Seismic performance of adobe buildings

A presentation
in
Three Acts

Marcial Blondet
October 2012

Catholic University of Peru
Departament of Engineering

Act 1

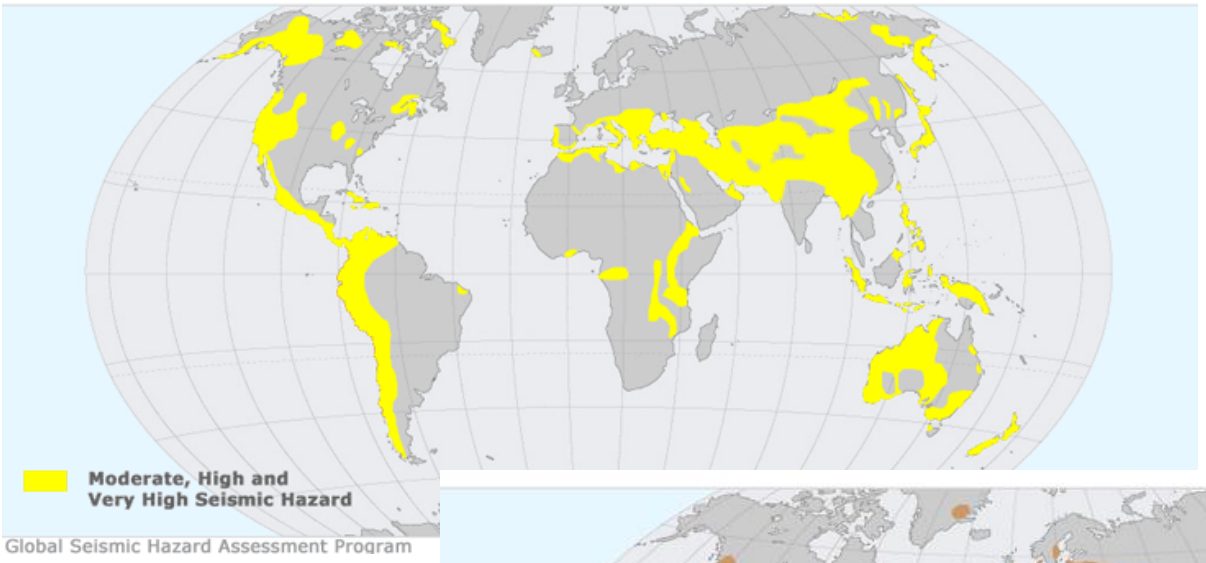
The Perverse Combination

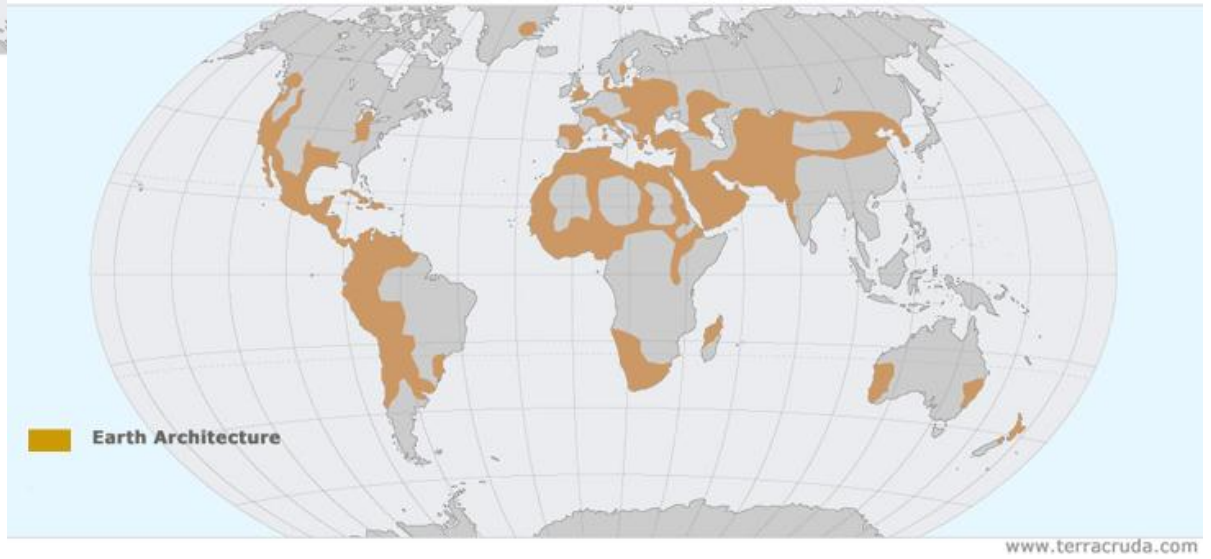
Humans have been building with earth all over the world for thousands of years

Courtesy of Hubert Guillaud

Djenné, Mali

Many developing countries where building with earth is common are located in seismic areas





De Sensi (2003)

Earthen constructions and earthquakes are a *perverse combination*

Pakistan, 2005

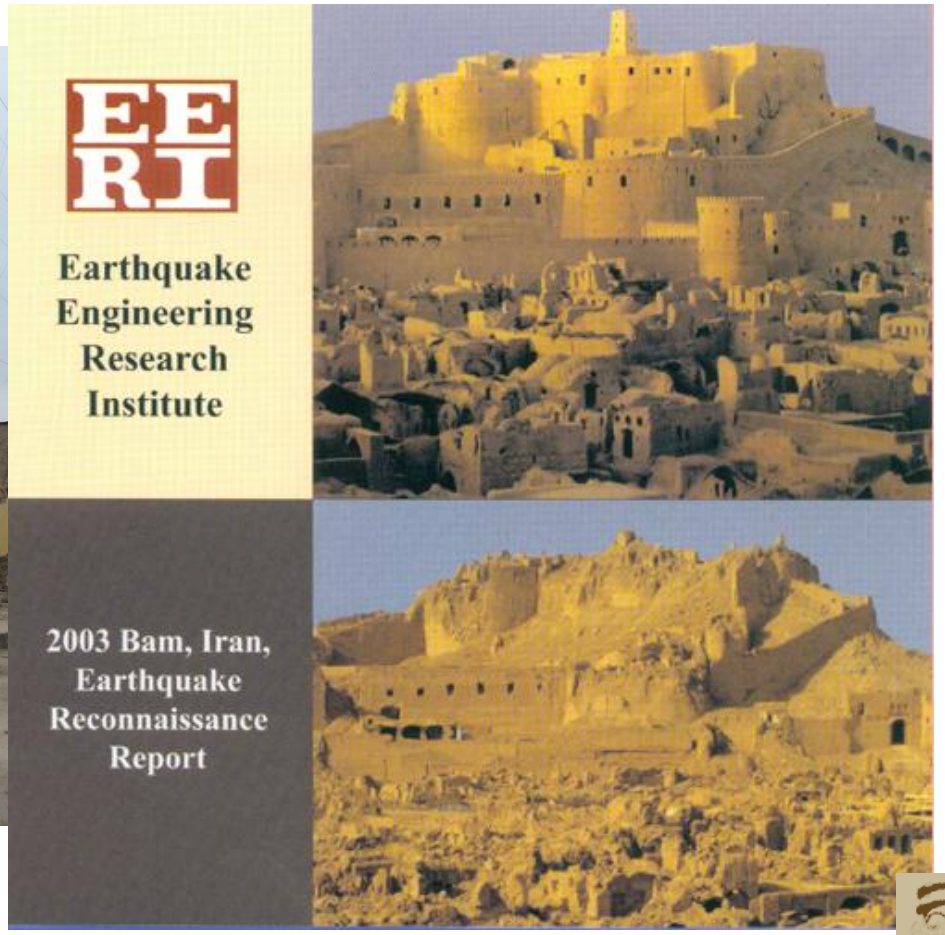
China, 2010

Unreinforced earthen constructions collapse during earthquakes because earthen material is heavy, weak and brittle

