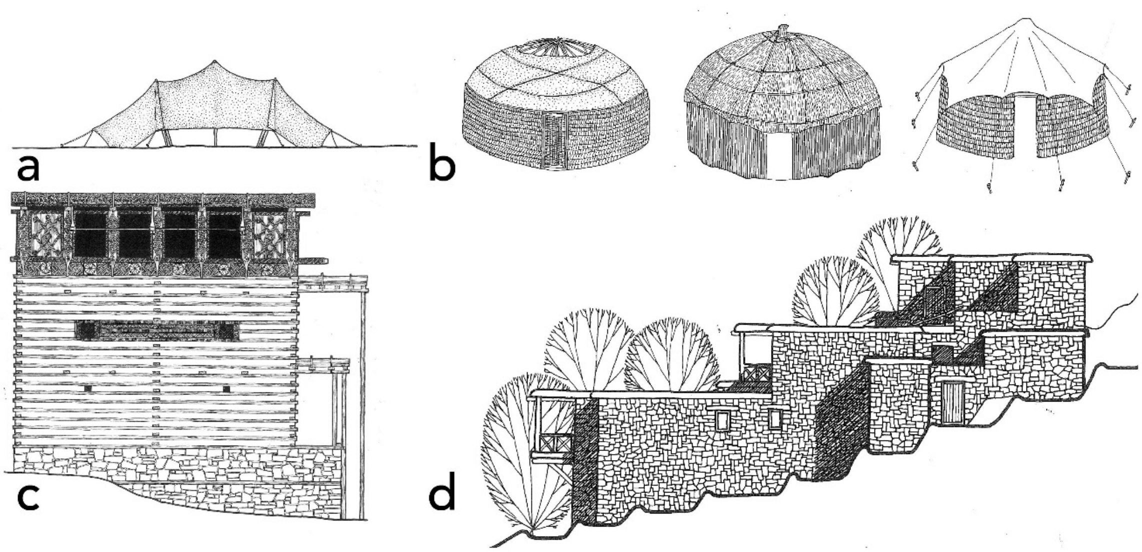
g) Afghanistan



h) Afghanistan

Adobe in Afghanistan

Amongst Afghanistan's plethora of vernacular building systems, varying from Ghezhdi the nomadic black tent (a), Chapars of Ghorband valley, Doshi and Aimag area (b), Nuristani hillside houses (c) with their majestic woodwork or the Salang mountain houses (d) with their beautiful stone masonry, to name a few, no other building technique/material is both as common and as vulnerable to earthquake as adobe.



Images of 'Traditional architecture of Afghanistan' (Hallet & Samizay, 1980)

Adobe's weaknesses

A traditional adobe construction responds very poorly to earthquake ground shaking. The seismic deficiencies of adobe buildings are caused by its heavy weight, low strength and brittleness. During earthquakes, these structures develop high levels of seismic forces they are unable to resist, and often fail abruptly. (Blondet et al, 2010)

It was also noted by Joop Paul, Joop den Uijl and Karel Terwel, all structural engineering experts focused on earthquake, that adobe mainly because of its weight and its inherent structural vulnerability, specially to tension, purely from seismic improvement perspective, is about the worst building material for regions with high risk of seismic activity, and one with highest human casualty potential, as a result of its sudden and brittle manner of failure and collapse.

Although it is worth mentioning that a research done by the Salvadorian Government after the January 2001 earthquake found that adobe houses were not worse affected than other houses. (Minke, 2005)

Poor workmanship, lack of proper connections between building elements are some of other shortcomings that contributes to the general vulnerability of non-engineered adobe buildings under earthquake loads.(Maheri, Naeim, & Mehrain, 2005)

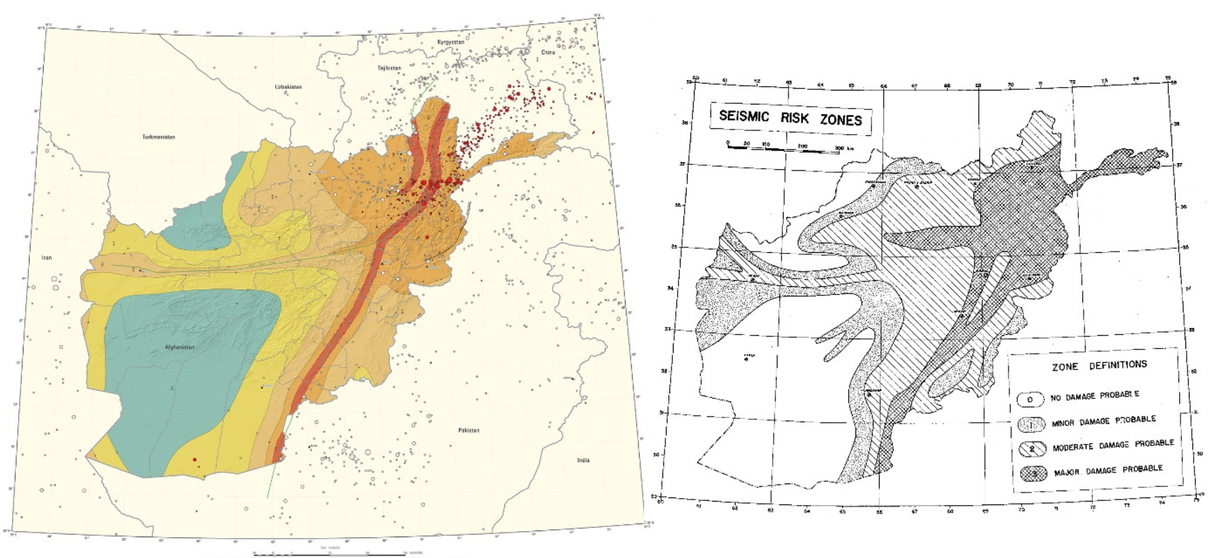
There are country and region specific issues that intensifies the inherent problems of this building technique. For instance one can witness a process analogous to natural selection in countries with a higher frequency of seismic activity i.e. Japan, Chile and Peru considering its vernacular architecture. It eliminates or improves building techniques that are not able to produce buildings capable of withstanding such a high frequency of earthquakes. Such process can be at least partially the cause of the improved performance of Salvadorian adobe houses mentioned earlier.

