Field investigation research to improve seismic capacity of new and existing Nepalese buildings

PI on Japan Side : Koichi Kusunoki, ERI, the Univ. of Tokyo

PI on Nepali Side: Krishna Kumar Bhetwal

Co-PI : Prakirna Tuladhar

Objectives

- To improve the seismic capacity of Nepali buildings
  - Behavior of **non-structural brick walls** needs to be investigated
  - Design procedure and construction guidelines for **soft-first-story buildings** needs to be provided
- One-year project cannot solve the problems
  - Settle the information on seismic behavior and design method of buildings with non-structural brick walls
  - Settle the information on design method of soft-first-story buildings
  - Develop a **roadmap** to solve the problems

Kumamoto EQ

- April 14 Mw = 6.2
- April 16 Mw = 7.0
- Casualties 49

Same damage in Japan

1995 Kobe EQ

2016 Kumamoto EQ

To overcome the problem

- For New Buildings
  - Improve the building code

To overcome the problem

- For Existing Buildings
  - Develop a seismic screening method
  - Promote retrofitting

To overcome the problem

- Non-structural walls

Items to investigate

- The damage of the non-structural wall and soft-first-story buildings
- Nepalese building codes, structural calculation, and detailed bar arrangements
- Behavior of existing Nepalese buildings (microtremor)
- Material properties (brick masonry)
- Applicability of Japanese seismic screening method for the buildings with non-structural brick walls

Members

- Japan
  - PI **Koichi Kusunoki**, Earthquake Research Institute, the Univ. of Tokyo, Leader of the AIJ investigation team
  - **Toshimi Kabeyasawa**, ERI, the Univ. of Tokyo Chairman of AIJ Disaster Management Committee
  - **Taiki Saito**, Toyohashi Univ. of Technology
  - **Yasushi Sanada**, Osaka Univ., Secretariat of the AIJ investigation team
  - **Yo Hibino**, Hiroshima Univ., Secretariat of the AIJ investigation team
- Nepal
  - PI **Krishna Kumar Bhetwal**, Tribhuvan University
  - **Prakirna Tuladhar**, Ministry of Urban Development and Building Construction