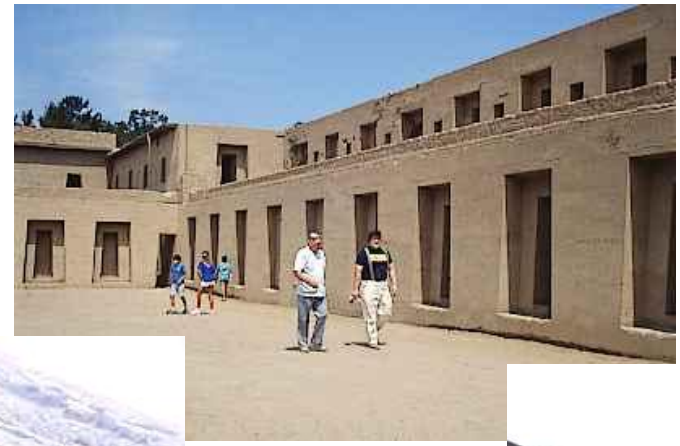
Dominic Dowling

NISEE

Many precious earthen monuments have been lost or heavily damaged by earthquakes



Peru is a seismic country with a long tradition of building with earth



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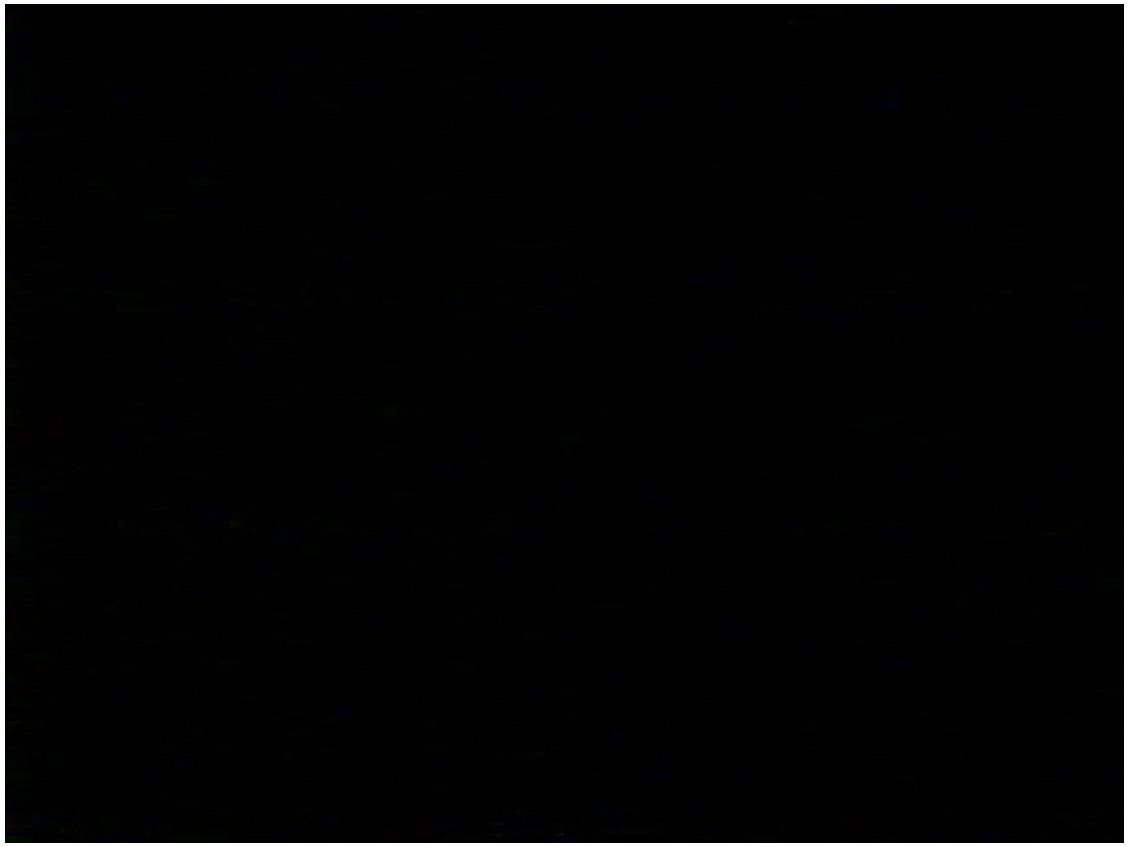
During the1970 Huaraz earthquake, around 30 000 persons were killed by their own adobe houses

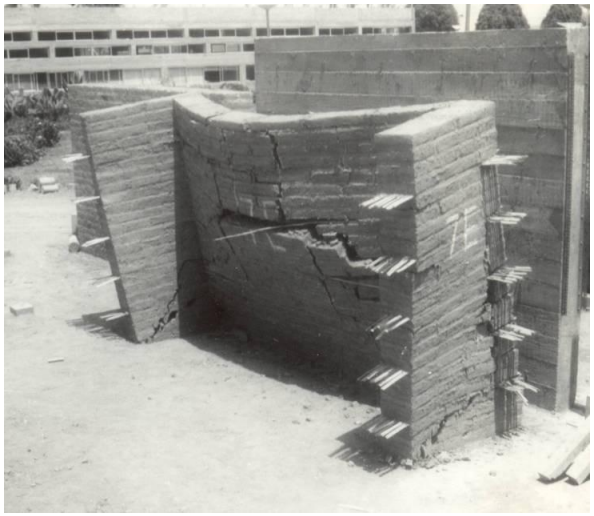
The1970 Huaraz earthquake was the worst tragedy caused by a natural phenomenon in Peru



The Huaraz earthquake motivated us to start investigating about adobe structures

NISEE

In the 70s we had very rudimentary testing capabilities



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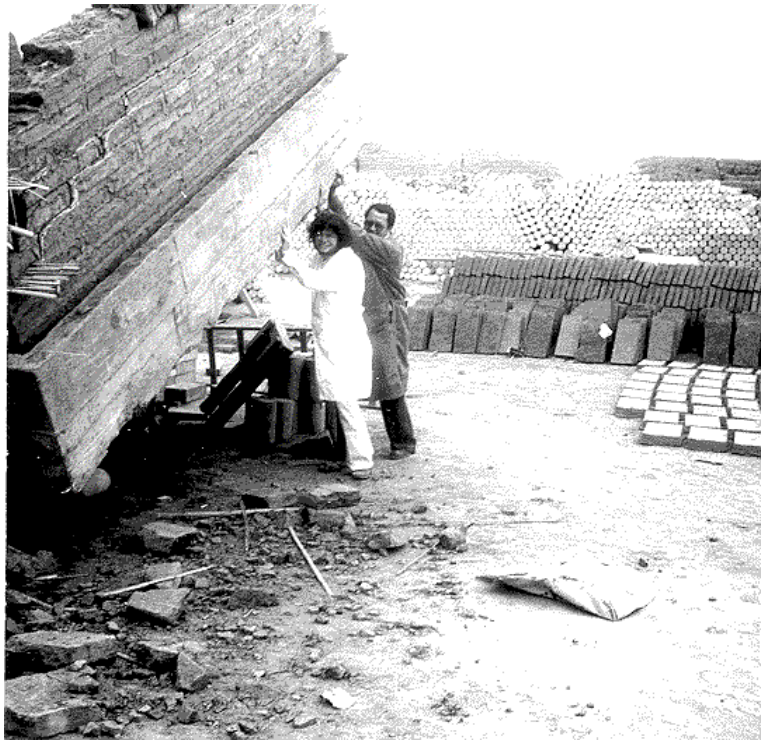
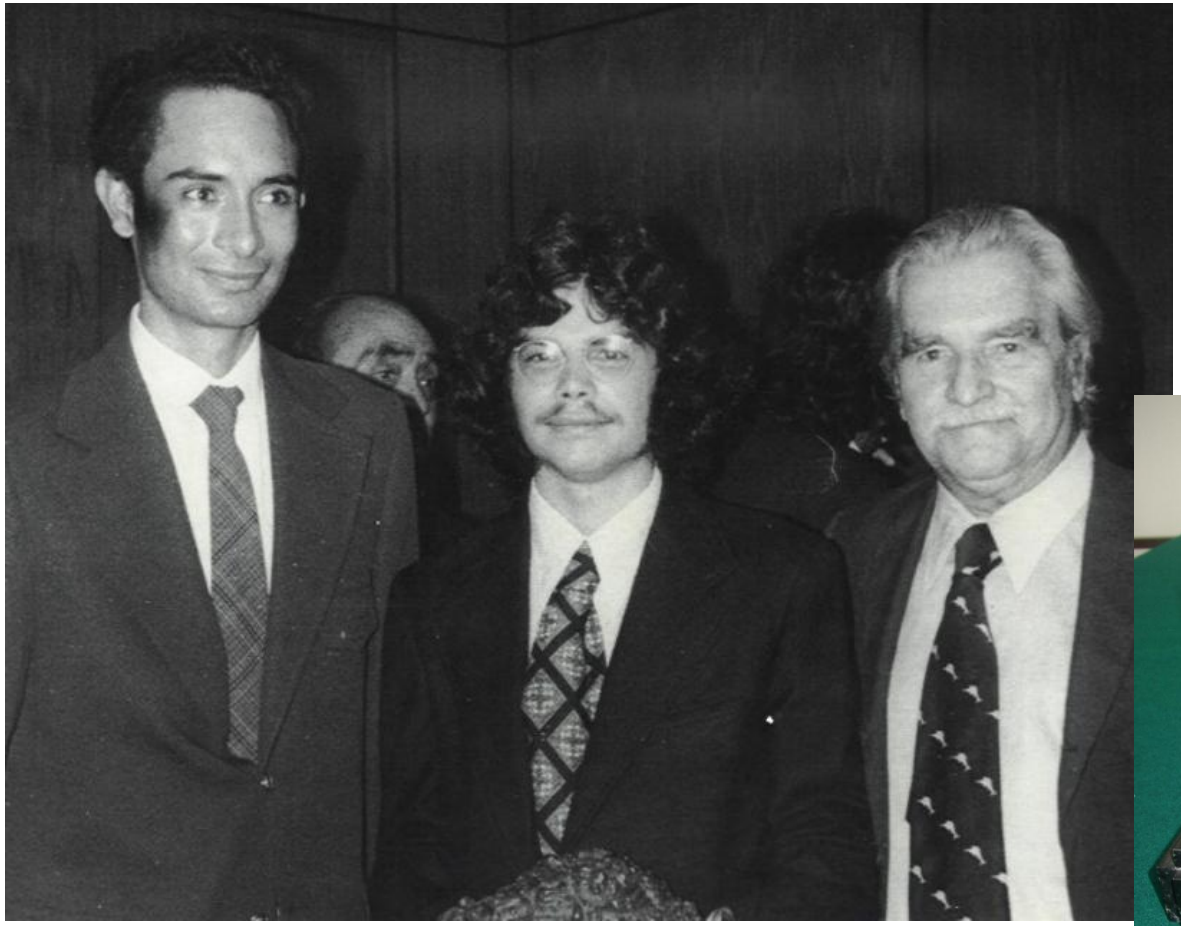
Miguel Corazao designed a tilting platform to test full-scale adobe housing models

