Group 3

Evaluation of seismic resistance of buildings in Peru

Group Leaders

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Dr. Taiki Saito	Professor, Toyohashi University of Technology

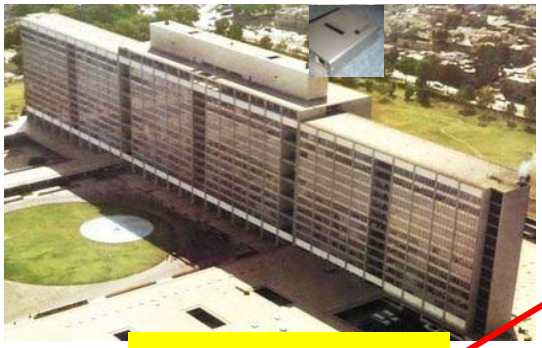
G3 Research Subjects

Category	Achievement
Seismic Design of buildings in Peru (for new buildings)	Seismic test database of masonry elements → design formula
	Material testing
	Design method of non-ductile wall
Seismic Evaluation of buildings in Peru (for existing buildings)	Proposing evaluation method (based on JP)
	Computer Simulation software of masonry using DEM
	Remote monitoring with IT sensors
	Micro-tremor measurement of historical Buildings
Seismic Retrofitting (for existing	Propose CF sheets retrofitting for non-ductile wall

NATIONAL UNIVERSITY OF ENGINEERING
FACULTY OF CIVIL ENGINEERING
JAPAN-PERU CENTER FOR EARTHQUAKE
ENGINEERING RESEARCH AND
DISASTER MITIGATION - CISMID

ITK Sensor Building Monitoring Network

ITK1-00x (CentUNI)



ITK2-00x (G2-FIC)

ITK3-00x (HOSP)

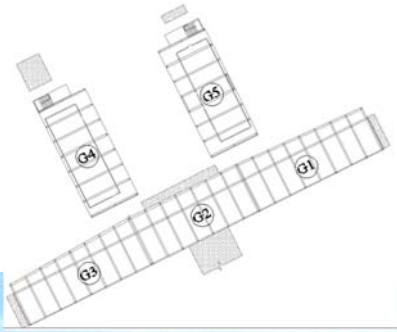
3 Buildings in Lima

Sensors E. REBAGLIATI HOSPITAL

Sensors at 9F, two places: A3& A2

Next to joint between C & B towers

Sensors setting in progress
Different levels and ground



RECORDED RESPONSE FIC - G2 block building

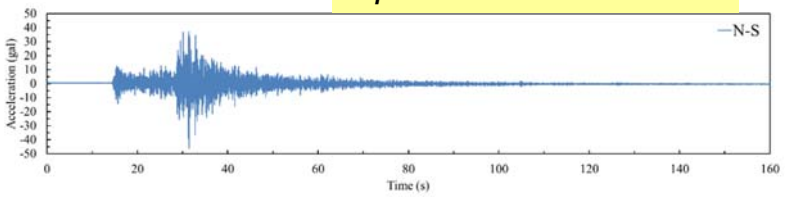
Response of each level: 1B (sótano= underground soil), 0F (ground), 1F (roof), 2F, 3F

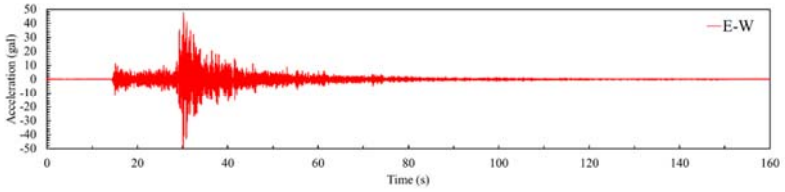
Civil Engineering Faculty (FIC) G2 block bldg

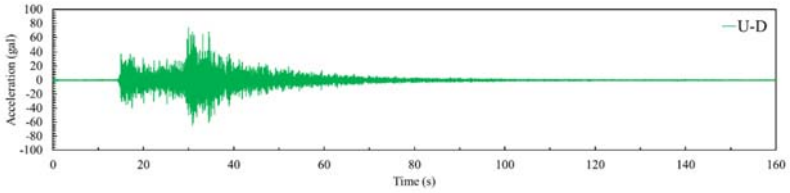
Registered Response - wave

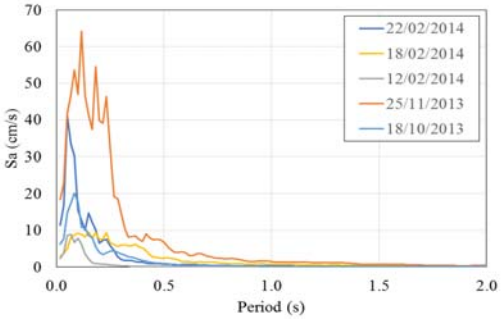
Data of 25/11/2013
Itk04 (3F 3rd Floor roof level)