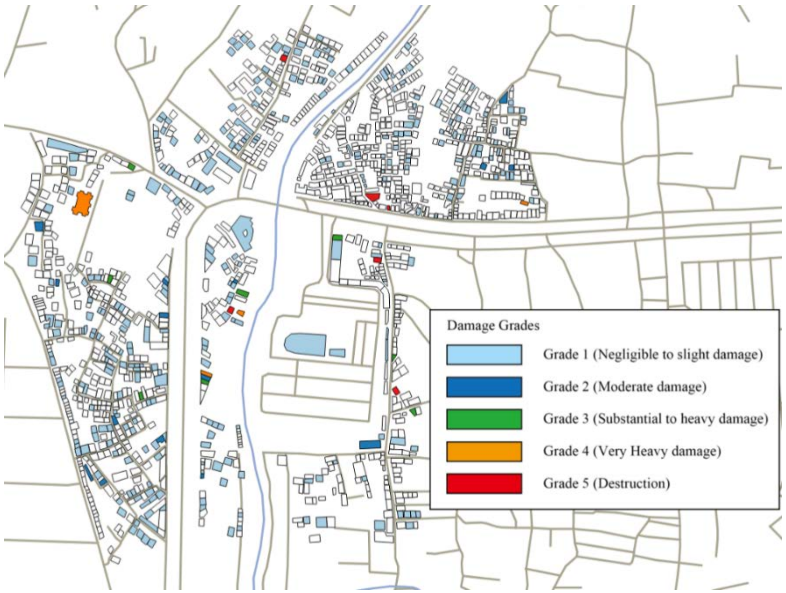
Damage of non-structural brick walls

Even structures are OK, non-structural walls were severely damaged

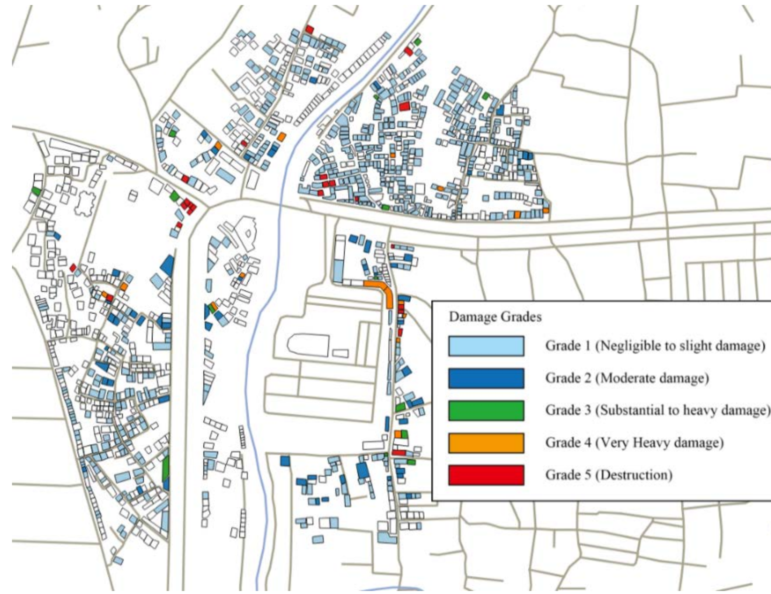
From AIJ reconnaissance

Soft-first story collapse

Damage grade



1 - 3 stories buildings

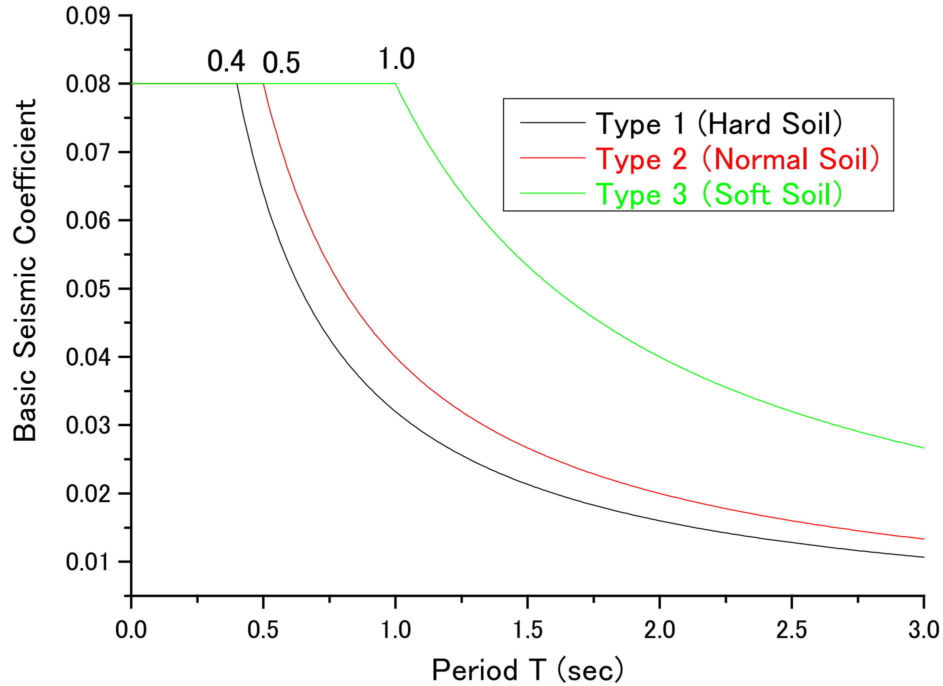


4 - 6 stories buildings

From AIJ Reconnaissance

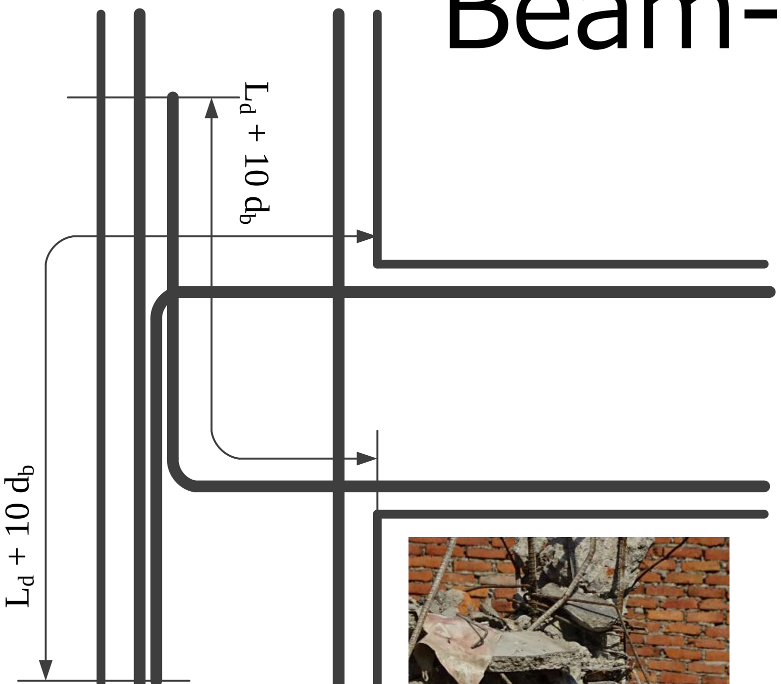
Nepalese Building Code 105 Design lateral force coeff. C_d

- $C_d = C\ Z\ I\ K$
  - C: Basic seismic coefficient



60th ANNIVERSARY OF DIPLOMATIC RELATIONS JAPAN & NEPAL

NepaleseBuilding Code Beam-column joint



- Bar anchorage length is defined in the code
- As for the reinforcement in the joint, **the special confining reinforcement** as required at the end of the column shall be provided through the joint as well, unless the joint confined as specified as follows.