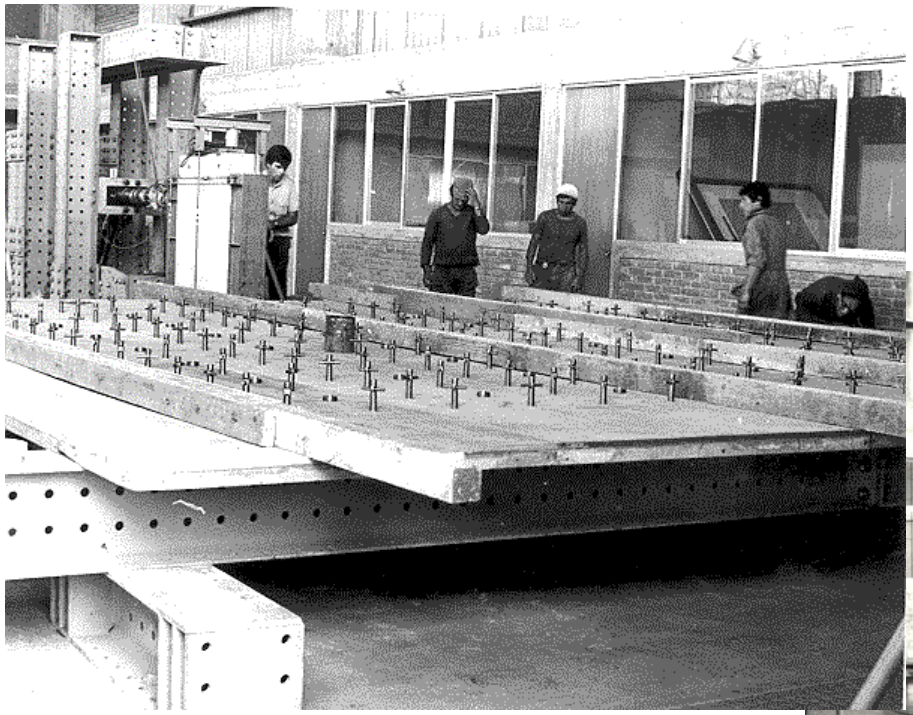
We attempted to find simple reinforcement solutions for adobe houses

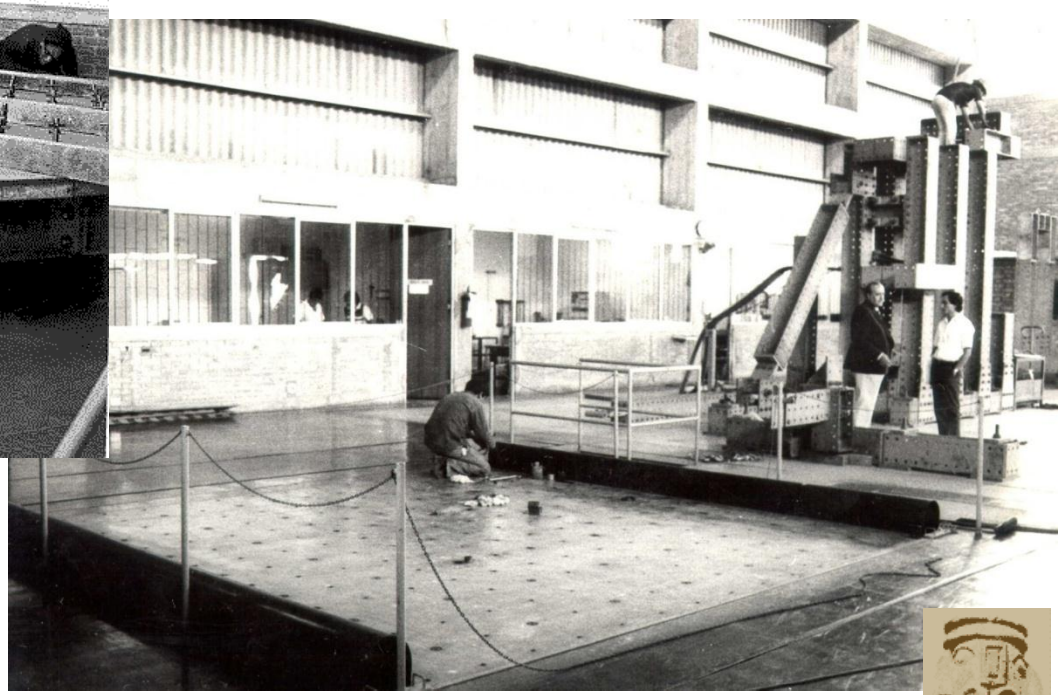


Miguel's research project obtained the 1973 "Sayhuite" Award

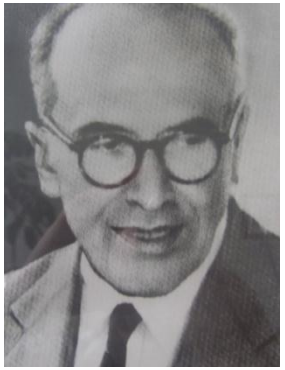


We then obtained funds from the governments of the Netherlands and Peru to develop an earthquake engineering lab at the PUCP





The Antiseismic Structures Laboratory “Cristóbal de Losada y Puga” was inaugurated on October 22, 1979

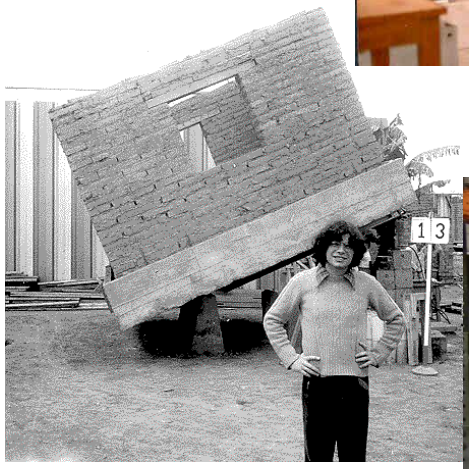


We are now able to perform more sophisticated tests because we have adequate infrastructure, facilities and equipment

We have been working since the 1970s to develop earthquake-resistant solutions for earthen construction