Although an important portion of Afghanistan sits on top of a very active seismic zone, the frequency of its high impact earthquakes is not as high as for example Chile's or Japan's. This in turn diminishes the evolutionary aspect of vernacular architecture, as in through the survival of the fittest building techniques, and reduces the urgency of taking action in mitigating the future earthquakes' damages.

The condition of civil war and political instability of the country in last four decades has been another contributing factor to the lack of meaningful improvements. In partial or total absence of a central government, which in a stable situation would be assisting and guiding the reconstruction process, the victims are left to their own meager means. Freshly hit by a natural disaster, mostly mourning the loss of family members and relatives, their livestock and work, they're in no shape to critically review their building process and come up with improvements by themselves. Their limited access to building materials beyond their immediate surroundings is another issue contributing to this vicious circle of non-improvement and standstill.

State of seismic research in Afghanistan

Following fall of Taliban regime in December 2001, to support various projects for infrastructure development and reconstruction, initiated and financed by US and international community, USAID (United States Agency for International Development) started the Afghanistan seismic hazard assessment project. (Dewey, 2006) To fulfill this assignment the Seismic Hazard Mapping group of USGS (United States Geological Survey) prepared a series of probabilistic seismic hazard maps to assist quantify the expected frequency and strength of earthquakes in Afghanistan. This so-called 'master earthquake catalog', while composed within the framework of limitations of geological and seismological data available on Afghanistan, according to USGS is comparable to "the type of analysis that underpins the seismic components of modern building codes in the United States." (Boyd et al, 2007)



The new (Dewey, 2006) and old (Heuckroth & Karim, 1970) seismic risk zones maps

Although a more precisely produced catalog of Afghanistan's seismicity would be a helpful development, and in the long term national interest of the country, for the time being the aforementioned USGS report is the most detailed set of documents available, and at least for the time being the main resource for seismic data about Afghanistan.

Research question, goal and product

It's within this framework that the **research question** gets formulated to:
How can one modify the local adobe building techniques in rural areas of Afghanistan to build better earthquake resistant buildings?
Research goal: Introduction of locally available, easily transferable design principles and techniques for building earthquake resistant adobe structures in rural Afghanistan.
Research product: Introduction of the research result in form of design principles and techniques through a visually oriented manual aimed at the rural population (rural Afghanistan has a literacy rate of around 20%), a booklet (or poster) with simple graphics explaining the steps for each advised technique, translated to Dari and Pashtun and easy to follow for the illiterate.
In the ideal scenario a part of the Afghan government, for example Ministry of Rural Rehabilitation and Development, will undertake the task of spreading these manuals in villages located in high risk areas.

To test the assumption that a graphically based manual can be of any help for the situation in Afghanistan, it was important to figure out whether the information chain was broken and if yes which part? Up to which extent was it due to a lack in availability of technical solutions, and to what extent a matter of lack of access to right material (or any other representation of financial limitations) or even resistance of the local population to new methods?
I discussed this matter with Grahame Hunter and Yasmeen Lari. Both has been active on this field, Grahame in Afghanistan and Ms. Lari in Pakistan. They confirmed my initial understanding about major shortcomings in communication of knowledge and skill to the right audience. Although matters of accessibility (local availability), cost, ease of practice and so on, were to be considered as categories in choosing the right techniques and approaches, nevertheless there is much to be done about the communication and transfer of knowledge and skill to the rural population. This confirmations was important especially because of these two experts' direct involvement with the issue in the same region.

Research Methodology

- General research (review of current knowledge base)
- Building type research (Afghanistan's rural architecture) and choice of dominant type in risk area's (adobe - mud brick)
- Review of relevant scientific literature: Books, scientific journals, conference proceedings and case studies on comparable regions with similar building technique (Pakistan, India, China, Peru…)
- Interpretation and contextualization of the results of above
- Formulation and application of criteria, resulting in production of end products (drawings, translating texts to local languages)
- Expert consultation: After the initial introduction to the related scientific literature a list of experts in the field was compiled (see Acknowledgement). They were approached with a list of common questions the author regarded essential to the research. Questions which were mainly based on the initial literature review. In some cases there were questions tailored according to the consulted expert's specific background and experience.

While this list has some chronological order, there were many overlapping steps. Especially in regards to the expert consultation which was an ongoing process throughout most of the process.

Scope of the research

It is necessary to clarify the goal which this research aims to achieve. It was decided from early in the process, that a full immunization of the non-engineered adobe buildings in risky rural areas of Afghanistan could not be a feasible goal. Such an endeavor would be even beyond the reach of the Afghan government. My general understanding of the situation confirmed by correspondence with experts such as Grahame Hunter indicated human loss and casualty as the costliest byproduct of an earthquake, both in terms of pain and suffering it causes, and in economic terms by way of losing irreplaceable workforce. Focusing on mitigation and if not possible, minimization of this aspect of earthquake creates a more feasible roadmap and a more realistic and achievable policy. To put it simply, applying at least some of the improvements in the manual can increase the time needed for abandoning the collapsing structure, thus saving lives. If followed fully it would decrease the risk of structural failure and collapse considerably.

Can earthquake research of other countries be interpreted for Afghanistan?

The initial research confirmed that there is indeed a shortage on seismic research in or about Afghanistan. It also confirmed that Afghanistan's rural architecture has major material and structural commonalities with vast seismically active areas in countries such as Pakistan, India, Iran and several south American countries such as Peru and Chile to name a few. I had come across many academic works and several built examples by Pontifical Catholic University of Peru, NED university of engineering and technology in Karachi - its Department of Earthquake Engineering is chaired by Professor M. Masood Rafi which kindly accommodated me with his consult and related research documents - or Indian Institute of Technology in Kanpur and of course proceedings of World Conferences on Earthquake Engineering (WCEE), to name a few, which led to my main question:

Is it reasonable to use or interpret the researches, case studies and experiments done about seismic stabilization of non-engineered adobe buildings in the aforementioned areas for Afghanistan?