Nepalese Building Code NBC201 Masonry brick

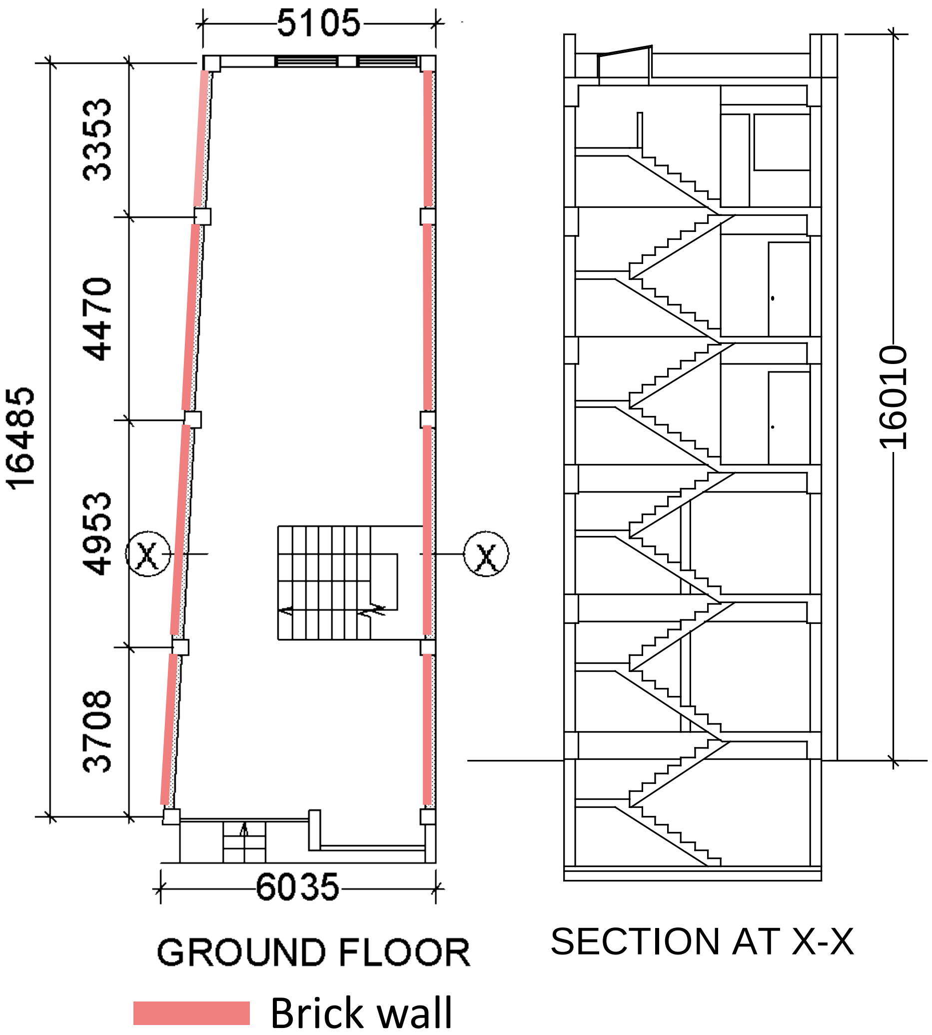
- The code is, however, not applied for the non-structural walls, even for structural walls, sometimes.
- The size of brick defined in the code can be somehow different from the size actually used in the practices.
- The brick strength mentioned in the code of 3.5MPa, is the lowest requirement. The actual brick in practice has higher strength, in general.

→ Actual brick property needs to be investigated!