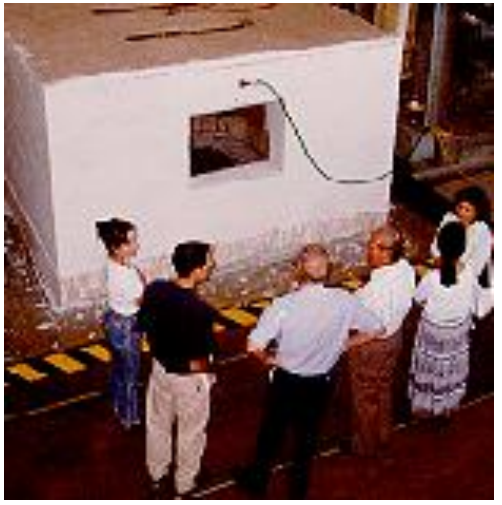
1983

1985



1974

2004



1997

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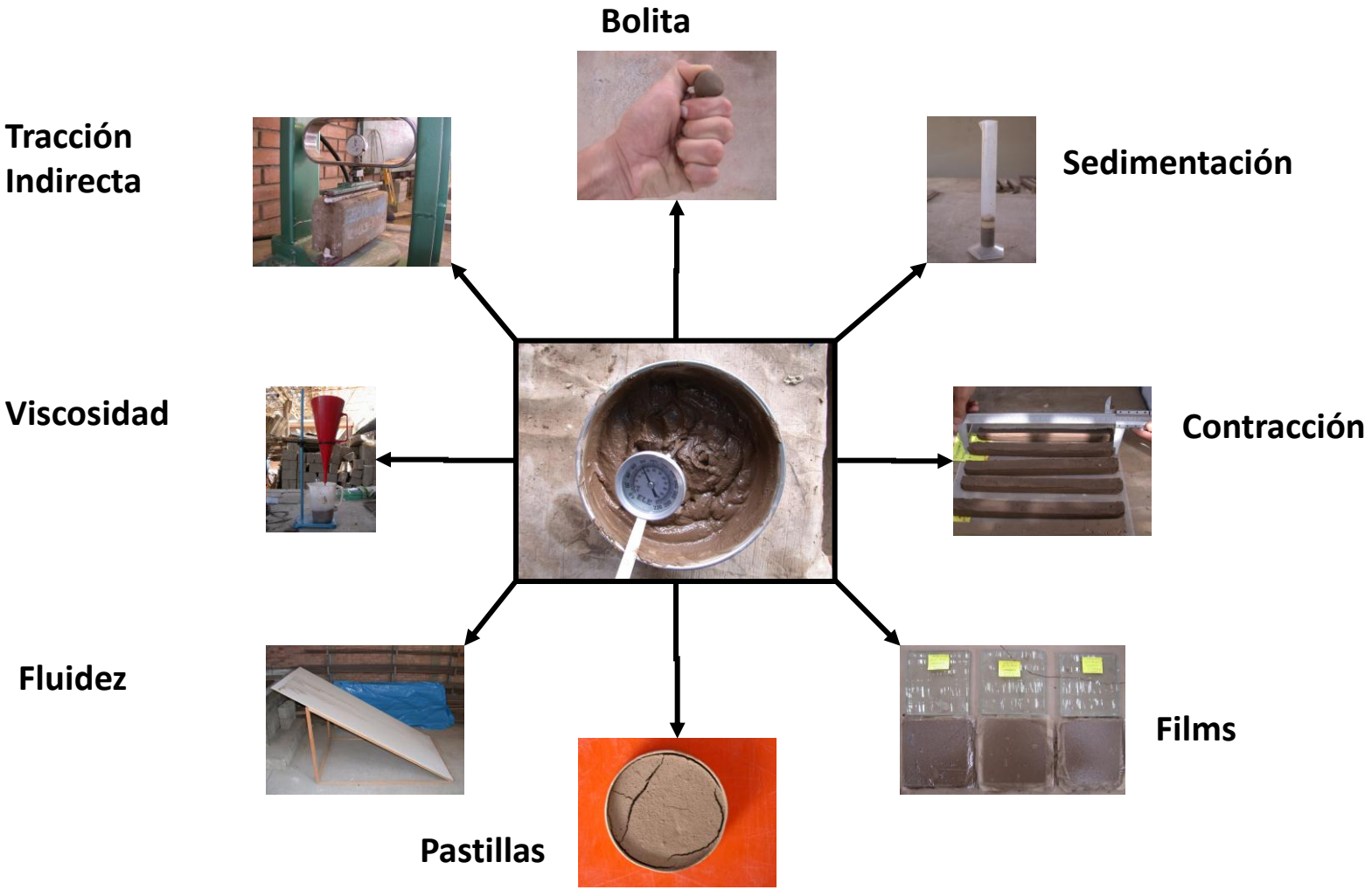
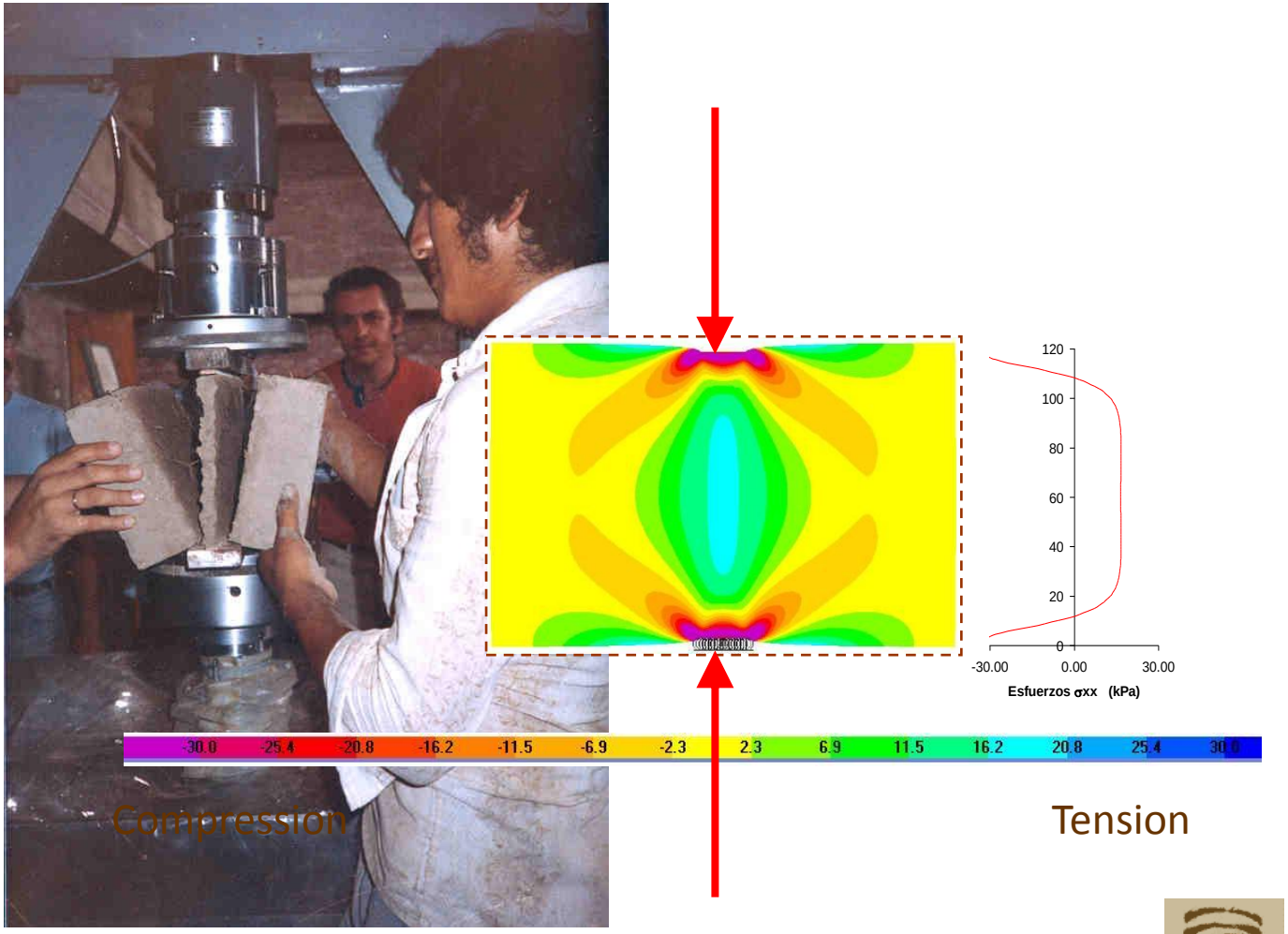
We are studying simple field methods to evaluate soils for adobe construction



We developed the indirect tension test with adobe sandwiches

Prof. Julio Vargas observes with great attention an indirect tension test of an adobe sandwich



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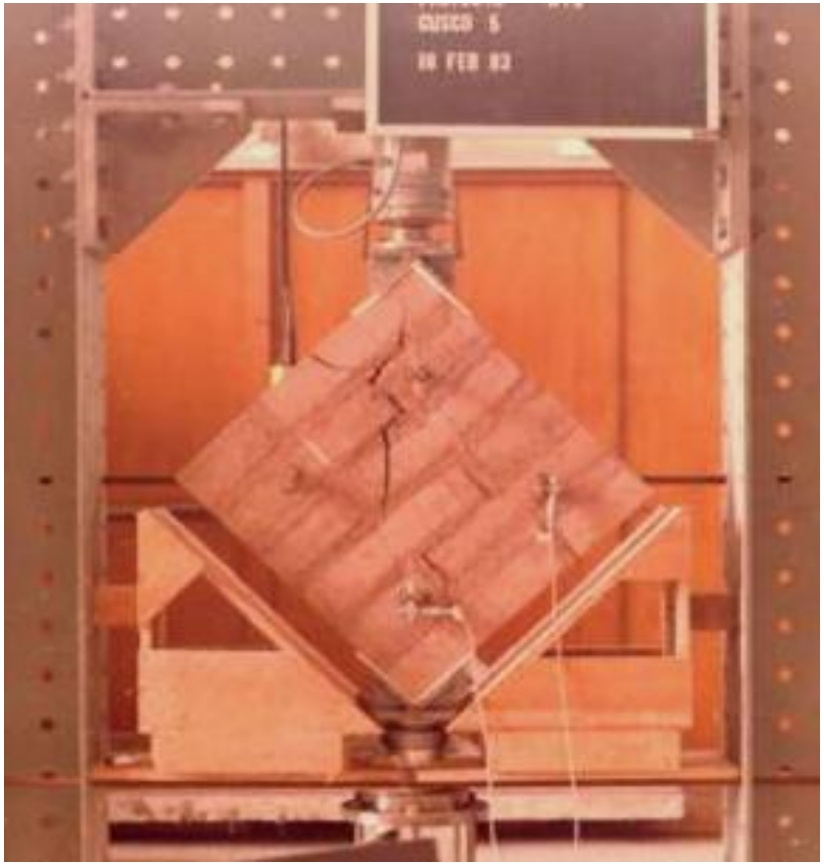
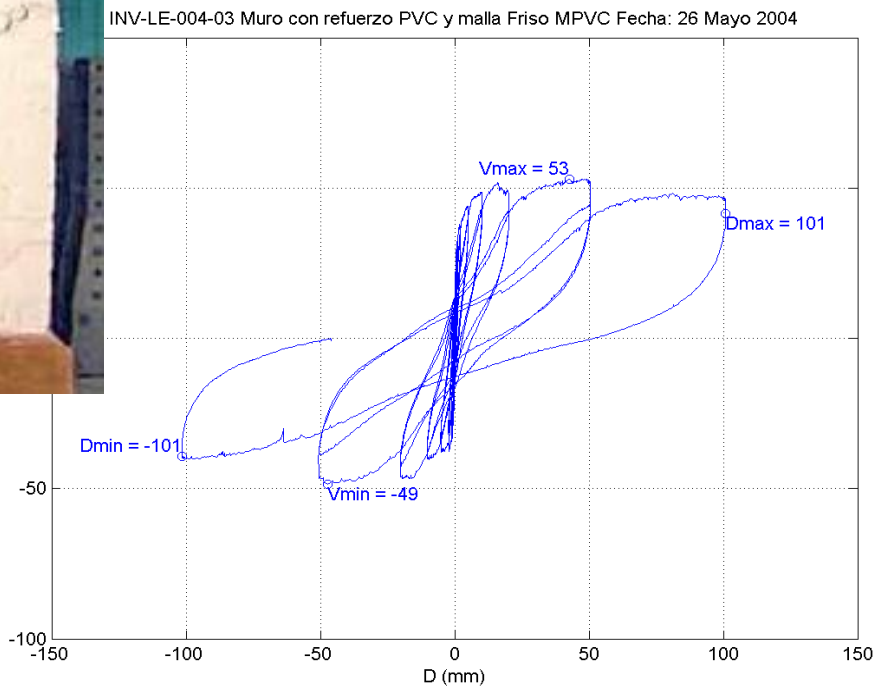
The diagonal compression test is used to measure the shear strength of the adobe masonry



Full scale tests of adobe walls subjected to in-plane and out-of plane loads are required to estimate their cyclic response

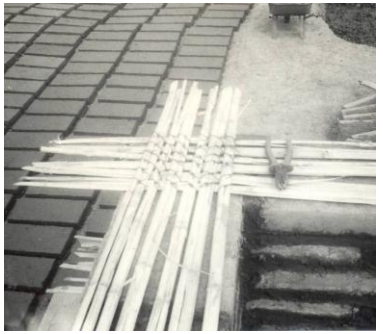


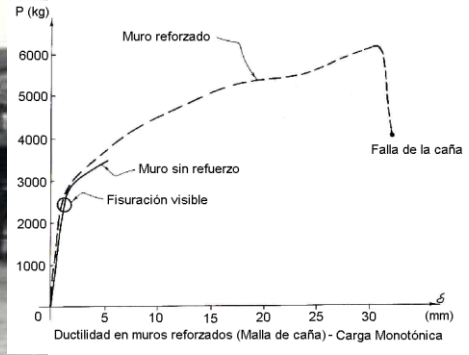
Shaking table test of full-scale models are the best way to understand seismic response of adobe structures

Act 2

A Life-saving Net

From the beginning it was clear that the adobe walls required seismic reinforcement to achieve some ductility (we reinforce concrete, don't we?)