The response to this question was a unanimous yes. They all shared the opinion that Afghan vernacular architecture can benefit immeasurably from the knowledge and experience acquired by countries with higher exposure to earthquake which have a comparable vernacular building culture. Countries such as Peru, Chile and Pakistan (to name a few) has been hit harder and more often by earthquakes throughout history which has led their building techniques to evolve to a more earthquake resistant version both in an organic way and by shear necessity and urgency of the situation. It would be a missed opportunity for Afghanistan not to seek their collaboration and assistance in tackling this issue.

The influence of soil type on the earthquake impact

Soil type influences the impact of earthquake in two main ways: soil liquefaction and ground acceleration

Soil liquefaction

Soil type plays an important role in the soil liquefaction. Eurocode defines this phenomenon as: "A decrease in the shear strength and/or stiffness caused by the increase in pore water pressures in saturated cohesionless materials during earthquake ground motion, such as to give rise to significant permanent deformations or even to a condition of near-zero effective stress in the soil" (2004, p.16) It can be simplified as loose sandy soil flowing like water. According to the same source a soil is susceptible to liquefaction when extended or thick layers of loose sand is either located beneath the water table level, or when the water table level is close to the ground surface.

Eurocode considers the adverse effects of loose sandy soil for buildings on shallow foundations, i.e. adobe houses in Afghan villages, negligible if:

-The saturated sandy soils is located deeper than 15 meters from ground surface.

-Or when α.S (ground acceleration ratio) < 0,15 and at least one of the following conditions is fulfilled:

- The sands have a clay content greater than 20% with plasticity index PI > 10;
- The sands have a silt content greater than 35% (Eurocode 8, 2004)

Regardless of the possibility that the soil type of risky areas of Afghanistan would fulfill these conditions, the altitude, climate, and soil conditions in Afghanistan varies greatly depending on where in the country one finds himself. The map of soil regions in Afghanistan (Appendix c.) identifies five main soil categories with a total of 25 subcategories. Although most of riskiest regions falls within the so-called central highlands with ecological regions that ranges from desert-steppe, to meadow-steppe types. (Encyclopedia Britannica, 2014) There's still at least 10 soil variations ranging from 'rocky land with lithic cryorthents' to 'torriorthents with torrifluvents'. Even if there was a precise catalog of soil types for each village, the expertise and time needed to address each and every one of the soil types would simply be unattainable.

Peak Ground Acceleration

Loose and unconsolidated soil moves more during an earthquake, as a result the impact on the buildings on the surface would be greater. PGA shows extreme variability over small distances which according to U. S. Geological Survey:

"*This is attributed to the small scale geological differences near the sites that can significantly change the high-frequency acceleration amplitude and waveform character. Although distance to the causative fault clearly dominates the pattern, there are often exceptions, due to local focusing and amplification. This makes interpolation of ground motions at one site to a nearby neighbor somewhat risky.*" (USGS, 2015)

To put it simply, the ground type can significantly influence ground acceleration, so PGA values can display extreme variability over distances of a few kilometers, particularly with moderate to large earthquakes. Due to the complex conditions affecting PGA, earthquakes of similar magnitude can offer disparate results, with many moderate magnitude earthquakes generating significantly larger PGA values than larger magnitude quakes. This level of complexity makes a thorough PGA analysis for low density population areas, i.e. villages, unfeasible.

Considering the overall influence of soil type on earthquake impact, because of the finitude of available resources (time, expertise, etc.) a triage-based approach to earthquake damage mitigation is the only feasible direction.

Triage in the non-medical sense can be used to describe the process of allocating limited resources for greatest effect in any situation where prompt action is necessary to minimize or limit serious loss or damage. (Buddemeier, 2015)

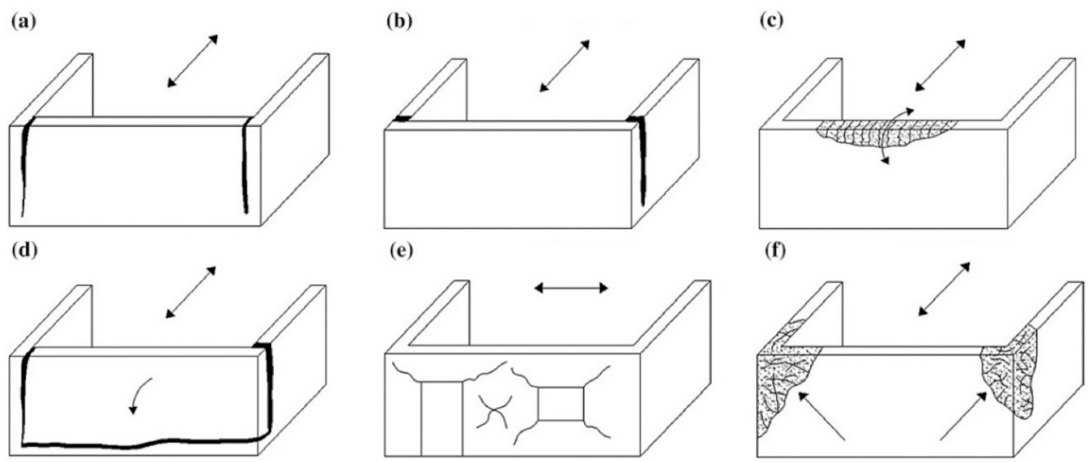
While recognizing the impact of soil type on any given earthquake outcome, considering the aforementioned arguments, I will disregard it within the context and limitations of this report. Disregarding the differences in soil type is also understandable considering the goal of this research in extending the building's structural stability beyond the immediate moment of seismic activity, providing the residents enough time to avoid casualty, rather than complete earthquake-proofing the building (which would be very difficult considering the inherent shortcomings of adobe building technique and material, amongst other reasons).

Nevertheless I included this short summary of the soil's influence on the scope of earthquake damage as a reminder of all that can and should be done in future to better understand and mitigate the risks.