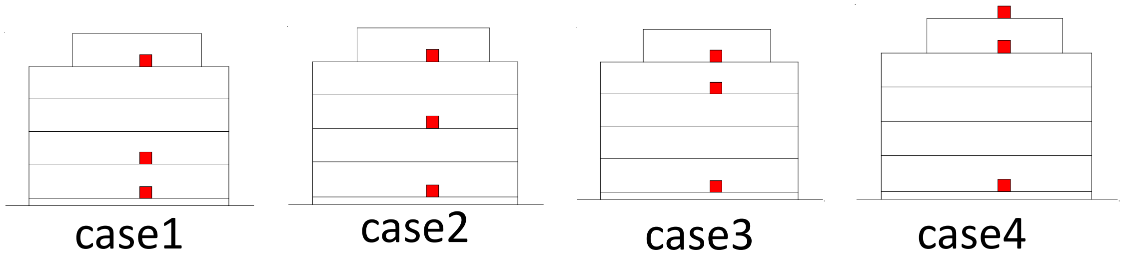
Investigated building at Kathmandu

Built after Nepal Earthquake

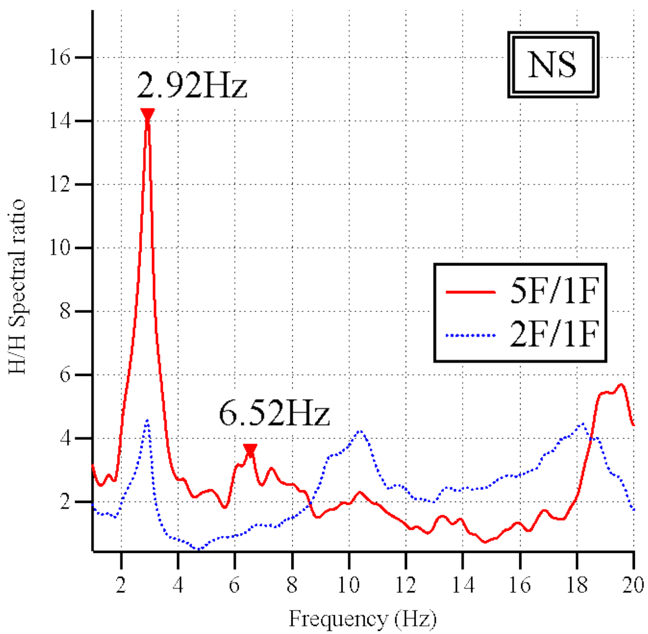
R/C residence with brick walls

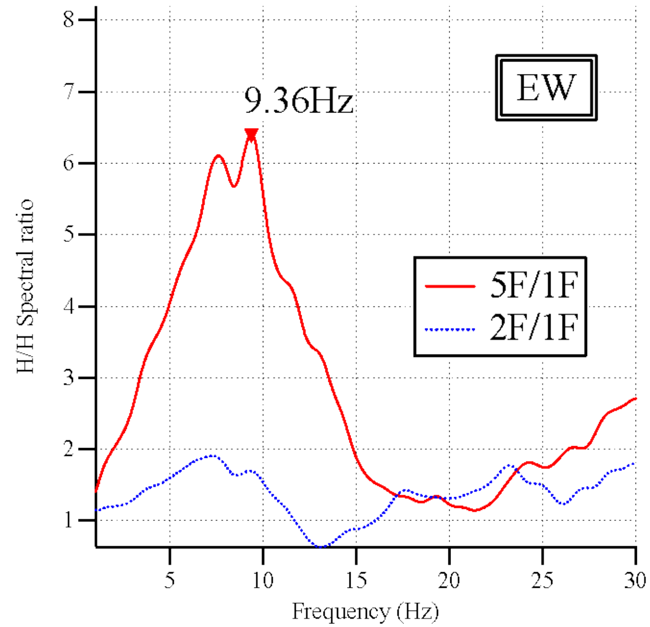


Microtremor measurements



case1

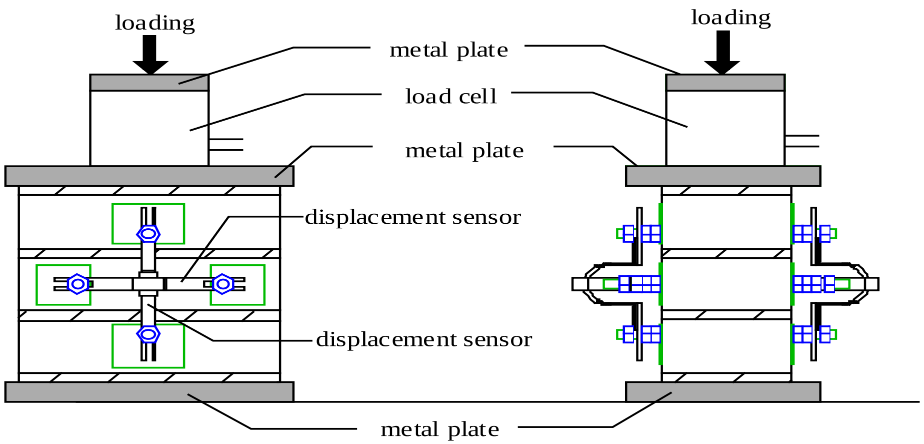




Higher frequency was observed in the EW direction
due to existence of more brick walls