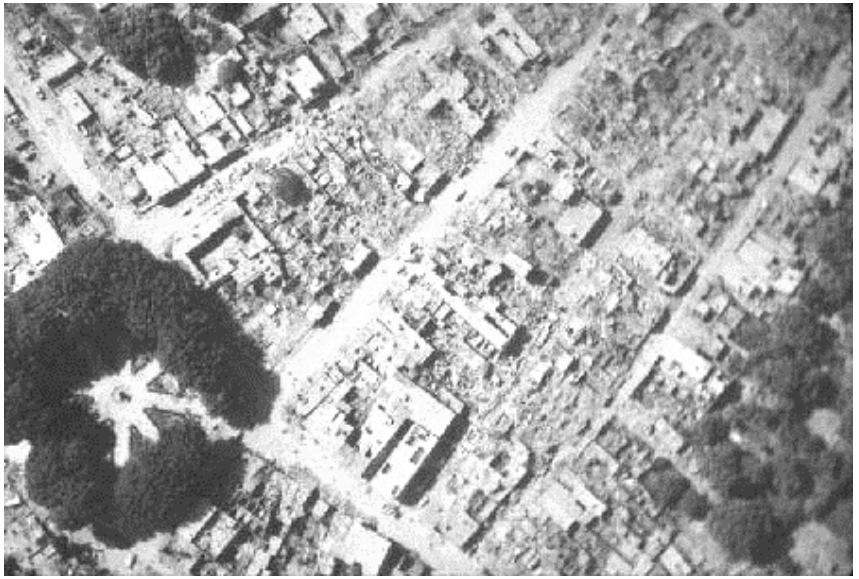


The adobe walls will break into pieces during shaking. Therefore some kind of net is required to keep the pieces together and avoid collapse

Traditional construction

Reinforced construction

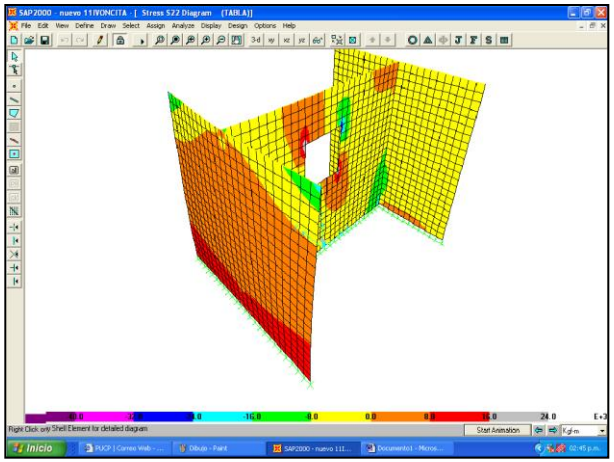
There is not enough cane to rebuild thousands of earthen houses after a strong earthquake



Casma, Ancash, 1970 (NISEE)

Since 2004 we are performing research on the use of synthetic materials to provide seismic reinforcement for earthen structures

Ivonne Madueño



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We have explored the use of internal and external reinforcement nets made with plastic

Internal PVC pipes and plastic mesh reinforcement

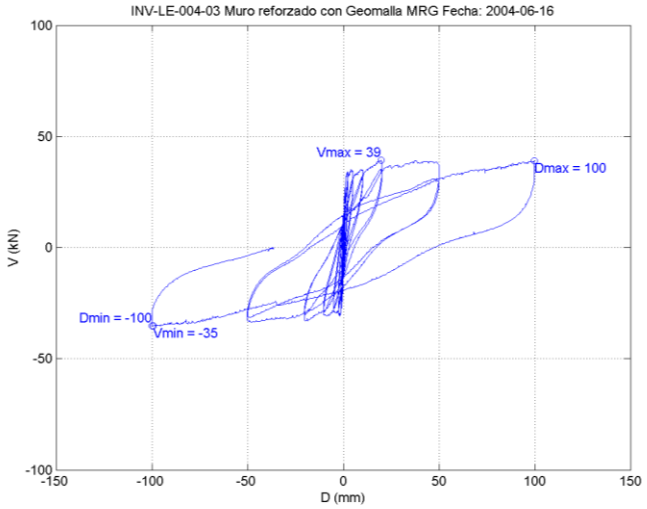
External geomesh reinforcement

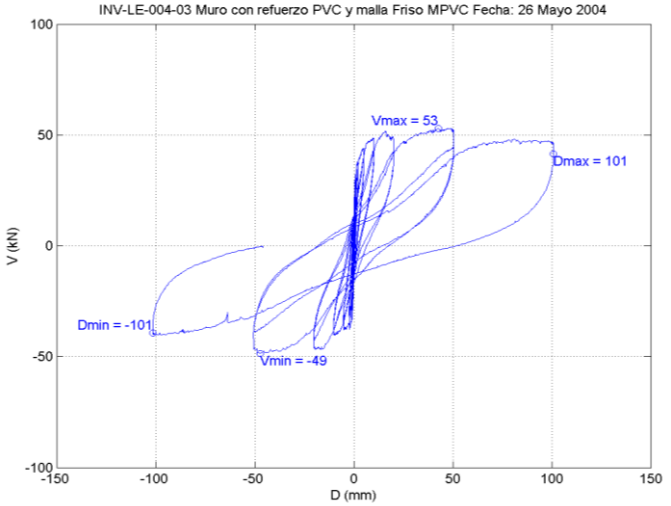
Adobe walls with plastic reinforcement showed excellent response to cyclic loading

Internal reinforcement: a net of PVC tubes and plastic mesh

External geomesh reinforcement

Adobe walls with plastic reinforcement showed excellent response to cyclic loading





In 2005 we developed a joint project with the Getty Conservation Institute to study reinforcement alternatives for earthen construction

External reinforcement net made with cane rods and rope

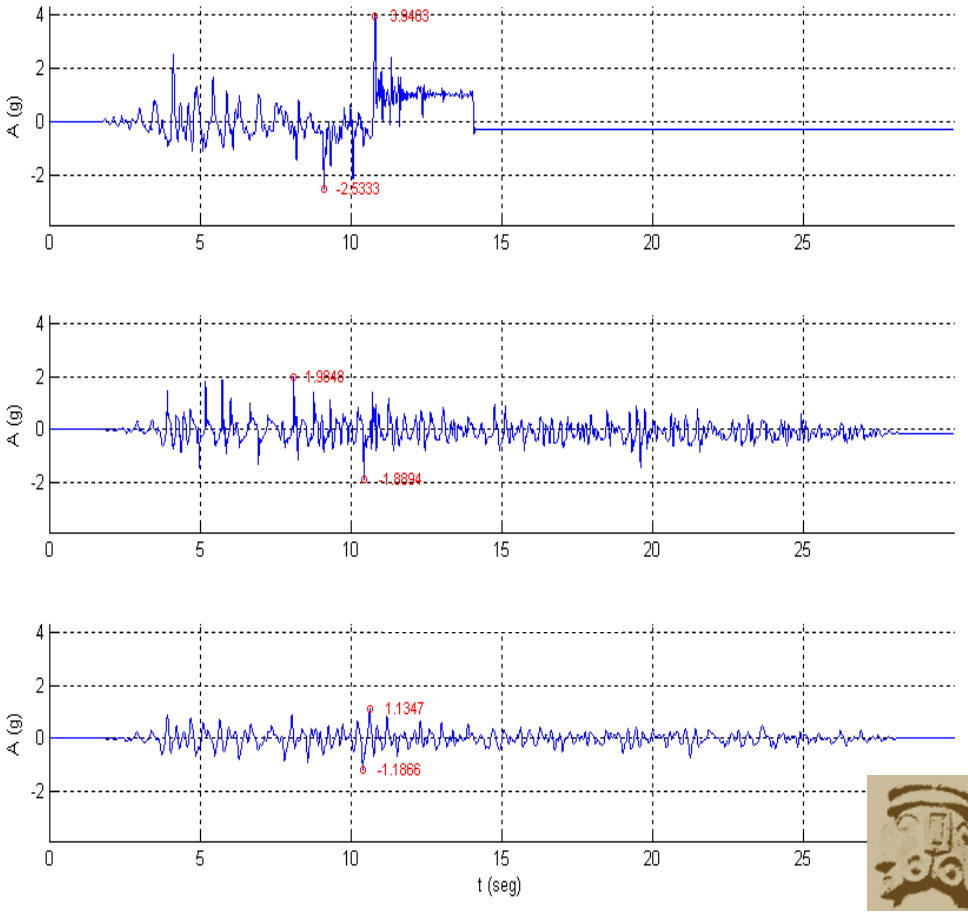
External geomesh reinforcement

An unreinforced model represented a typical adobe dwelling

An unreinforced model represented a typical adobe dwelling

As expected, the unreinforced model collapsed during shaking

M000 after (D = 130 mm) test



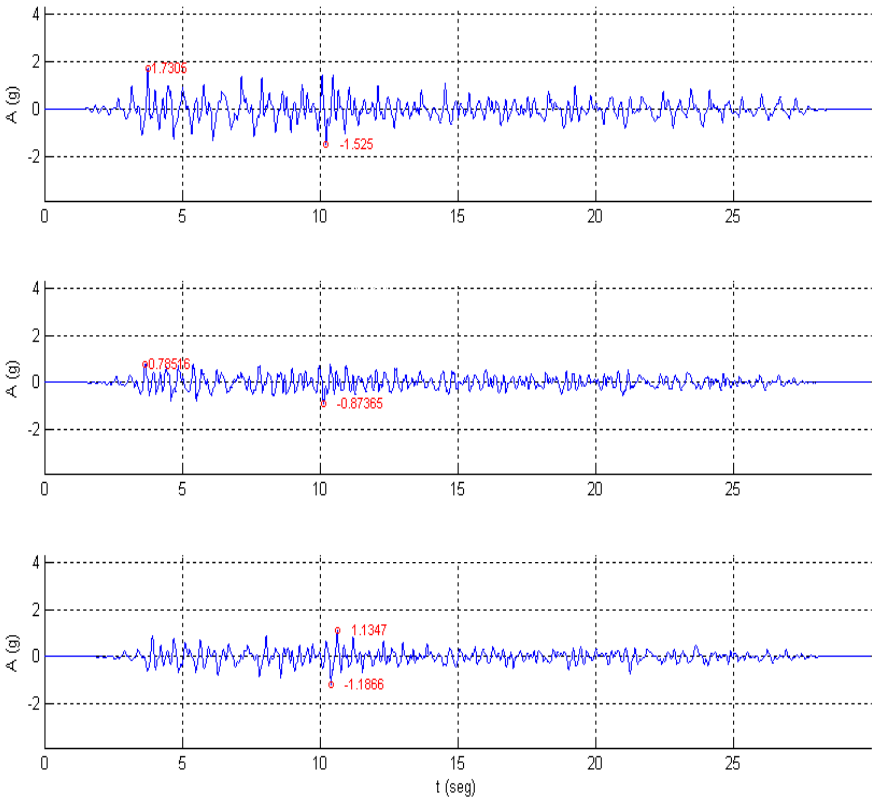
Model M100-T12 was fully reinforced with a polymer mesh (geogrid) and a wooden crown beam

