BUILDING GROUP (G3)

Enhancement of Seismic Resistance of Buildings

9-10 March 2011

MEMBER
Japan

Taiki Saito, BRI
Masaomi Teshigawa, Nagoya Univ.
Koichi Kusunoki, Yokohama Univ.
Carlos Cuadra, Akita Pref. Univ.
Shunsuke Sugano, BRI
Shoichi Ando, BRI
Hiroshi Fukuyama, BRI
Hiroto Kato, BRI
Tomohisa Mukai, BRI
Toshikazu Kabeyasawa, BRI
Masanori Tani, BRI
Akio Abe, Tokyo Soil

Peru, Chile, Ecuador

Carlos Zavala, CISMID
Patricia Gibu, CISMID
Ricardo Proaño, CISMID
Dina Cotrado, Tacna Univ.
Miguel Diaz, Yokohama Univ.
Ruben Boroschek, Chile
Patricio Placencia, Ecuador

OBJECTIVES

Enhancement of seismic resistance of buildings is the high priority in Peru to reduce the human losses due to earthquakes. To achieve this objective, we set the following research subjects:

1. Development of seismic performance model of buildings in Peru by experiments, analysis, monitoring, etc.

2. Development of seismic evaluation and rehabilitation technologies for buildings in Peru

3. Enhancement plan of seismic resistance of buildings in Peru

4. Dissemination of knowledge to Latin countries

RESEARCH SUBJECT 1

Development of seismic performance model of buildings in Peru

- Identification of building types
- Study of building damage (in Peru, Chile)

- Creating database of test results and models
- Conducting structural tests
- Development of performance model

Creating database of test results and models

Quite a few researches have been done conducting structural tests of masonry structures around the world to evaluate the seismic resistance capacity. However, the test results and obtained knowledge are not shared among countries.
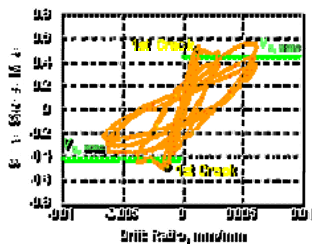
- Material properties
- Failure patterns
- Mathematical models
- Design equations
- etc.
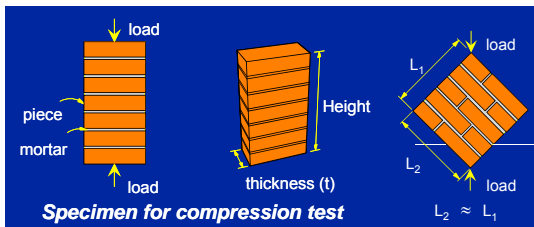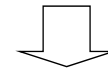
Database for seismic performance of masonry structures are quite useful to share the knowledge and develop effective technology to enhance seismic resistance of buildings.

Specimen for compression test

Structural Test (1)

- ⊙ Objectives
  - ▪ Focus on the failure mechanism of shear wall with perpendicular elements
  - ▪ Adequate confinement at wall end to prevent brittle failure (inspired by the building damage in Chile earthquake)
- ⊙ Structural test in CISMID
  - ▪ Installation and preliminary test of new
  - ▪ Low ductile RC wall
  - ▪ Confinement masonry wall
  - ▪ Adobe-quincha wall
- ⊙ Structural test in Yokohama University
  - ▪ RC wall with perpendicular elements
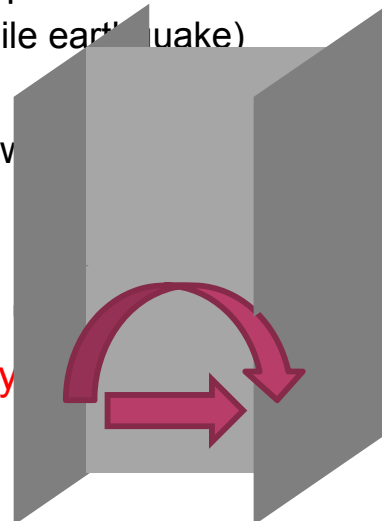
Structural Test (2)