Experimental test

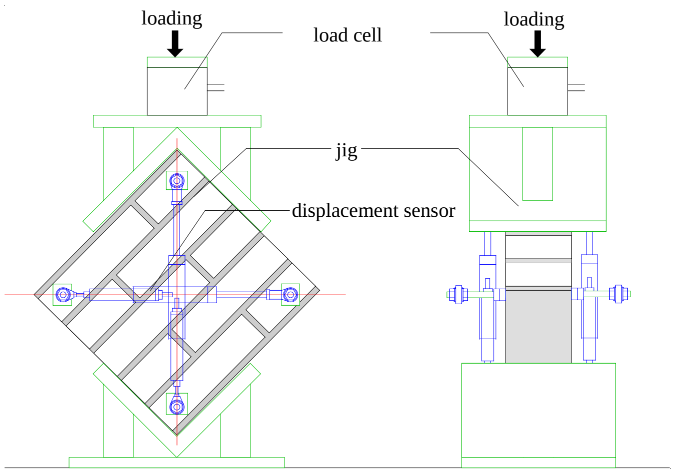
Compression test set-up

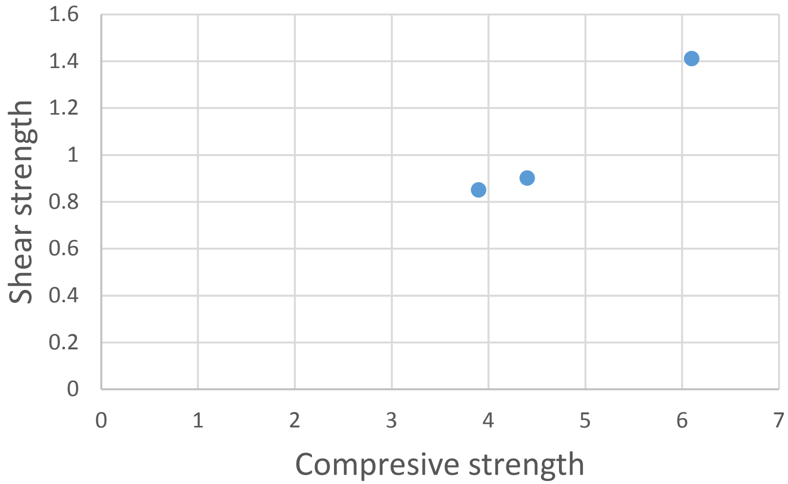


Strength is very low compared with R/C. But they have strength!

	Area (mm^2)	Maximum load (N)	Compression strength (N/mm^2)
Non-mortar finishing	24613	107013	**4.4**
Mortar finishing on one side	28428	109512	**3.9**
Mortar finishing on both sides	30552	185537	**6.1**