How adobe fails

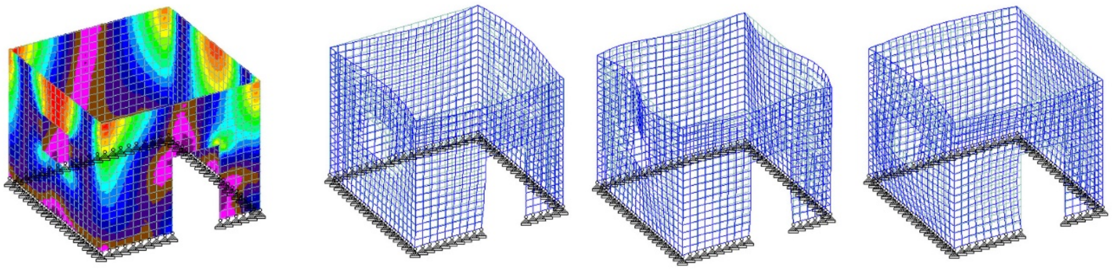
In principle the forces created by the seismic activity can be simplified into two main form of horizontal forces that the walls have to withstand for the structure to be able to survive the earthquake intact; parallel to the wall and perpendicular to it. The angled forces can be divided into parallel and perpendicular components. Structures are mainly affected by the horizontal forces. The vertical forces are usually less than 50% of the horizontal ones. It is the perpendicular forces which are more likely to provoke a collapse of the wall if not properly stabilized, although too thin or tall walls may still collapse due to the bending forces that create buckling even if stabilized. The parallel forces pose less of a danger. The thrust produced by them creates the typical diagonal cracks in adobe walls with poor mortar.(Minke, 2005)

These cracks generally follows the stepped patterns along the mortar joints. They often begin at the edge of the doors and windows which are places with high stress concentration.(Blondet & Aguilar, 2007)



Typical damage and failure mechanisms on adobe masonry constructions. (a) Vertical corner angle cracking due to shear forces. (b) Vertical corner angle cracking due to out-of-plane forces. (c) Diagonal cracking in wall due to in-plane shear forces. (d) Global overturning of wall panel. (e) Diagonal cracking in wall due to in-plane shear forces. (f) Sequence leading to corner dislocation (Varum et al., 2014)

The dense and heavy adobe walls have extremely low tensile strength which explains the concentration of cracks in lateral corners of the walls where the tensile stresses are higher. This causes the large vertical cracks which eventually separates the walls, causing their collapse and consequently causing the partial or total roof collapse.



Stress distribution and deformation modes of a non-engineered house under seismic loads (Chaudhary, 2014)

Typical patterns of earthquake damage in adobe walls (Blondet & Aguilar, 2007):

a) Vertical cracking and separation of walls – 1997 Jabalpur, India earthquake

b) Out-of-plane wall collapse - 2007 Pisco, Peru earthquake

c) Diagonal cracking of adobe walls– 2010 El Maule, Chile earthquake

d) Total collapse of adobe walls – 2001 El Salvador earthquake

e) Roof collapse on adobe building – 2007 Pisco, Peru earthquake

f) Parapet collapse on adobe building– 2003 Bam, Iran earthquake

Old village of Nahrin in Afghanistan, 100% destroyed by earthquake March 2002 (ACTED, 2002)

Literature summary for the manual

The review of available body of literature on the topic reveals three key categories for the improved seismic performance of non-engineered adobe construction:

- Adobe block composition and quality of construction.
- Compact, box-type layout.
- Seismic reinforcement

What follows is a literature review of these three factors' application and results in real life or in simulations such as shaking table test, mainly done in a collaboration between British Columbia Institute of Technology, and Pontifical Catholic University of Peru. The unreferenced images and information are from the "Earthquake-resistant construction of adobe buildings: A tutorial" which is the result of the aforementioned collaboration published by World Housing Encyclopedia.

See the attached document: Literature Review

Conclusions and recommendations

Affordability

According to Joop Paul the issue of affordability (which can be also seen as availability in this context) is the main challenge in gaining widespread acceptance. He found the role of government in addressing this obstacle crucial. The higher financial cost, either in extra reinforcing materials, or in time because training is required or the new building process is more elaborate, can be addressed by subsidizing them. If a full subsidization is out of reach a partial subsidy can be used to boost the efforts that improves the seismic performance of adobe structures.

Without a governmental dedication to this cause the effects of the knowledge will be limited to only those who can afford the extra costs. It is thus highly recommended to have a national earthquake mitigation policy for rural areas coupled with financial aids to increase its chance of application.

Importance of social sensibility

While availability of technical solutions alone, can not be regarded sufficient in addressing the unacceptably high seismic risk for the millions of adobe house dwellers, Blondet et al addressing the issue of the local population's resistance in some cases note that:

"*This problem has important social dimensions that need to be addressed, because in many cases significant cultural transformations are required to change the way people build their dwellings. Many people who have traditionally used soil as a construction material are reticent to change the way they build. In many cases it is because the communities have an adverse reaction to interference in their traditional way of life from persons extraneous to the community.*" (2008)

They consider this social inertia, alongside the financial load, and the quickly diminishing sense of emergency after an earthquakes as the main obstacles for the availability of technical solutions to reach its full potential.

Grahame Hunter confirmed both Paul's concerns about the financial aspect and Blondet's call to more sensitivity in introduction of new techniques, mentioning his and USAID's failed efforts to have a lasting impact on the Afghan local builders:

"*We went down a wrong route by obtaining support from USAID to try and redesign a new type of house with innovative steel web reinforcement* *(documented first by the Peru source you cite) which had little traction with the local market for many of the reasons you mention in 4. We then did some other interventions that were better received - but always with NGO funding of the extra costs. We never knowingly persuaded any local builder to change their technique. So from that point of view, we had zero impact in over 4 years.*"

Mentioning "4" Hunter is hinting at the challenging social aspect of the introduction of new technical solutions to a traditional rural population, which was the subtext of the fourth question in that correspondence.

A sensible careful approach to this matter could be as important as the issue of availability itself. The author recommends maintaining a good relationship with the local population, with a sense of collaboration towards a common goal rather than a top-down attitude.

Trojan horse approach

Improving seismic characteristics, because of its little immediate gain, according to Grahame Hunter, will have difficulties gaining widespread traction in a poor country. He proposes a so-called trojan horse approach:

"Combining better strength with something more tangible like better insulation and electric lights, so that these go in as a package and somehow the benefits of a solar panel for example are delivered with enhanced seismic performance."