PUCP – GCI Project

The geomesh reinforcement was effective to prevent seismic damage

The model reinforced with geomesh suffered only slight damage after strong shaking

M100-T12 after D = 130 mm test



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A cheap plastic mesh was also studied

The plastic mesh kept the structure together

The plastic mesh avoided collapse, but the house was unrepairable after the strong shaking

Reinforcement made with welded steel mesh covered by cement mortar increases the seismic strength but does not provide ductility

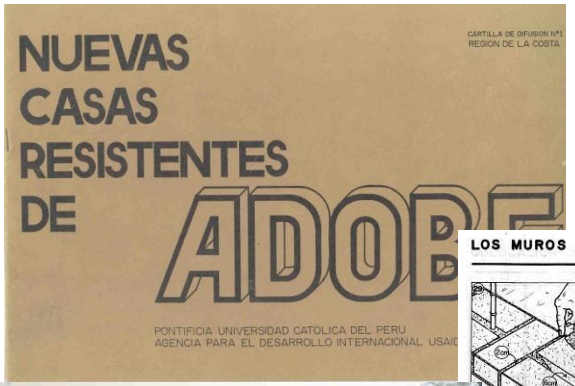
Conclusions

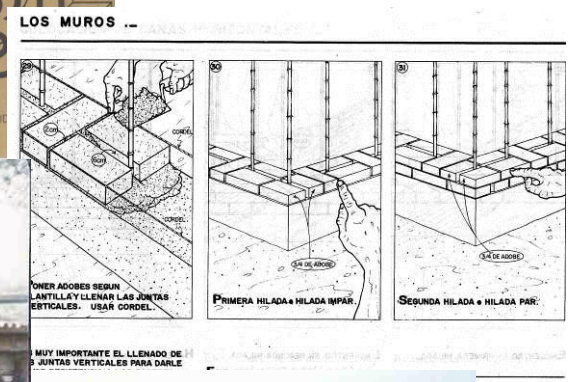
- Unreinfored earthen constructions will suffer heavy damage or collapse during earthquakes
- Reinforcement must be provided to protect earthen buildings located in seismic areas
- Reinforcement should be made of materials compatible with earthen material

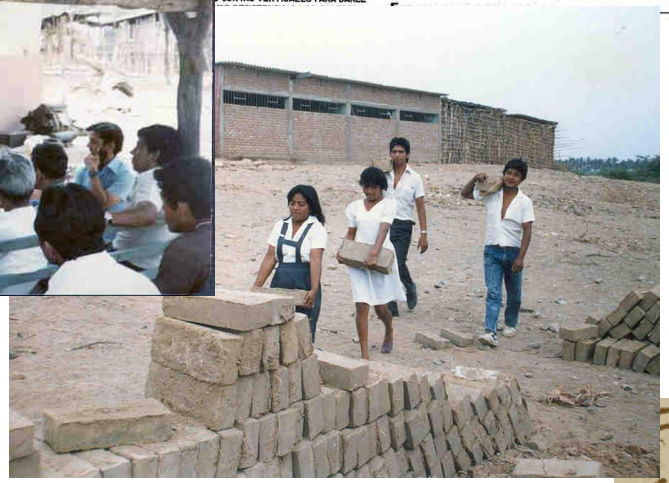
Act 3

What about the people?

We have made attempts to show the users how to build earthquake-resistant adobe houses…







Our work has been recognized worldwide


THE BIG IDEA | EARTHQUAKE ENGINEERING

Safe Houses

The earthquake in Haiti was a reminder: Billions of people live in houses that can't stand shaking. Yet safer ones can be built cheaply—using straw, adobe, old tires—by applying a few general principles.

In Los Angeles, Tokyo, and other rich cities in fault zones, the added expense of making buildings earthquake resistant has become a fact of life. Concrete walls are reinforced with steel, for instance, and a few buildings even rest on elaborate shock absorbers. Strict building codes were credited with saving thousands of lives when a magnitude 8.8 quake hit Chile in late February. But in less developed countries like Haiti, where a powerful quake in January killed some 222,500 people and left more than a million homeless, conventional earthquake engineering is often unaffordable. "The devastation in Haiti wouldn't happen in a developed country," says engineer Marcial Blondet of the Catholic University of Peru, in Lima. Yet it needn't happen anywhere. Cheap solutions exist.

Blondet has been working on ideas since 1970, when an earthquake in Peru killed 70,000 or more, many of whom died when (Continued on next page)

Pakistan
MOST DESTRUCTIVE QUAKE
LOCATION Northern Pakistan/Kashmir
MAGNITUDE 7.6
FATALITIES 75,000

Haiti
January 12, 2010
Port-au-Prince area
7.0
222,500

Peru
May 31, 1970
Chimbote
7.9
70,000

Indonesia
December 26, 2004
Sumatra
9.1
227,900 (includes global tsunami deaths)

Light walls and gables
Lightweight structures are subject to smaller forces and are less likely to fall when the ground shakes.

Quake-resistant houses are being built in Pakistan—of straw. The compressed bales are held together by nylon netting and sandwiched between layers of plaster.

Light roofs
In Haiti heavy concrete roofs collapsed on many homes; in general, metal roofs on wooden trusses are more resilient.

Small windows
Small, regularly spaced openings create fewer weak spots in walls. But the bigger problem in Haiti was that walls were not properly reinforced.

Bamboo
Reinforced walls
The reinforcing rods need not be made of metal. Natural materials such as eucalyptus or bamboo work well too.
In Peru the walls of some adobe houses have been retrofitted with a plastic mesh to prevent collapse.
Mesh

Crown beam
Corner column
Confined masonry
In Indonesia and elsewhere, brick walls can be framed and connected to the roof by corner columns and a crown beam of reinforced concrete. In a quake the structure moves as a unit.
Metal rod
Shock absorbers
Trays filled with stones or sand and fastened between floor and foundation can serve as cheap ground-motion absorbers for many types of building.

SOURCES: GERNOT MINKE, UNIVERSITY OF KASSEL; ELIZABETH A. HAUSLER, BUILD CHANGE; NINA LAVIS, UNIVERSITY OF CALIFORNIA, SAN DIEGO; MARCIAL BLONDET AND ALVARO RAMOS, CATHOLIC UNIVERSITY OF PERU; PIERRE PAU, POLITECNICO DI MILANO; UNIVERSITY OF BUFFALO; USAID

30 NATIONAL GEOGRAPHIC • JUNE 2010


BBC NEWS

Peru rebuilds two years on from quake

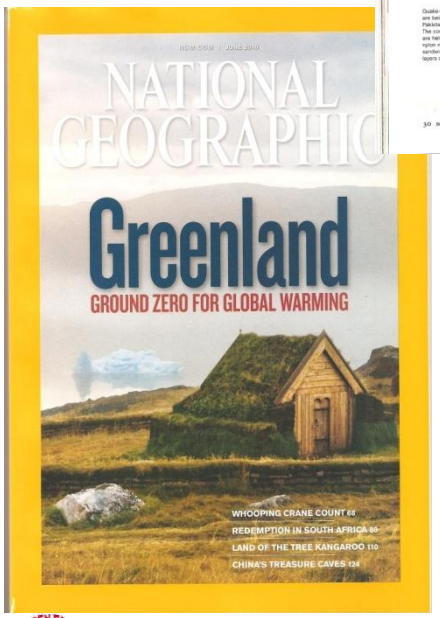
By Dan Collyns
BBC News, Chincha, Peru

Since 1970, Peru has been hit by five powerful and deadly earthquakes. The latest struck Peru's coast exactly two years ago with a magnitude of 8.0 on the Richter scale.

It fiercely shook the capital Lima, but its devastating epicentre was about 200km (124 miles) to the south, near the town of Pisco, a small fishing port built largely of adobe - mud bricks which Peruvians have used for thousands of years.

More than 500 people were killed and about 75,000 homes were left uninhabitable.

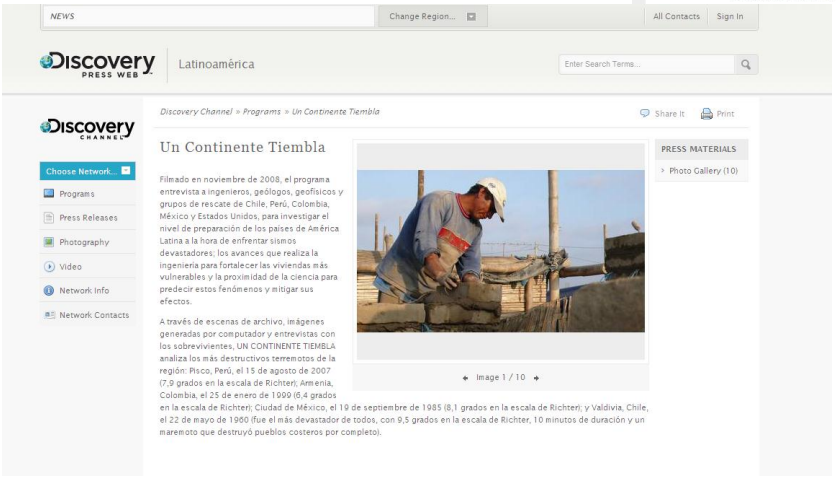
For Peruvian engineer Marcial Blondet, it was the devastating quake in 1970 that first motivated him to develop earthquake-resistant buildings, particularly for those who could least afford them.