Diagonal test set-up

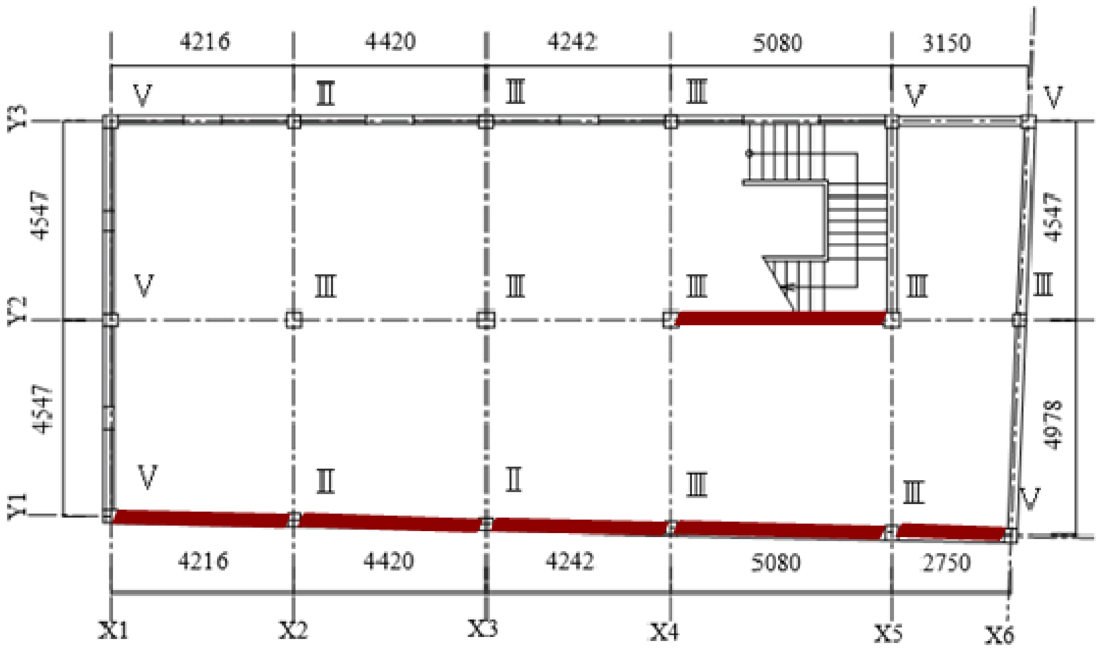




	Area (mm²)	Maximum load (N)	Shear strength (N/mm²)
Non-mortar finishing	58377	52535	**0.90**
Mortar finishing on one side	68070	57810	**0.85**
Mortar finishing on both sides	70371	99072	**1.41**

An example of seismic screening method w/ considering the effect of non-structural brick wall

Case study of seismic screening method for 5-story building with non-structural brick walls in Nepal



Studied direction

Brick wall

	C1	C2	C3
column dimensions (mm)	305×305	305×305	355×355
column longitudinal rebar	8-T25	8-T20	8-T25
column hoop	T10@100-2legs	T10@150-2legs	T10@150-2legs

Screening method

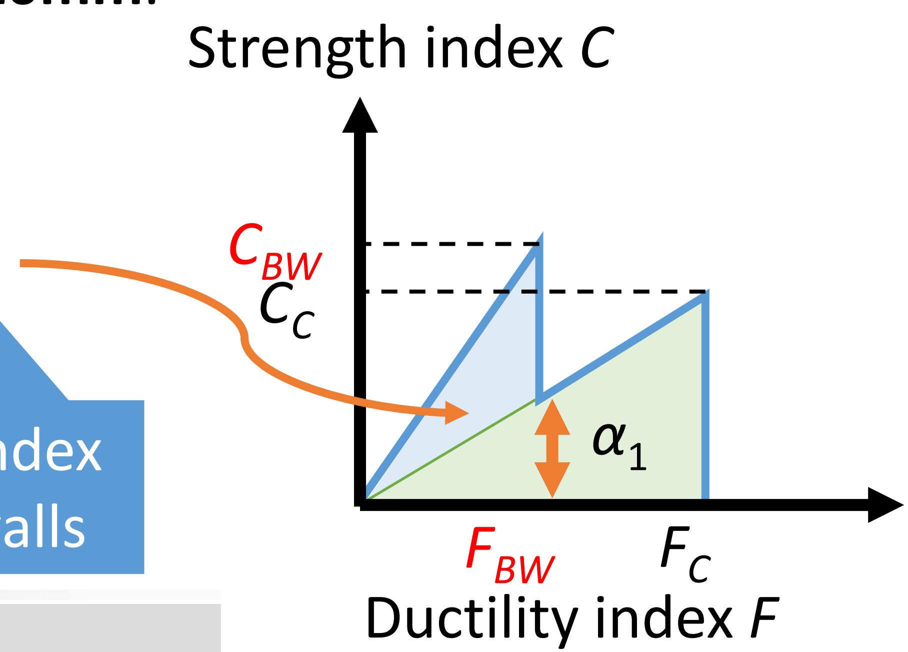
- Assumptions
  - Mass ratio of each floor: **12 kN/m²**.
  - Compressive strength of concrete: **40N/mm²**.
  - Average shear stress of brick walls: **0.15N/mm²**.
  - Thickness of brick wall is **220mm.**