Incidentally this is one of the approaches that Pakistan's Heritage Foundation under leadership of Yasmeen Lari has been using.

In October 2007, Pakistan was hit by a strong earthquake which left more than 80,000 dead and 3.5 million people homeless. (Wikipedia, 2016)

Ms. Lari mentioned the combinatory approach to general life improvement in several cases. The prime example of it is use of lime plaster/render on the mud brick walls. It's a universal technique to apply a layer of plaster on adobe walls to protect it against elements and improve its durability. In rural Afghanistan as it is common in many other places, villagers apply a mud plaster. According to Pakistan's Heritage Foundation lime plaster not only performs at least as good as mud plaster in protecting the adobe walls against elements, increasing its durability, it also has a higher thermal insulation value and more importantly improves the wall's seismic performance. Considering the fact that lime is relatively easy to obtain in Afghanistan, I too recommended its use in the manual.

Bamboo

Other example, which Ms. Lari enthusiastically recommended for Afghanistan, was the introduction of bamboo. She mentioned their successful introduction of bamboo plants to areas with no prior familiarity with the plant and its use in seismically improved structures.

My initial research indicated some points of caution though:

a- Bamboo is known to be very invasive and hard to control (Baessler, 2015) The introduction of non-local species should be approached cautiously, especially in areas with limited access to fertile soil and water, a category which includes majority of Afghan villages.

b- Most of Afghanistan's risky areas (with adobe structures) can be categorized under Semi-arid and cold desert climate (Wikipedia, 2015), thus not the most welcoming environment for plants even as resistant as bamboo with its more than 1000 subspecies (Wikipedia, 2015).

Although a full study of the pros and cons of bamboo in Afghan context falls beyond the scope of this research, the author highly recommends a more thorough research accompanied by test runs and case studies to identify the right subspecies and formulate a properly customized approach.

Entrepreneurial approach

If an improvement to the building condition simultaneously contributes to the local economy, long term success would be more achievable.

One such example is the compost toilet project in rural Pakistan. This project not only improves livelihood of the users by means of improving hygiene conditions, but also creates new jobs and helps women empowerment. Compost toilets introduced by the Pakistan's Heritage Foundation have a simple design and are easy to build. Local population have come up with clever ways to make a business model around it. Some families collaborate and make the different parts of the system. In doing so they create surplus value for themselves and for the eventual users. Ms. Lari mentioned her interactions with a few of these "bare-foot entrepreneurs" very fondly. Her advice was to look for comparable scenarios in Afghanistan.

Although this thesis project's scope could not accommodate a thorough inspection of such potentials around the issue of seismic improvement of Afghanistan's rural adobe houses, nevertheless it remains a very relevant theme.

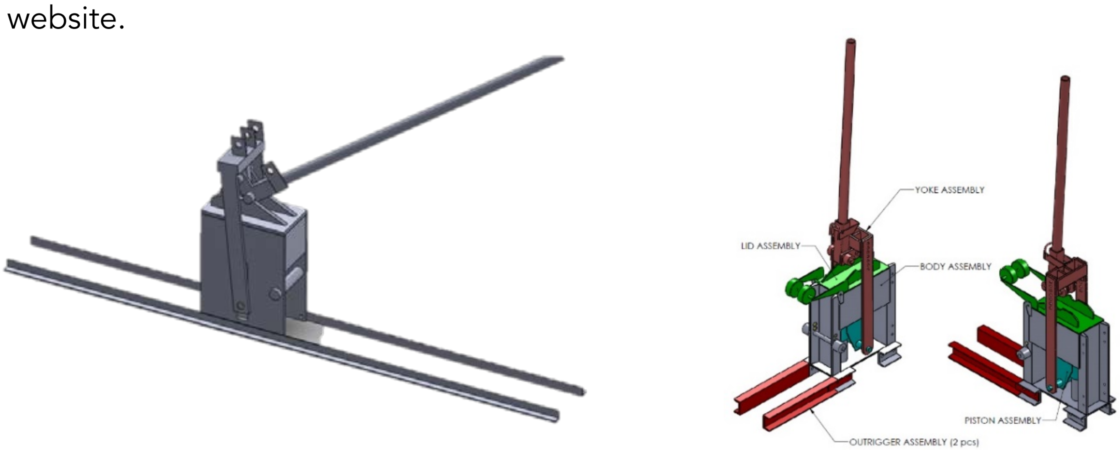
In a country that scarcity of resources and capital is the daily order of life, creating or exploiting such opportunities can be an influential factor in success of such experiments amongst local communities.

Compressed Earth Blocks

A compressed earth block (CEB), also known as a pressed earth block or a compressed soil block, is a building material made primarily from damp soil compressed at high pressure to form blocks. Compressed earth blocks use a mechanical press (which can be either manual or hydraulic) to form blocks out of an appropriate mix of fairly dry inorganic subsoil, non-expansive clay and aggregate. (Wikipedia, 2016)

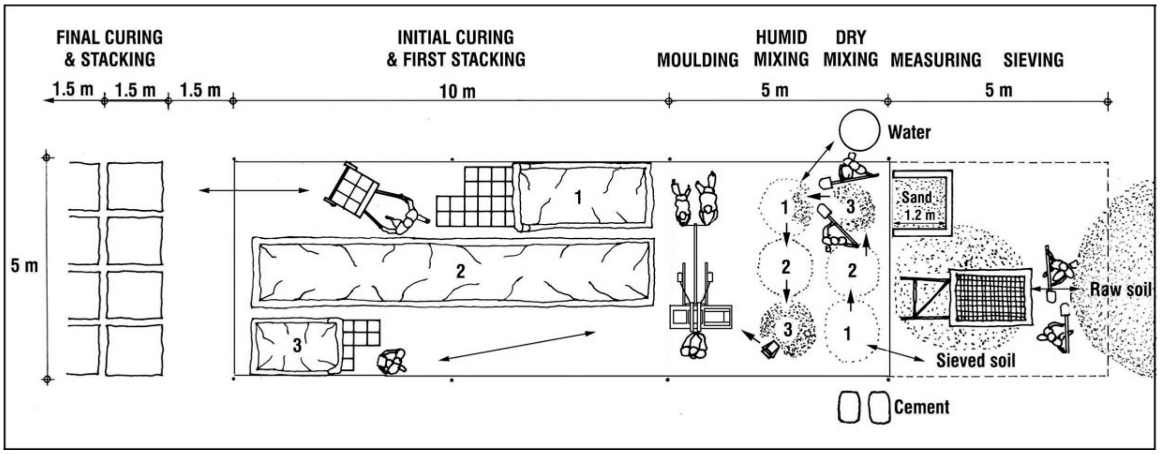
On-site soil can be used, which reduces cost and increases efficiency and sustainability. The uniformity of the blocks simplifies construction, and minimizes or eliminates the need for mortar, thus reducing both the labor and materials costs. The blocks are strong, stable, water-resistant and long-lasting. They have a significantly better overall structural and thermal performance compared to adobe. Producing the blocks and building structures with them doesn't need any specific skill which would fall beyond the local population's reach.