◉ Objectives
  ▪ Behavior of out-of-plane failure of masonry wall
◉ Structural test in BRI with Akita Pref. University
  ▪ Shaking table test for out-of-plane failure of masonry wall

Tilting table test of Adobe house
in El Salvador, JICA-TAISHIN Project

Shaking table test, Sidney

RESEARCH SUBJECT 2

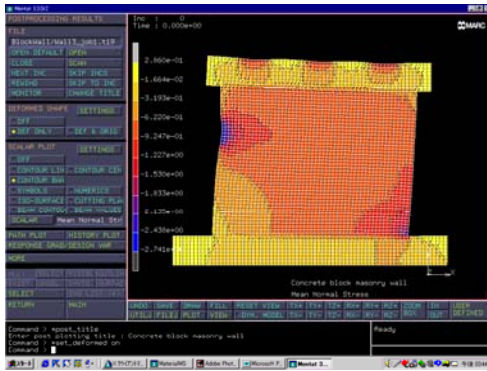Development of seismic evaluation and rehabilitation technologies for buildings in Peru

■ Development of seismic screening method of buildings
■ Computer simulation for seismic evaluation

■ Development of rehabilitation technologies
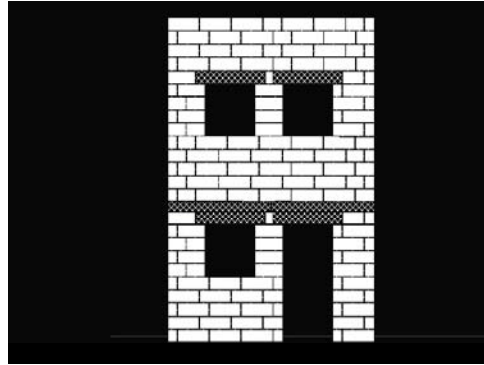■ Conducting structural tests to verify the technologies
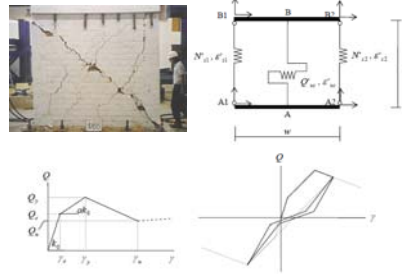
Computer simulation for seismic evaluation

FEM analysis (SAP, DIANA)

DEM analysis (original)

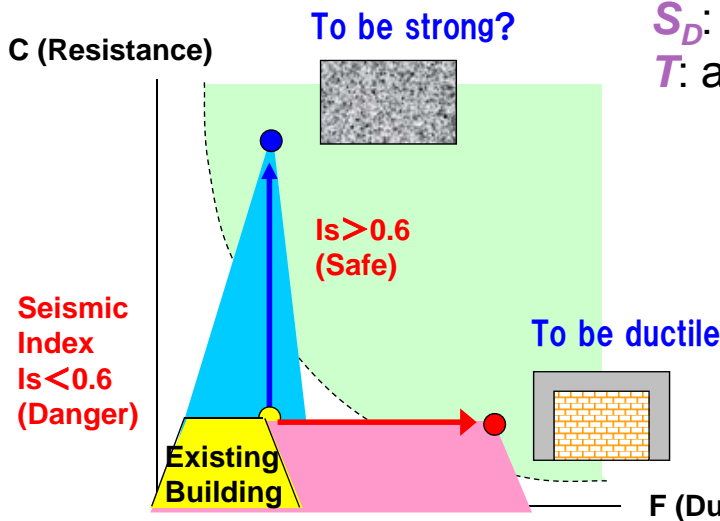**Frame analysis (STERA 3D Software)**
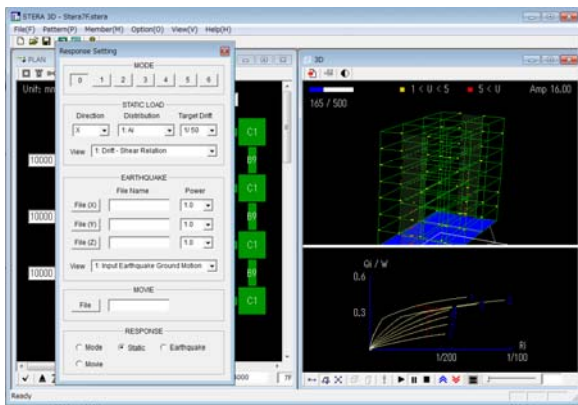
Seismic Evaluation Standard in Japan