Record of response at top roof level









Civil Engineering Faculty (FIC) G2 block bldg

DATA ADQUISITION: Registered Response

Peak accelerations

Quake	itk00	itk01	itk02	itk03	itk04	itk00	itk01	itk02	itk03	itk04
Date	N-S	N-S	N-S	N-S	N-S	E-W	E-W	E-W	E-W	E-W
18/10/2013	5.92	6.14	12.61	13.08	14.66	6.39	7.74	9.69	6.85	13.65
25/11/2013	13.02	16.08	26.23	30.89	46.18	18.66	24.7	48.3	35.61	59.78
12/02/2014	3.03	4.56	7.06	6.85	5.64	2.39	3.88	3.46	3.23	4.44
18/02/2014	3.46	3.66	7.6	9.08	20.57	3.08	4.14	6.82	8.04	10.41
22/02/2014	8.44	10.97	13.18	15.83	16.28	11.58	16.14	14.16	14.61	15.24

Data of 25/11/2013

MATERIAL TESTING TO IMPROVE MASONRY STANDARDS

Solid brick (Handmade)

Solid brick (Factory)

CHARACTERISTICS RESISTANCES OF MASONRY

Mpa (kg / cm^2)

MATERIAL	NAME	UNITE f'_b	PILE f'_m	Diagonal Wall test
Arcilla	King Kong Artesanal	5,4 (55)	3,4 (35)	0,5 (5,1)
	King Kong Industrial	14,2 (145)	6,4 (65)	0,8 (8,1)
	Rejilla Industrial	21,1 (215)	8,3 (85)	0,9 (9,2)
Sílice-cal	King Kong Normal	15,7 (160)	10,8 (110)	1,0 (9,7)
	Dédalo	14,2 (145)	9,3 (95)	1,0 (9,7)
	Estándar y mecano (*)	14,2 (145)	10,8 (110)	0,9 (9,2)
Concreto	Bloque Tipo P (*)	4,9 (50) 6,4 (65) 7,4 (75) 8,3 (85)	7,3 (74) 8,3 (85) 9,3 (95) 11,8 (120)	0,8 (8,6) 0,9 (9,2) 1,0 (9,7) 1,1 (10,9)

Source *N.T.E. 070, Masonry Standard*

TEST PROGRAM FOR MASONRY MATERIALS

- Bricks
- Mortar
- Masonry specimen:
  - Compressive strength: 48 specimens
  - Diagonal tensión test: 48 specimens
  - Direct shear test: 48 specimens

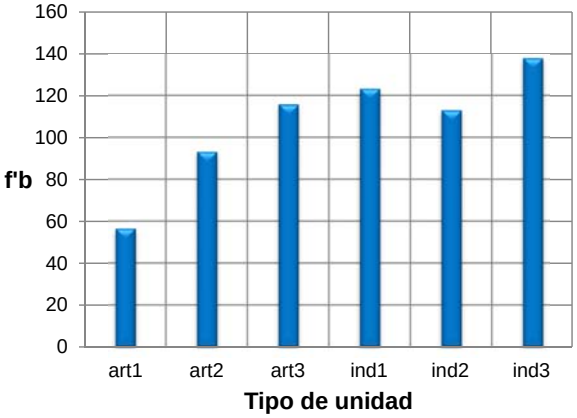
Prism

Wallets

Direct shear specimen

BRICKS PROPERTIES

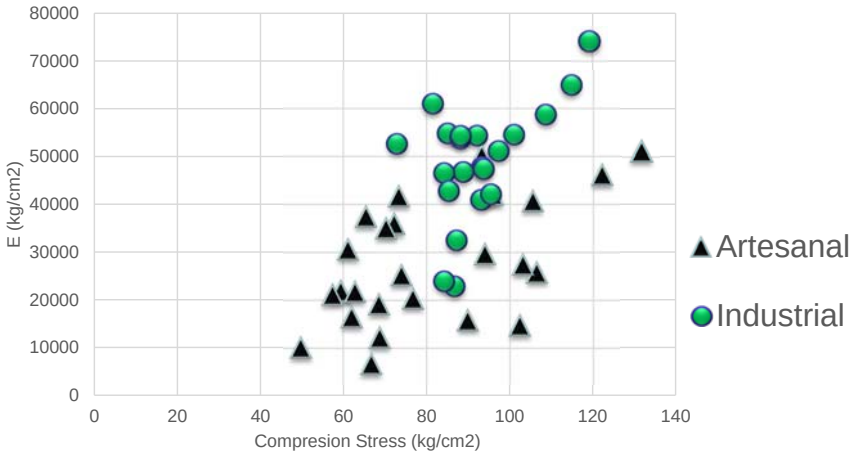
Compression strength Bricks



Test of brick

PRISMS TEST RESULTS

(Compresion stress againts Elastic Modulus (E))