A simple online search reveals that manual units can be purchased from China for less than a 1000 USD. There are open source versions available too. Which means one can download the parts technical design and produce it locally. One such press is Cinva Ram that can be downloaded from Open Source Ecology website.



Examples of open source CEB presses (Opensourceecology.org, 2015)

One idea worth considering would be mass manufacturing the manual block presses in Afghanistan as a governmental initiative and providing villages with a unit or two. It does not need to be fully funded by the government either. It can be sold to the local masons accompanied with a low or zero rent microloan or a partial subside, to encourage local builders or any villager seeing a potential for creating surplus value to begin their own small manufacturing and constructing units. Comparable experiments has been successfully done in several countries such as Uganda (in collaboration with UN-HABITAT) and Sudan (by Division for Educational Policies and Strategies of UNESCO) to name a few.



A typical CEB production unit (Auroville Earth Institute, 2014)

See Appendix d. for a comparative analysis and advantages of CEBs by UN-HABITAT in Uganda

Conclusion

Afghan vernacular architecture can benefit immeasurably from the knowledge and experience acquired by countries with higher exposure to earthquake which have a comparable vernacular building culture. Countries such as Peru, Chile and Pakistan (to name a few) has been hit harder and more often by earthquakes throughout history which has led their building techniques to evolve to a more earthquake resistant version both in an organic way and by shear necessity and urgency of the situation. It would be a missed opportunity for Afghanistan not to utilize their experience and seek their collaboration and assistance in tackling this issue.

Although the availability of technical solutions alone will not be enough to address the unacceptable seismic risk for the millions of Afghans living in unsafe adobe houses, it needs not to be regarded as a binary situation. Each step toward a safer living condition, no matter how small, counts. The authorities and policy makers should be able to see the long term benefit of these simple improvements in reduction of the human cost of earthquakes. Hopefully with assistance of Afghan government this small step can be led to its full fruition.

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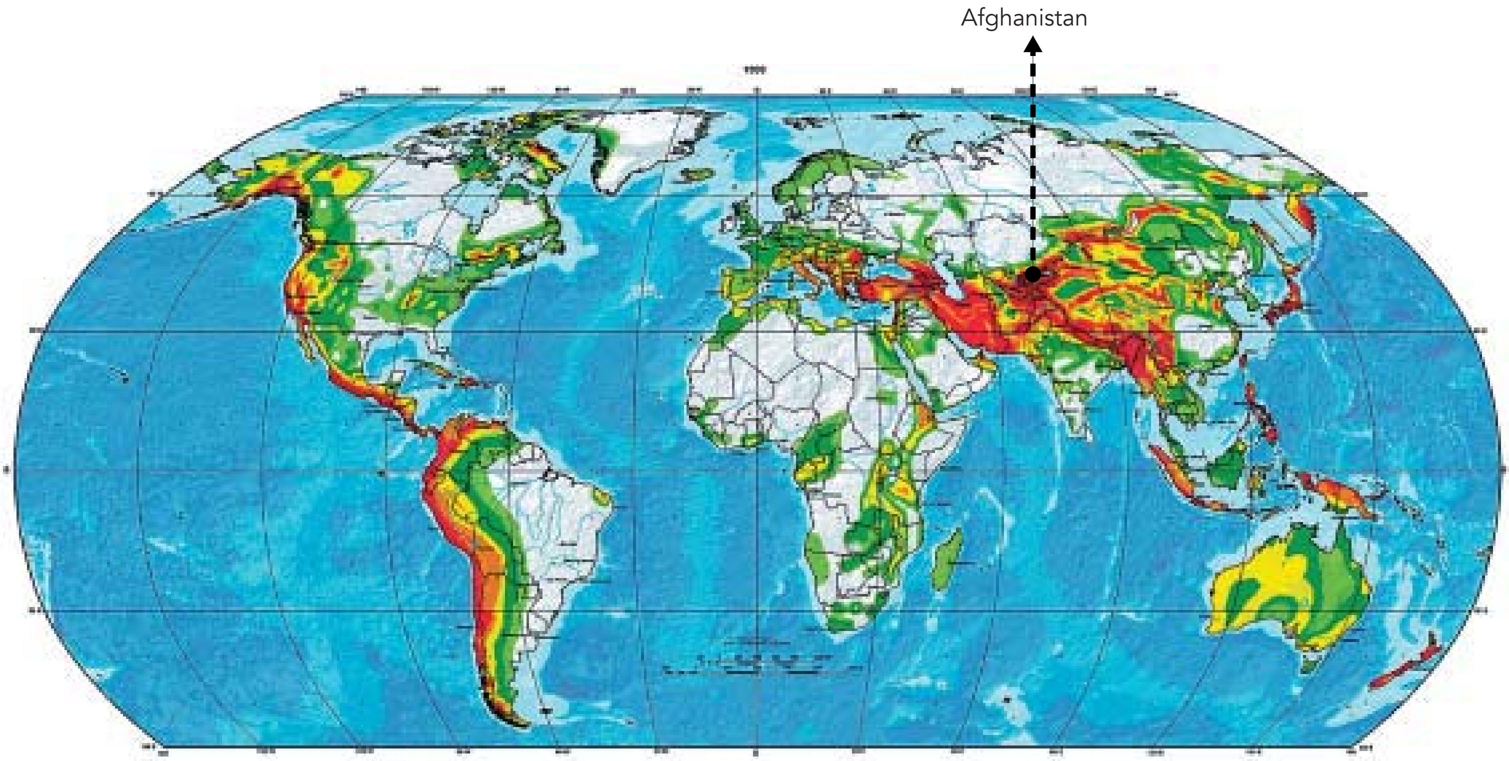
Appendix a