NATIONAL GEOGRAPHIC

Greenland

GROUND ZERO FOR GLOBAL WARMING

WHOOPING CRANE COUNT 68
REDEMPTION IN SOUTH AFRICA 80
LAND OF THE TREE KANGAROO 110
CHINA'S TREASURE CAVES 124


Discovery PRESS WEB

Latinoamérica

Discovery Channel » Programs » Un Continente Tiembla

Un Continente Tiembla

Filmado en noviembre de 2008, el programa entrevista a ingenieros, geólogos, geofísicos y grupos de rescate de Chile, Perú, Colombia, México y Estados Unidos, para investigar el nivel de preparación de los países de América Latina a la hora de enfrentar sismos devastadores; los avances que realiza la ingeniería para fortalecer las viviendas más vulnerables y la proximidad de la ciencia para predecir estos fenómenos y mitigar sus efectos.

A través de escenas de archivo, imágenes generadas por computador y entrevistas con los sobrevivientes, UN CONTINENTE TIEMBLA analiza los más destructivos terremotos de la región: Pisco, Perú, el 15 de agosto de 2007 (7,9 grados en la escala de Richter); Armenia, Colombia, el 25 de enero de 1999 (6,4 grados en la escala de Richter); Ciudad de México, el 19 de septiembre de 1985 (8,1 grados en la escala de Richter); y Valdivia, Chile, el 22 de mayo de 1960 (fue el más devastador de todos, con 9,5 grados en la escala de Richter, 10 minutos de duración y un maremoto que destruyó pueblos costeros por completo).

Image 1 / 10

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We know that it is possible to build safe adobe houses in seismic areas

However…

… no one has spontaneously built his adobe house using seismic reinforcement

Why?

We think this is because:

1. Inadequate communication methods
2. Additional cost (time and money)
3. Resistance to change
4. Short seismic memory
5. Negative reaction to foreign intervention

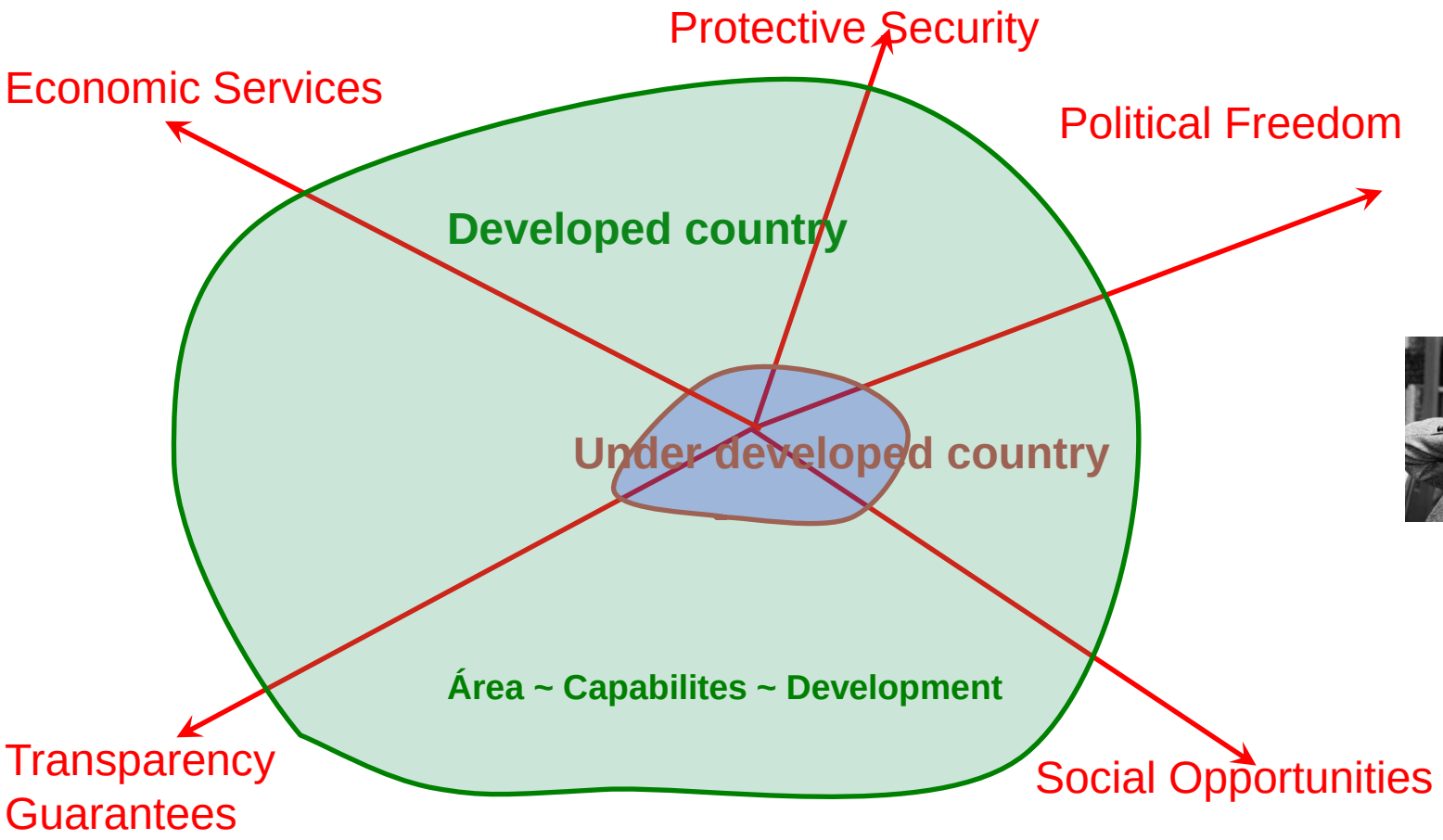
The August 15, 2007 Pisco earthquake killed near 600 persons and destroyed almost 75,000 houses, most of then built with adobe

Many families rebuilt their homes the same way as before

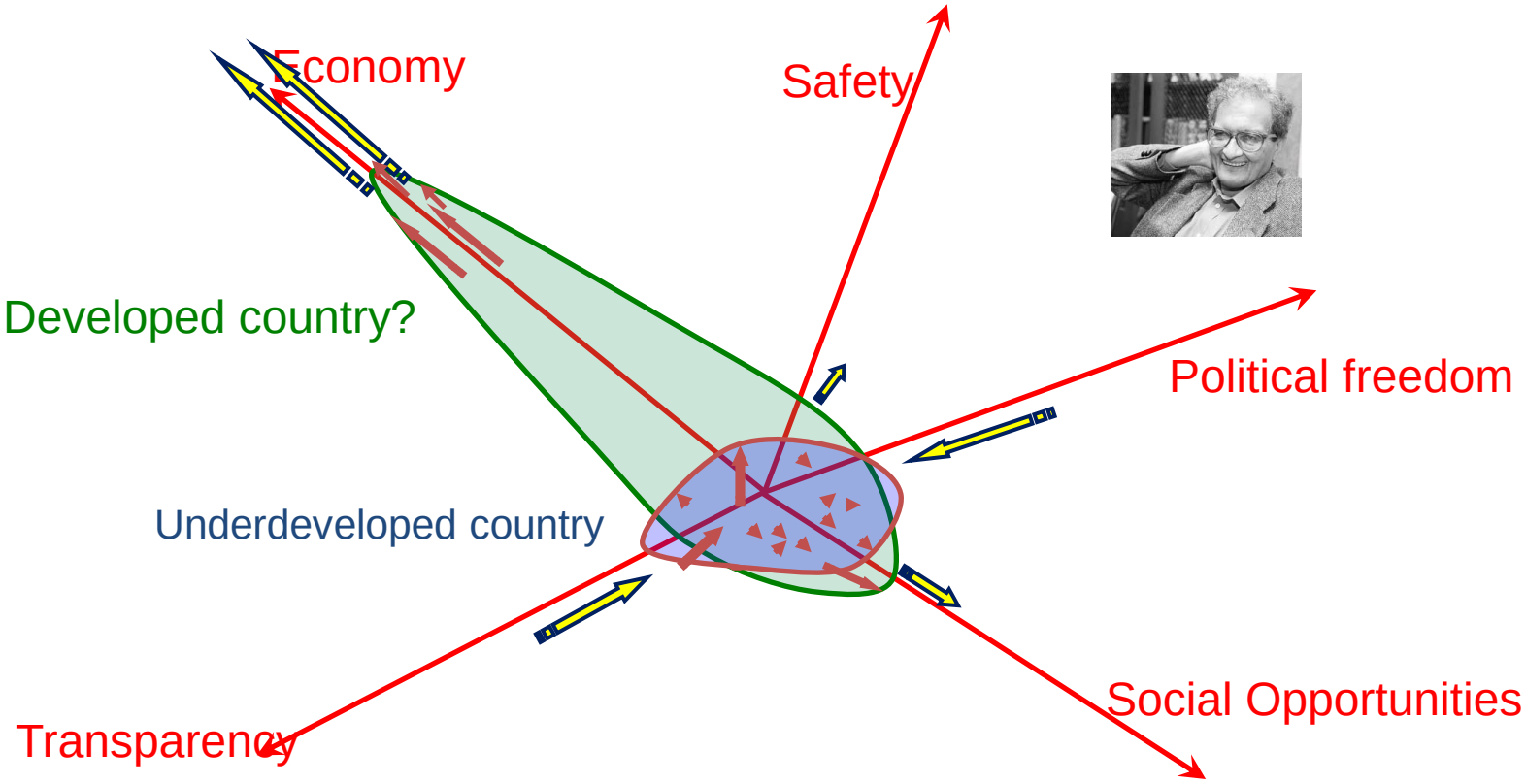
This tragedy gave us an opportunity to try a different approach to the reconstruction of the affected areas