E=439f'm

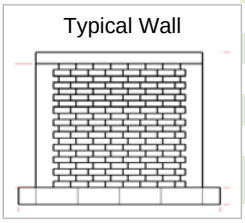
E= 500 f´m Current value of NTE-070 Standards should be modifie

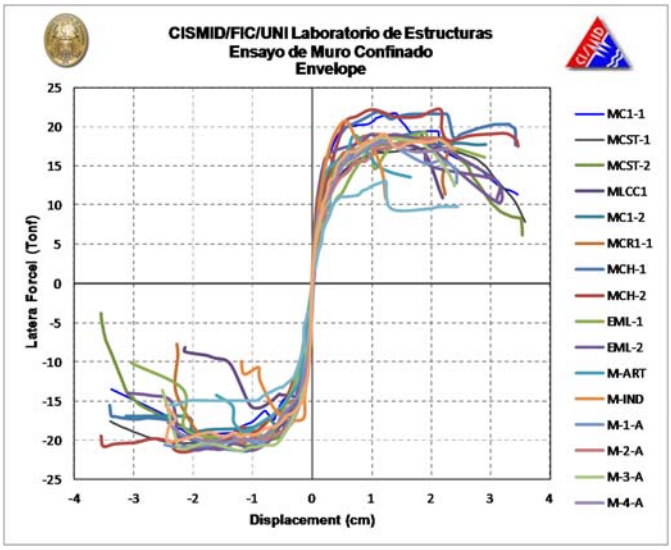
DIAGONAL TENSION TEST

TIPO	V promedio (kg/cm2)
ART 1 15	8.1
ART 2 15	18.9
ART 3 15	
ART 1 13	14.6
ART 2 13	21.1
ART 3 13	24.7
IND 1 15	12.1
IND 2 15	9.9
IND 3 15	11.1
IND 1 13	33.6
IND 2 13	39.0
IND 3 13	17.7