Global Seismic Hazard Map

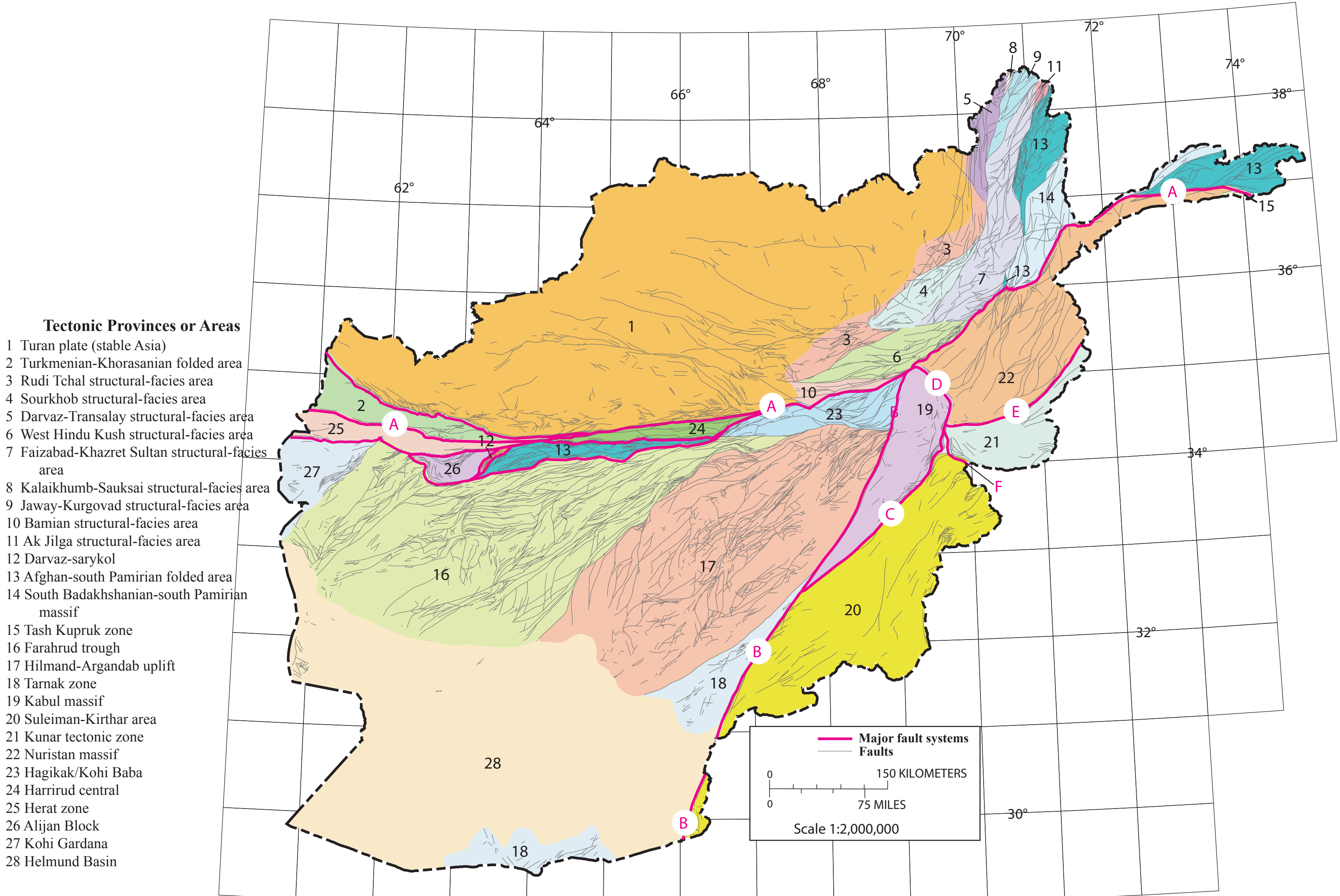
Produced by the Global Seismic Hazard Assessment Program (GSHAP),
Assembled by D. Giardini, G. Grünthal, K. Shedlock, and P. Zhang
(Bachmann & Office fédéral de l'environnement Suisse, 2003)