This approach is based on the philosophy of human development presented by Amartya Sen (1988 Economics Nobel Prize)

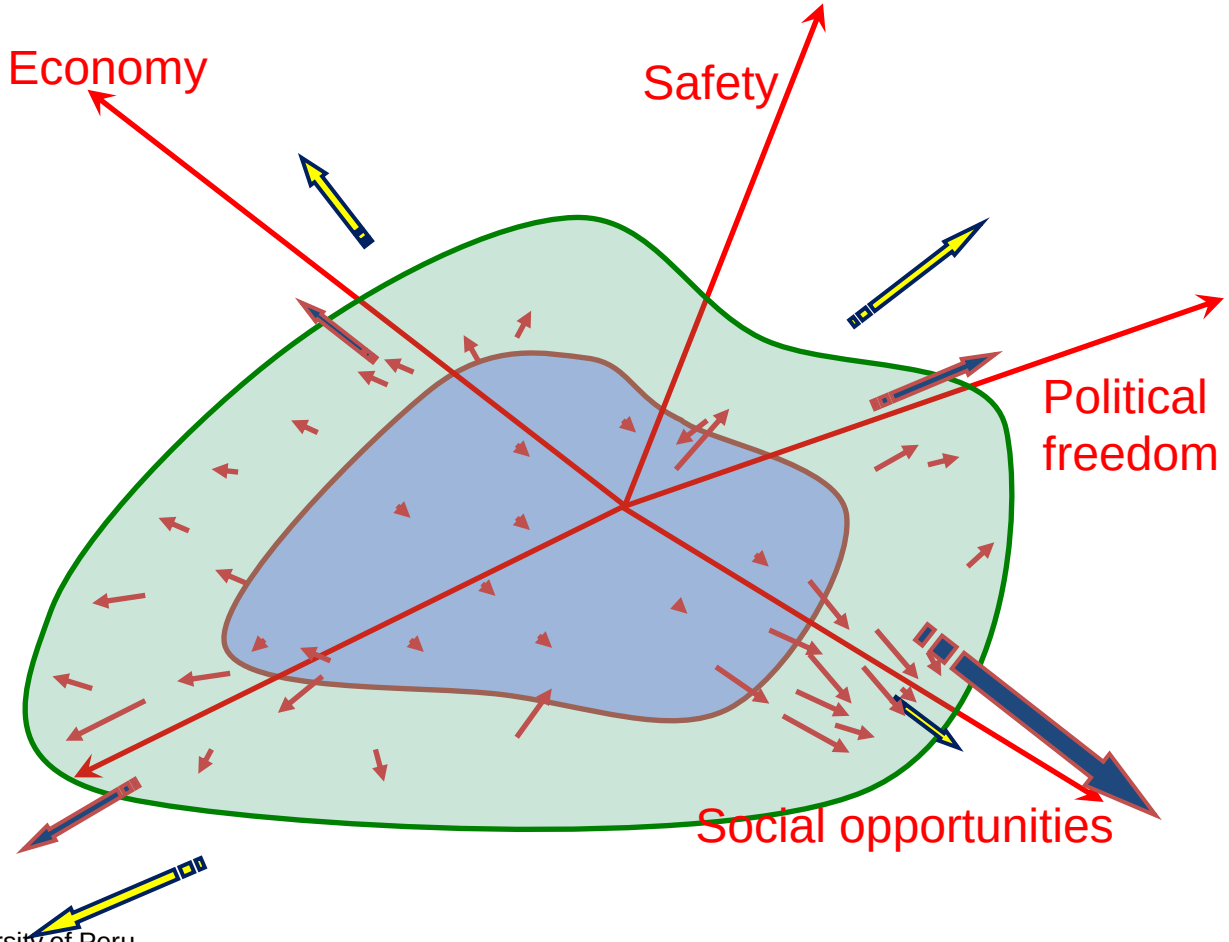
According to Sen, development is achieved when people have the capability (or the freedom) to live the way they value



Many countries attempt to reach development by promoting mainly the economic dimension, with the idea that the remaining freedoms will arrive later…



It is possible to make progress towards development by increasing the capabilities of the communities in dimensions that not require great economical investment



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Many times external aid is inefficient or wasteful

The communities should not be mere recipients of external aid

… they should be agents of their own development

In many developing countries earthen construction is inevitable…

… and it doesn't make sense to ask the communities to build by themselves improved (safe and healthy) adobe houses

It is necessary to increase the capacity of the communities so that they can build better adobe houses

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Possible steps:

- Development of better reinforcement systems (simpler, cheaper)
- Public education on the vulnerability of traditional adobe construction and the possibility of building better houses
- Development of appropriate communication and training methods
- Implementation of massive construction programs

This is a multidimensional problem. It requires multidimensional and interinstitutional solutions

Central government

International organizations

Communal organizatinos

Local government

Instituto Nacional de Defensa Civil - INDECI

SENCICO

Nacional institutions,NGOs

Universidties

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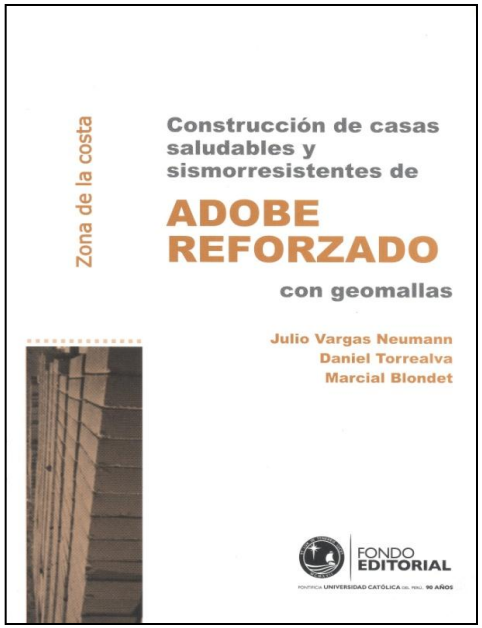
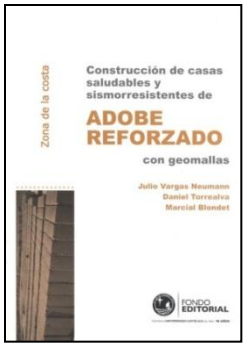
After the Pisco earthquake PUCP, CARE-PERÚ and FORSUR joined forces



One objective was to develop a methodology for community training on the construction of safe and sanitary adobe houses

About 100 builders from the affected areas were trained at the PUCP



Ing. Julio Vargas

Three reinforced adobe houses were built by the communities in Cañete, Chincha and Pisco (9 total)

"Learning by doing"

Several NGOs are now working on a national rural housing program. They have built more than 4000 houses with reinforced adobe

The Peruvian government is aware of the problem

The BBC reported 2 years after the Pisco earthquake

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Peru rebuilds two years on from quake

By Dan Collyns
BBC News, Chincha, Peru

CLICK TO PLAY

Professor Marcial Blondet explains how the adobe structure works

Since 1970, Peru has been hit by five powerful and deadly earthquakes. The latest struck Peru's coast exactly two years ago with a magnitude of 8.0 on the Richter scale.

It fiercely shook the capital Lima, but its devastating epicentre was about 200km (124 miles) to the south, near the town of Pisco, a small fishing port built largely of adobe - mud bricks which Peruvians have used for thousands of years.

More than 500 people were killed and about 75,000 homes were left uninhabitable.

For Peruvian engineer Marcial Blondet, it was the devastating quake in 1970 that first motivated him to develop earthquake-resistant buildings, particularly for those who could least afford them.

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Almost 5 years later, Pisco still waits for reconstruction

An interdisciplinary team has developed communication and training tools

Marcial Blondet, Civil engineer

Alvaro Rubiños, Civil engineer

Katherine Chávez, Civil eng. student

Jorge Alencastre, Mechanical engineer

Carla Colona - Communicator

Patricia Ruiz-Bravo - Sociologist

Pablo Quintanilla - Phiosopher

Makena Ulfe - Antropologist

Tesania Velasquez - Psychologist

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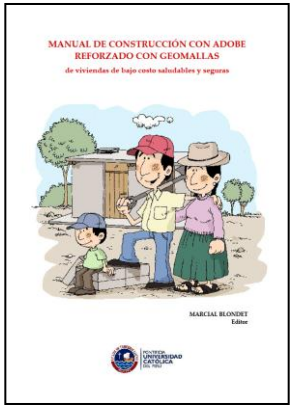
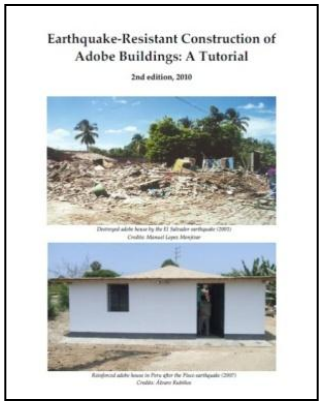
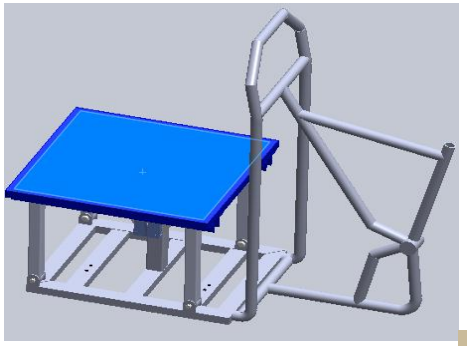
We have developed the following products:

- Adobe Construction Tutorial www.world-housing.net
- Construction Manual
- Motivational Video
- Technical Video
- Portable Shaking Table







The Portable Shaking Table will be used to make demostrations to the communities

Katherine has built the first adobe casitas, has performed preliminary system tests…

…and has disappeared! (where are you, Katherine?)

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Thank you

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