EXPERIMENTAL DATABASE OF MASONRY WALLS TEST

Typical Wall



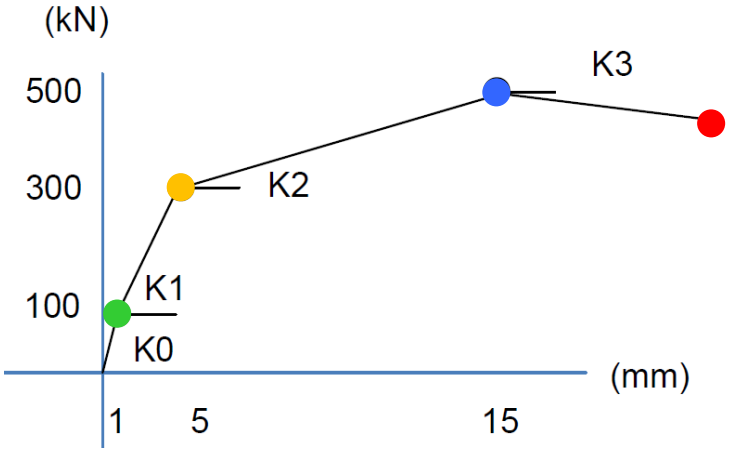


N°	Author	ID	type of unit	dimension	f´m(kg/cm²)	beam (b xh)	Col. (b xh)	Horiz. Bars	Vert. Bars
01	P. Gibu , C. Serida (1993)(T)	MCST1	Factory	9.5x12x25	97.91	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
02	P. Gibu , C. Serida (1993)(T)	MCST2	Factory	9.5x12x25	97.91	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
03	P. Gibu , C. Serida (1993)(T)	MLCC1	Factory	9.5x12x25	97.91	200x20	25x15	4 ϕ 3/8"+Malla 3/8"	4 ϕ 3/8"
04	J. Delgadillo (1994)(T)	MC1-1	Factory	9.x12x24	251	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
05	J. Delgadillo (1994)(T)	MC1-2	Factory	9.x12x24	251	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
06	J. Delgadillo (1994)(T)	MCR-1	Factory	9.x12x24	251	30x20	25x15	4 ϕ 1/2"	4 ϕ 1/2"
07	J. Delgadillo (1994)(T)	MCH-1	Factory	9.x12x24	251	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
08	J. Delgadillo (1994)(T)	MCH-2	Factory	9.x12x24	251	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
09	J. Delgadillo (1994)(T)	EML-1	Factory	9.x12x24	251	200x20	25x15	4 ϕ 3/8"+Malla 3/8"@20	4 ϕ 3/8"
10	J. Delgadillo (1994)(T)	EML-2	Factory	9.x12x24	251	200x20	25x15	4 ϕ 3/8"+Malla 3/8"@20	4 ϕ 3/8"
11	M. Salinas, F. Lazares (2007)(T)	M-ART	Handmade	10.x11.5x23	33.2	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
12	M. Salinas, F. Lazares (2007)(T)	M-IND	Factory	11.x11.5x23	22.1	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
13	M, Ramirez (2001)(T)	M-1-A	Factory	9.0x13x24	108	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
14	M, Ramirez (2001)(T)	M-2-A	Factory	9.0x13x24	108	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
15	M, Ramirez (2001)(T)	M-3-A	Factory	9.0x13x24	108	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
16	M, Ramirez (2001)(T)	M-4-A	Factory	9.0x13x24	108	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
17	M, Ramirez (2001)(T)	M-3-B	Factory	9.5x12x25	91	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
18	M, Ramirez (2001)(T)	M-4-B	Factory	9.5x12x25	91	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
19	Zavala, Kaminosono, 2003	WALL A1-3	Handmade	9.x14x24	59.26	30x20	30x25	4 ϕ 3/8"	4 ϕ 3/8"
20	Zavala, Kaminosono, 2003	WALL A1-4	Handmade	9.x14x24	59.26	30x20	30x25	4 ϕ 1/2"	4 ϕ 1/2"
21	Zavala, Kaminosono, 2003	WALL A2-3	Handmade	9.x14x24	59.26	30x20	30x25	4 ϕ 3/8"	4 ϕ 3/8"
22	Zavala, Kaminosono, 2003	WALL A2-4	Handmade	9.x14x24	59.26	30x20	30x25	4 ϕ 3/8"	4 ϕ 3/8"
23	Zavala, Kaminosono, 2003	WALL C2-HM	Handmade	9.x14x24	59.26	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"
24	Zavala, Kaminosono, 2003	WALL C2-FM	Factory	9.x14x24	70.24	30x20	25x15	4 ϕ 3/8"	4 ϕ 3/8"

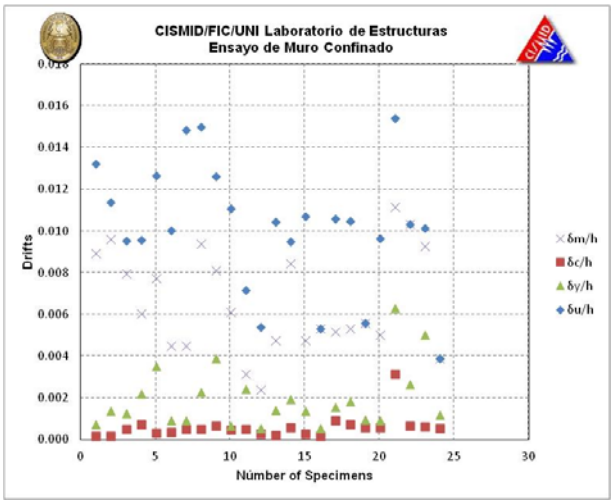
MASONRY QUADLINEAR ENVELOPE CURVE

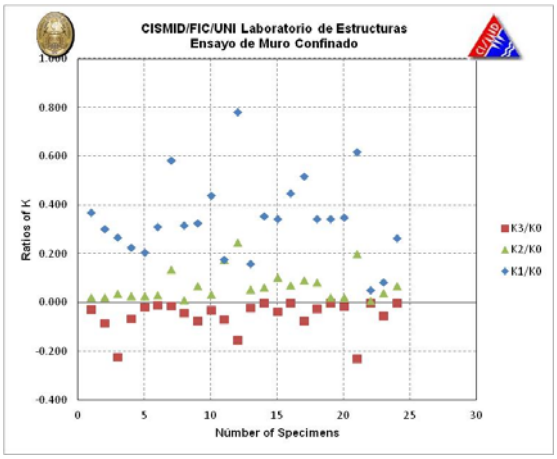
QUAD-LINEAR MODEL

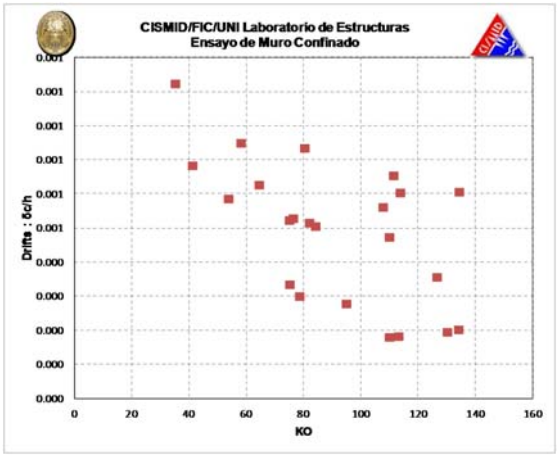
- 4 Linear segments
- Craking Point
- Yielding Point
- Maximun Point
- Ultimate Point