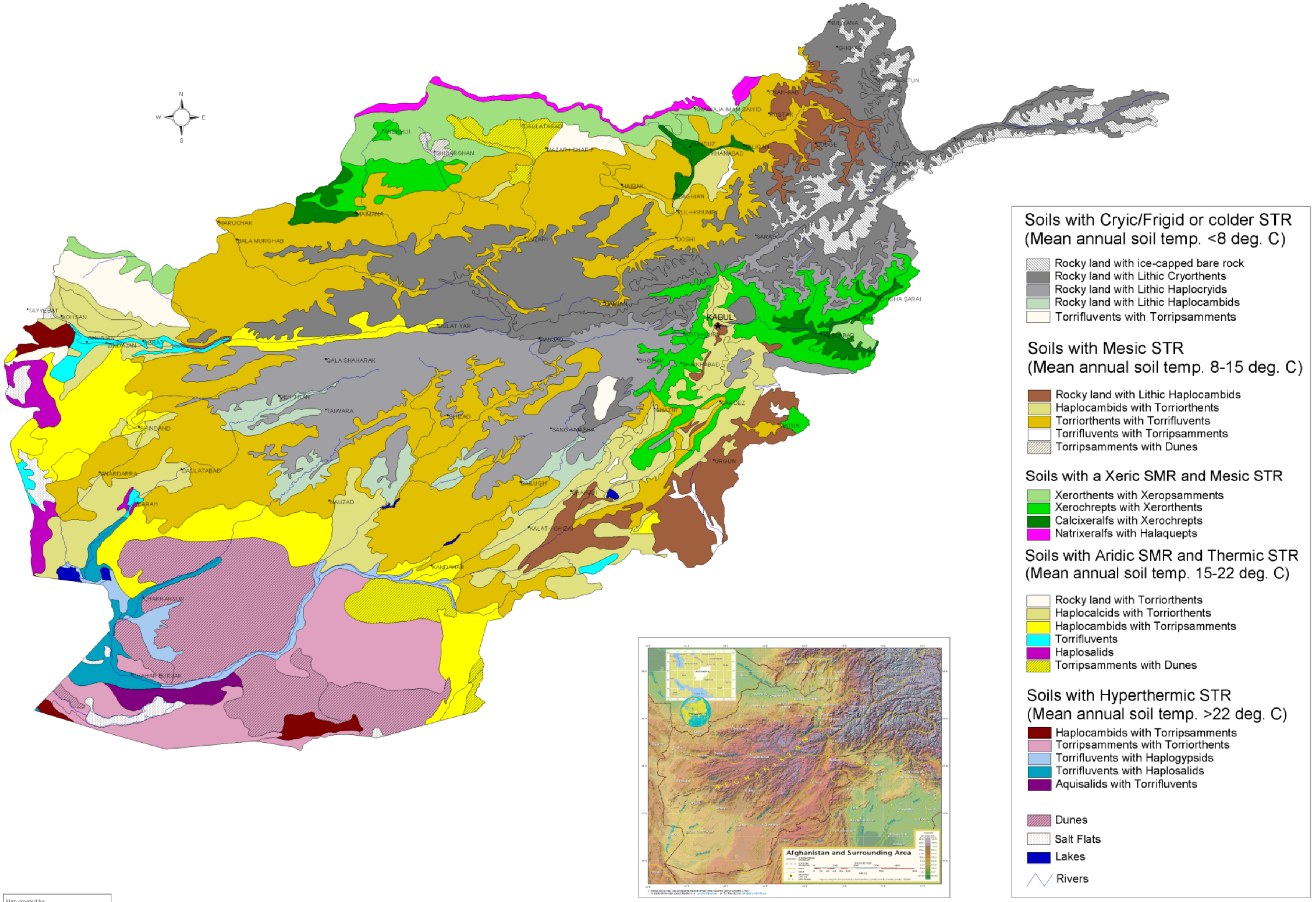
PEAK GROUND ACCELERATION (m/s^2)
10% PROBABILITY OF EXCEEDANCE IN 50 YEARS, 475-year return period

0 0.2 0.4 0.8 1.6 2.4 3.2 4.0 4.8

LOW	MODERATE	HIGH	VERY HIGH
HAZARD	HAZARD	HAZARD	HAZARD


Tectonic Provinces or Areas
1 Turan plate (stable Asia)
2 Turkmenian-Khorasanian folded area
3 Rudi Tchal structural-facies area
4 Sourkhob structural-facies area
5 Darvaz-Transalay structural-facies area
6 West Hindu Kush structural-facies area
7 Faizabad-Khazret Sultan structural-facies area
8 Kalaikhumb-Sauksai structural-facies area
9 Jaway-Kurgovad structural-facies area
10 Bamian structural-facies area
11 Ak Jilga structural-facies area
12 Darvaz-sarykol
13 Afghan-south Pamirian folded area
14 South Badakhshanian-south Pamirian massif
15 Tash Kupruk zone
16 Farahrud trough
17 Hilmand-Argandab uplift
18 Tarnak zone
19 Kabul massif
20 Suleiman-Kirthar area
21 Kunar tectonic zone
22 Nuristan massif
23 Hagikak/Kohi Baba
24 Harrirud central
25 Herat zone
26 Alijan Block
27 Kohi Gardana
28 Helmund Basin
62°
64°
66°
68°
70°
72°
74°
38°
36°
34°
32°
30°
Major fault systems
Faults
0
150 KILOMETERS
0
75 MILES
Scale 1:2,000,000

Soil Regions of Afghanistan



Map created by:
U.S. Department of Agriculture
Natural Resources Conservation Service

For more information contact:
Dr. Hari Eswaran
hari.eswaran@usda.gov

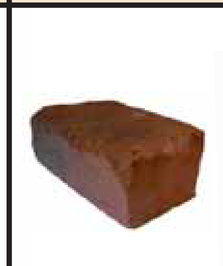
Original Scale 1:1,000,000

Country boundaries are not authoritative

November 2001

COMPARATIVE ANALYSIS and ADVANTAGES OF ISSB

The advantages of ISSB technology are many and even when compared to other technologies; it is affordable, environmentally sound, user friendly, performs well, versatile in use, among others. However, like with any other construction technology, care must be taken to ensure quality. The quality of ISSB's depends on good and locally available soil selection, a stabilizer to compliment the type of soil, and good practices during production and implementation.

Properties	Interlocking Stabilised Soil Block	Sun-dried Mud Block	Burned Clay Brick	Stabilised Soil Blockb	Concrete Masonry Unit
GENERAL INFO					
Block Apperance					
Wall Apperance (not rendered)					
Dimension (L x W x H) (cm)	26.5 x 14 x 10 cm	25 x 15 x 7 cm to 40 x 20 x 15	20 x 10 x 10 cm	29 x 14 x 11.5 cm	40 x 20 x 20 cm
Weight (kg)	8-10 kg	5-18 kg	4-5 kg	8-10 kg	12-14 kg
Texture	Smooth and flat	rough and powdery	rough and powdery	smooth and flat	coarse and flat
Blocks needed to make up a sq.m.	35	10 to 30	30	21	10
PERFORMANCE					
Wet Compressive Strength (mps)	1 - 4	0 - 5	0.5 - 6	1 - 4	0.7 - 5
Thermal Insulation (W/m C)	0.8 - 1.4	0.4 - 0.8	0.7 - 1.3	0.8 - 1.4	1 - 1.7
Density (kg/m3)	1700 - 2200	1200 - 1700	1400 - 2400	1700 - 2200	1700 - 2200
AVG. PRICE (2009)					
Per Block (UgS)	350	50	150	400	3000
Per Sq Meter	35000	10000	55000	45000	75000

Information for this chart gathered from Craterre publication: "Compressed Earth Blocks :Manual of Production" and GET