Seismic Structural Index I$_s$

$$I_S = \phi \times (C \times F) \times S_D \times T$$

ϕ: story index
S_D: irregularity index
T: age index

C (Resistance)

To be strong?

Is＞0.6
(Safe)

Seismic Index Is＜0.6 (Danger)

To be ductile

Existing Building

F (Ductility)

Development of rehabilitation technologies

$$Is = (\varphi \times C \times F) \times S_D \times T$$

C (Resistance)

Improve C

Replace brick wall to infill RC wall

Seismic index in Japanese screening method

Seismic Index Is＜0.6 (Danger)

Improve C & F

Is＞0.6 (Safe)

Retrofitting by steel brace

Improve F

Existing Building

F (Ductility)

Retrofitting by FRP sheet

Development of rehabilitation technologies

Retrofit using seismic dampers

C (Resistance)

Damper

Oil Damper

Damper

レビス　カバー　ガイドリング
シリンダー
ピストン
特殊充填材
ロッド

OILES Co.
http://www.oiles.co.jp

(Safe)

(Danger)

Steel Damper

Energy dissipation by Dampers

Kajima Co.
http://www.kajima.co.jp

Existing Building

F (Ductility)
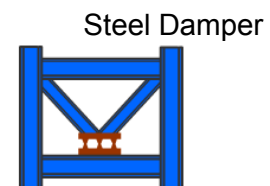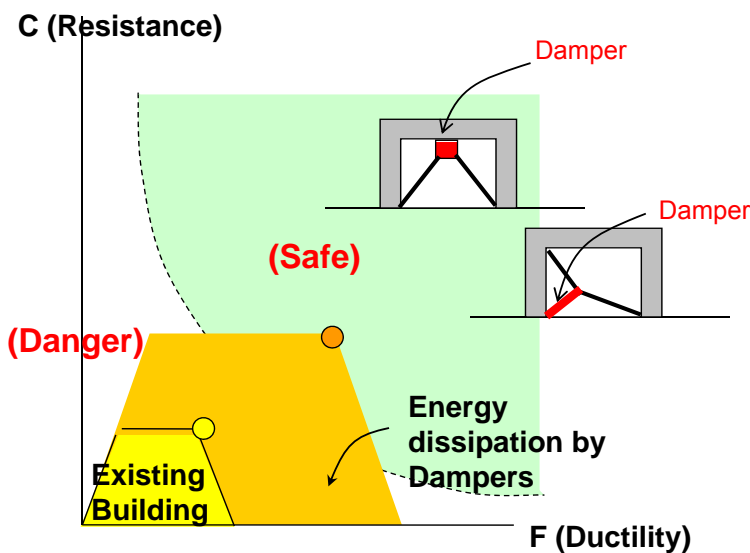
Many other devices

Development of rehabilitation technologies

Retrofit using seismic isolation

C (Resistance)

(Safe)

(Danger)

Existing Building

F (Ductility)