Drifts & Ratios of K



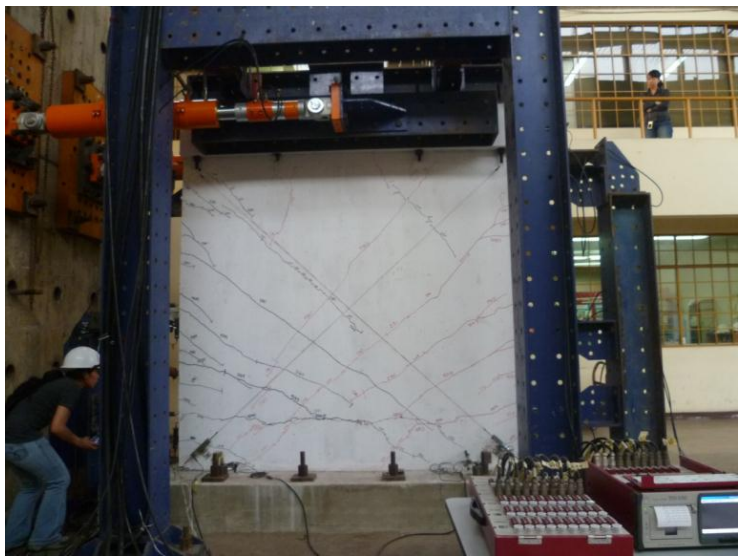


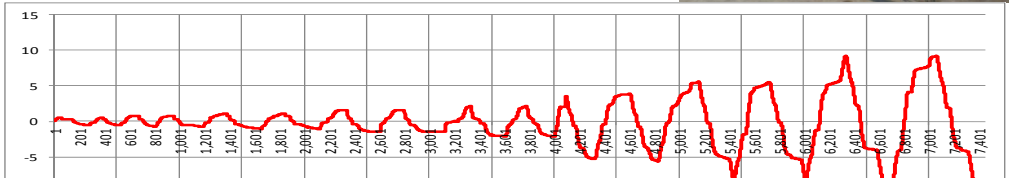


$\delta c/h \approx 0.0006$
$\delta y/h \approx 0.0018$
$\delta m/h \approx 0.007$
$\delta u/h \approx 0.010$

$K_0 \approx 103.0$ Tonf/cm
$K_1/K_0 \approx 0.313$
$K_2/K_0 \approx 0.058$
$K_3/K_0 \approx -0.046$