Laminated Rubber bearing

Lead damper

Steel damper
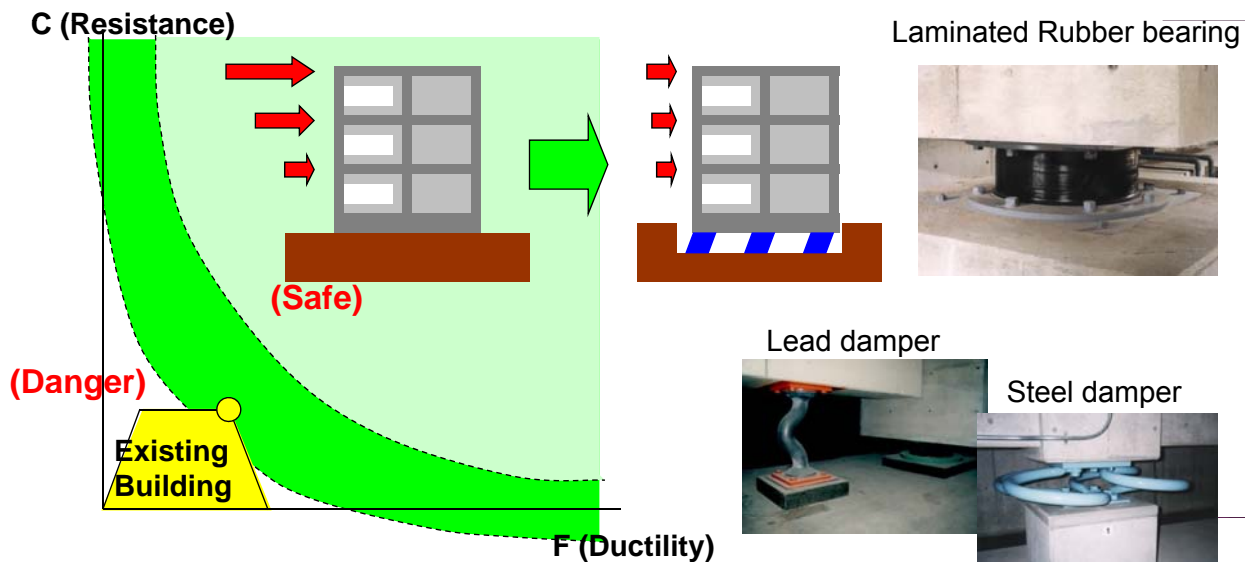
RESEARCH SUBJECT 3

Enhancement plan of seismic resistance of buildings in Peru

- Study on specific buildings in Peru
  - Important buildings (church, hospital, school, etc.)
  - Historical buildings (world heritage, colonial age, etc.)
  - Residential buildings (in urban area)

- Test and analysis of existing buildings
  - Non-destructive test such as micro-tremor measurement
  - Sampling test for material strength
  - Computer simulation of seismic performance

- Proposal of enhancement plan

Current status

- 2010.4-2011.3
  - Dispatch investigation team to Chile for 2010 Chile earthquake disaster
  - Documents, bidding etc. for all equipments
  - Skype meetings for research plan
    - 10/28, 11/30, 12/10, 01/18, 02/22
  - Dispatch of Japanese researchers
    - February 2011, Saito, Mukai and Sugano
    - Building investigation in Lima and Tacna
    - Meeting with Peruvian counterparts
    - Seminars & Lectures in CISMID, Tacna

Damage Investigation of Buildings at the 2010 Chile Earthquake

From 26 April to 3 May, 2010

JST-JICA

Taiki Saito, Koichi Kusunoki,
Carlos Zavala, Patricia Gibu

AIJ *(Architectural Institute of Japan)*

Susumu Kono, Yo Hibino,
Masanori Tani, Tomoya Matsui,
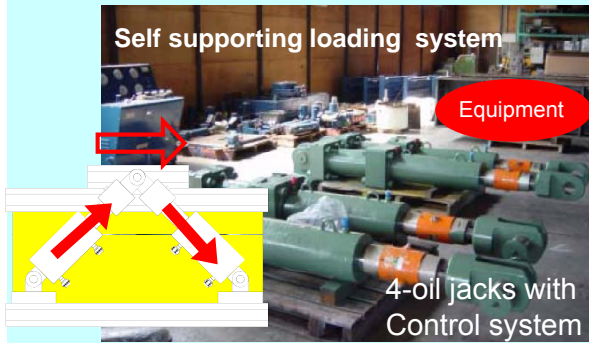Yousok Kim