Cyclic Load Test Plane and H – Masonry and Low Ductility Concrete Wall

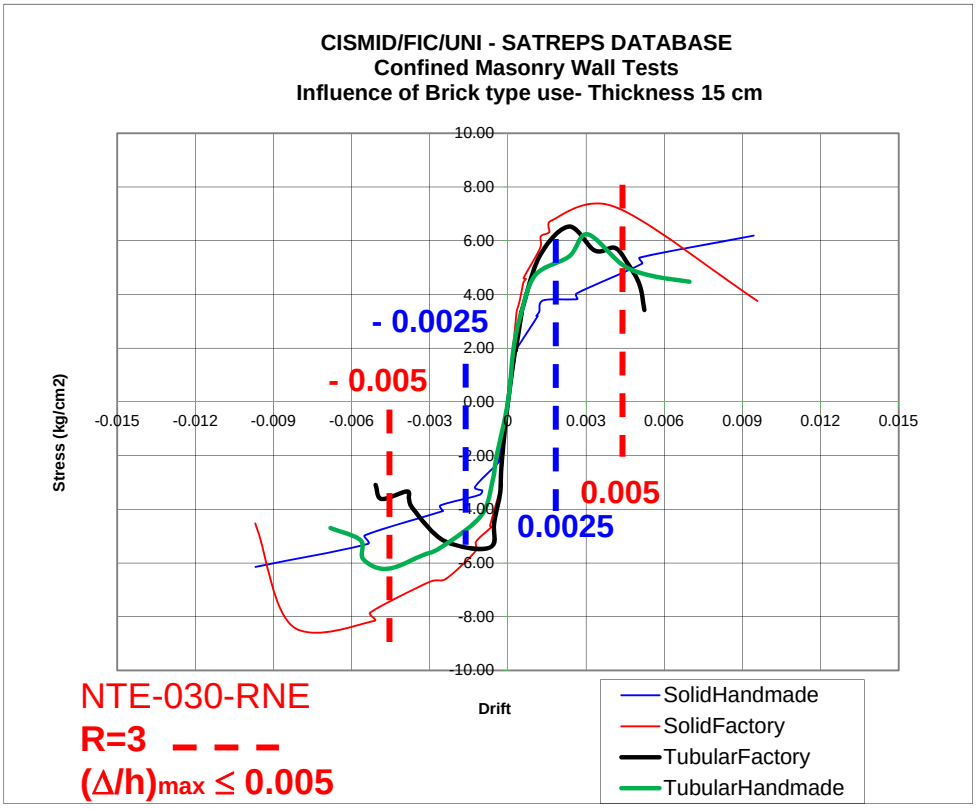




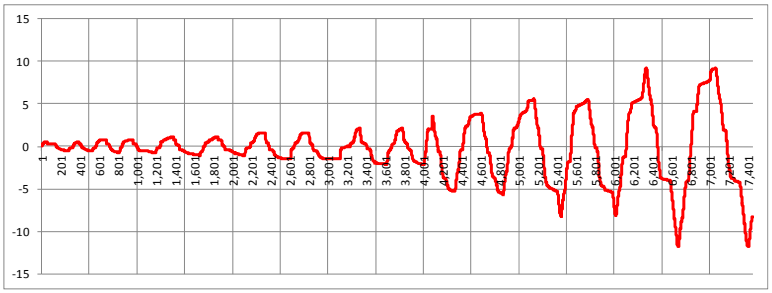
Comparison of Behavior curves of Plane Walls