Great assistance from Chile

Prof. Boroschek and Mr. Tomas (University of Chile)
Prof. Cruz (Pontifical Catholic University)
Mr. Raul (ex-JICA participants)

Group 3 Building (Equipment)
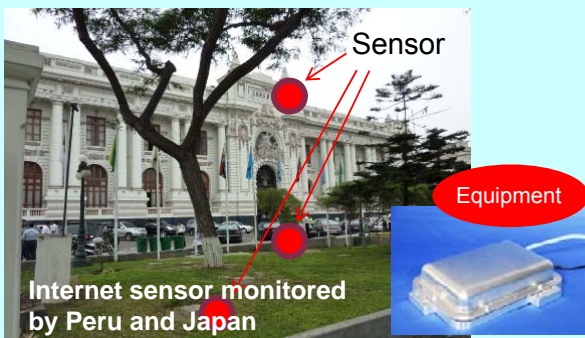
Structural testing

Self supporting loading system

Equipment

4-oil jacks with Control system

Material testing

Renewal of old CISMID machine

Equipment

Equipment

50ton Universal

300ton Compression

Building monitoring

Sensor

Equipment

Internet sensor monitored by Peru and Japan

Dynamic behavior monitoring & test

Shaking machine

Equipment

Acc. sensor

Laser sensor

Target building 1: Rebagliatti Hospital

LIMA

Reason to select this building

RC building, largest hospital in Lima, important building, necessary for evaluation & retrofit (in transverse direction)

Three buildings are connected by seismic joints, no damage by previous earthquake except some pipes and nonstructural walls.

All drawings are available (concrete strength 21MPa – 36MPa).

What to do in the Project

Non-destructive test for concrete strength, Micro-tremor measurement for dynamic characteristics

Make analytical model based on drawings, Perform nonlinear analysis (static and dynamic)

Propose seismic retrofitting plan

Install network sensor

Target building 2: UNI CE Faculty building

Reason to select this building
RC building, educational facility, easy access from CISMID, necessary for evaluation & retrofit
All drawings are available
What to do in the Project
Non-destructive test for concrete strength, Micro-tremor measurement for dynamic characteristics
Make analytical model based on drawings, Perform nonlinear analysis (static and dynamic)
Apply Japanese evaluation method
Propose seismic retrofitting plan
Install network sensor

Target building 3: UNI main building

Reason to select this building
RC building, educational facility, easy access from CISMID
What to do in the Project
Install network sensor

Target building 4: Teatro Municipal

Reconstruction of quincha wall

Reason to select this building
Monument, rehabilitation work in underway after the damage by fire
Masonry + concrete, New adobe + quincha building for annex building
Already studied by CISMID (SAP model, retrofit of column using steel angle, etc.)
What to do in the Project
Micro-tremor measurement of main building and annex building
Nonlinear FEM analysis (using DIANA) … very complicated
Install of sensor?

21

Target building 5: Comercio Hotel

LIMA

Severe deterioration in upper stories

Reason to select this building
Monument, typical building in Centro Lima (Historical Area)
Adobe + quincha building, partially collapsed because of deterioration.
Already studied by CISMID (SAP model)
What to do in the Project
Micro-tremor measurement
Nonlinear FEM analysis (using DIANA) … very complicated

22

Target building 6: Lima Cathedral

Reason to select this building
Monument in Centro, Lima, collapsed three times by earthquakes, roof is supported by wood columns, one column is inclined, small crack on the out side wall in out-of-plane direction
Already studied by CISMID (SAP model)
What to do in the Project
Micro-tremor measurement
Nonlinear FEM analysis (using DIANA) … very complicated

23

Target building 7: Historical building in Tacna

Casa Museo Basadre

Reason to select this building
Tacna is located in high seismicity area in Peru
What to do in the Project
Install network sensor

24