Solid Block

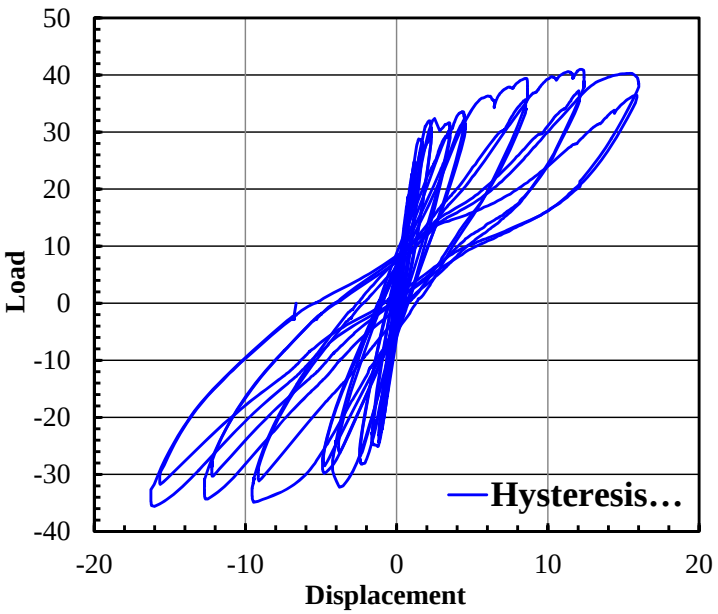
Tubular Block

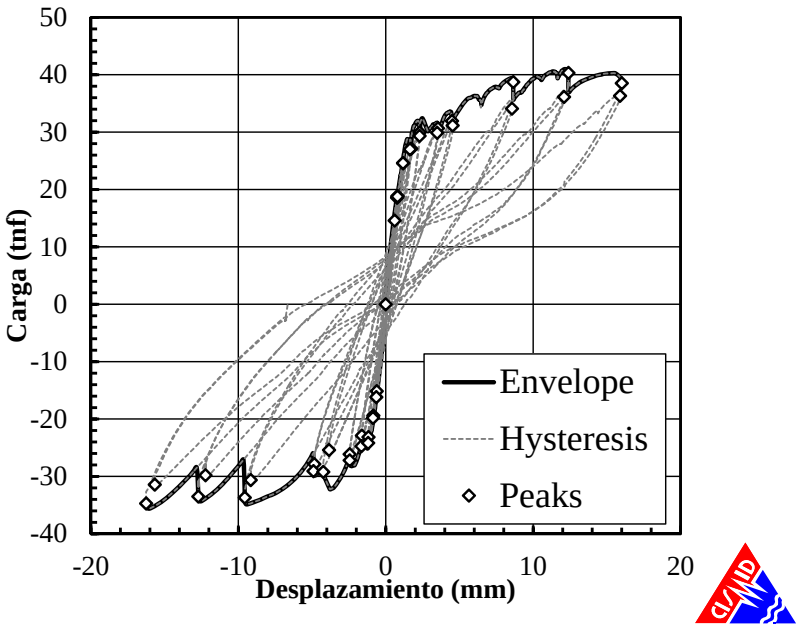


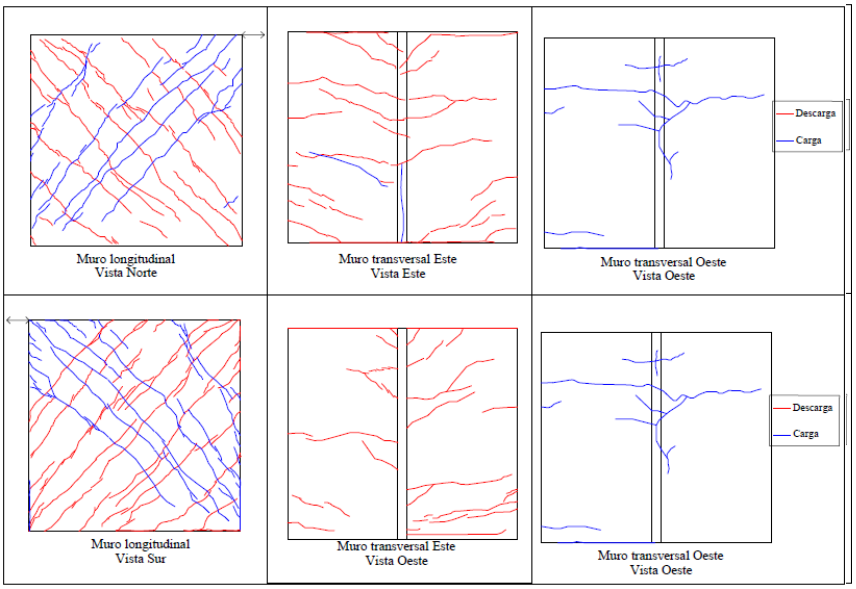
Cyclic Load Test H Wall-05



WALL-05

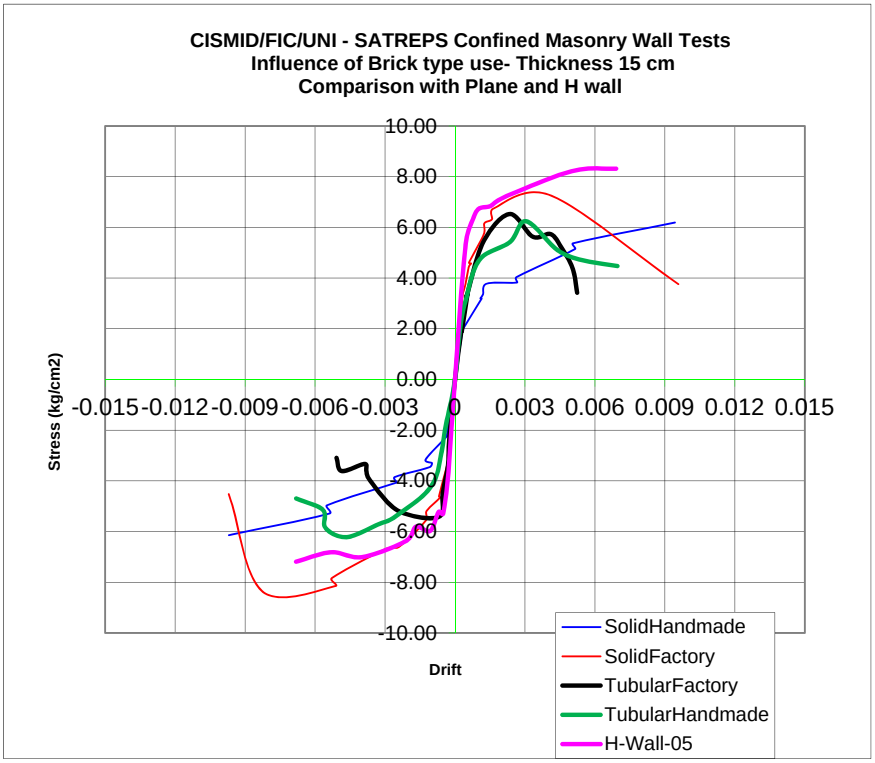






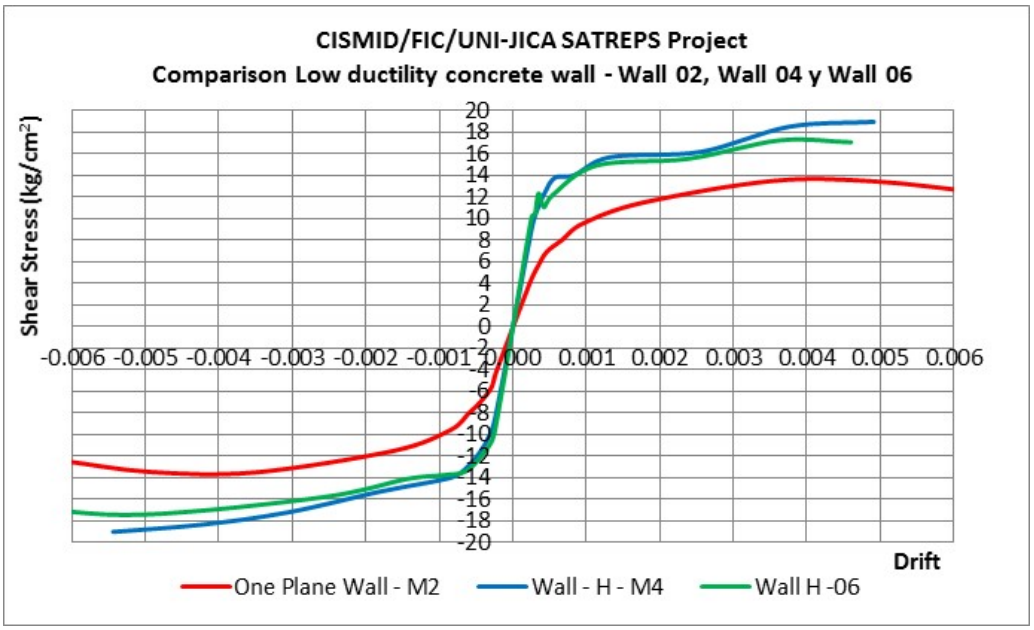
Distorsión 1/154
Distorsión 1/200
Distorsión 1/280
Distorsión 1/549
Distorsión 1/1075
Distorsión 1/1503
Distorsión 1/2105
Distorsión 1/2941
Distorsión 1/4167

COMPARISON OF PLANE AND H WALL MASONRY WALL

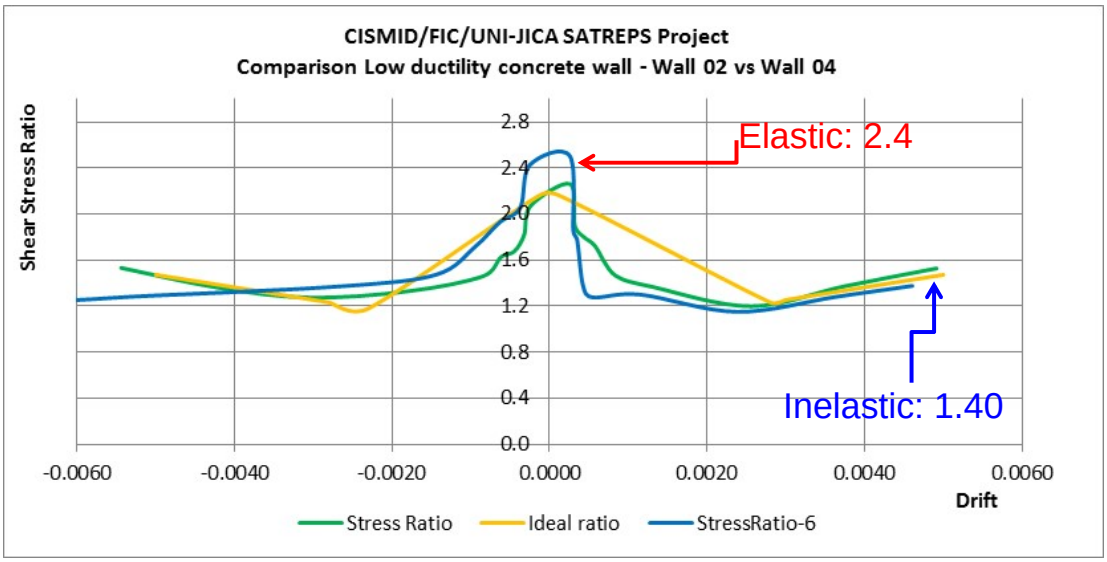


Final Stage Cyclic LDCW

Comparison with 2012, 2013 Tests



CONFIRMATION IF THE TENDENCY OF INFLUENCE THE PERPENDICULAR WALL ACTION



COMMENTS & CONCLUSIONS

- *First building monitoring network has been installed in Peru and **in full operation** at the present time in Lima as a part of the Project for Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru (JICA/JST) under the cooperation scheme of SATREPS*
- *For several earthquakes near Lima last year, response of bldgs were recorded. For recent recorded events, has been possible only direct acquisition of data response from local server at each bldg.*
- *From Masonry material test, There have been variations of the geometric and mechanical properties of the units used respect to 20 years ago.*
- *Modifications on Peruvian Standards are required due to industry reduce the quality bricks.*
- *Wall test on Masonry and Low ductility concrete, considering perpendicular wall action has been performed. Influence of perpendicular wall on inelastic range is very important.*