- Seismic capacity

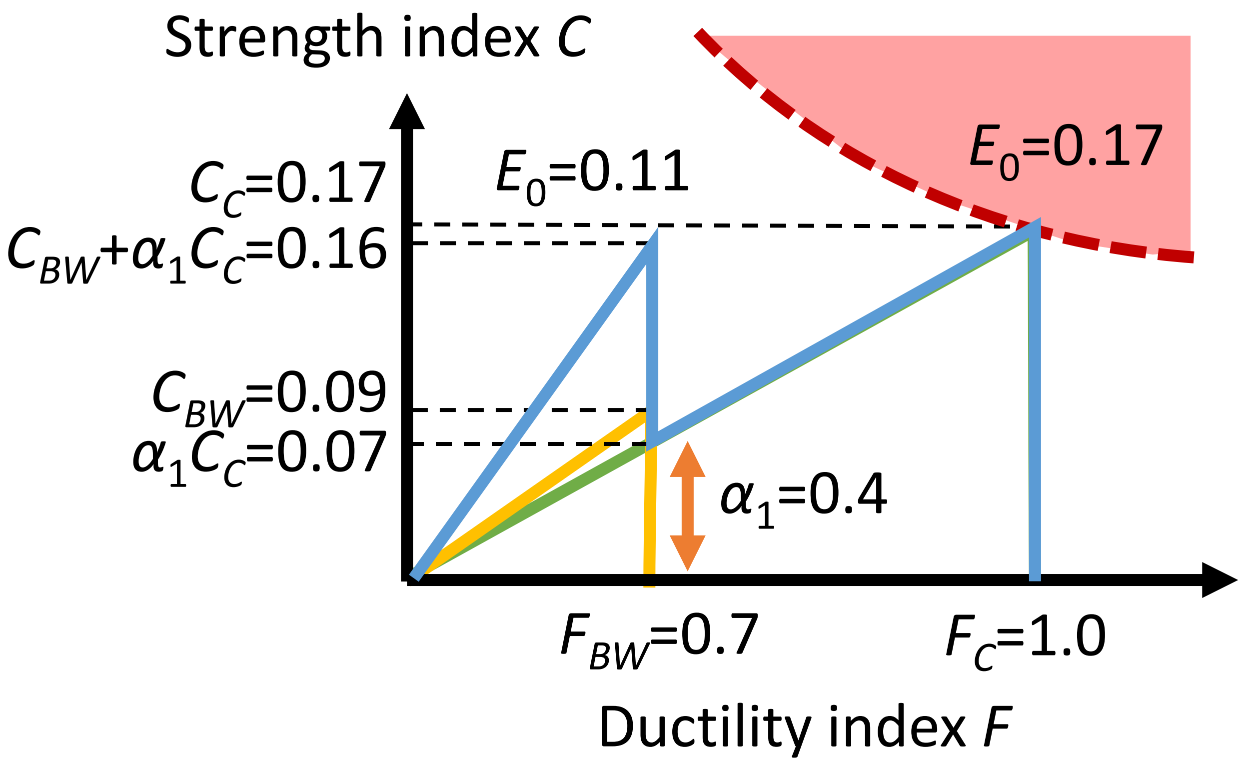
$$E_0 = \begin{cases} (C_{BW} + \alpha_1 C_C) \cdot F_{BW} \\ C_C \cdot F_C \end{cases}$$

Strength index of brick walls

Ductility index of brick walls



Seismic capacity E_0 considering non-structural brick walls



If shear strength contribution of brick walls becomes large, the seismic capacity is determined at when brick walls fail.

	C_C, $\alpha_1 C_C$	C_{BW}	F_C, F_{BW}	E_0
when brick walls fail	0.07	0.09	0.7	0.11
when columns fail	0.17	0	1.0	0.17

Nepalese Side

Roadmap to improve the buildings

Research Roadmap

Building damage at the 2015 Nepal Gorhka earthquake

Research Target 1
Non-structural Brick Wall

- Investigate size and strength of masonry material
- Conduct structural test to assess the strength of the brick wall

- Consider non-structural wall in seismic design for new masonry buildings
- Develop screening and retrofitting method for existing masonry buildings

Research Target 2
Soft first story

- Investigate design details of soft first story
- Conduct structural test to assess the ductility of soft first story

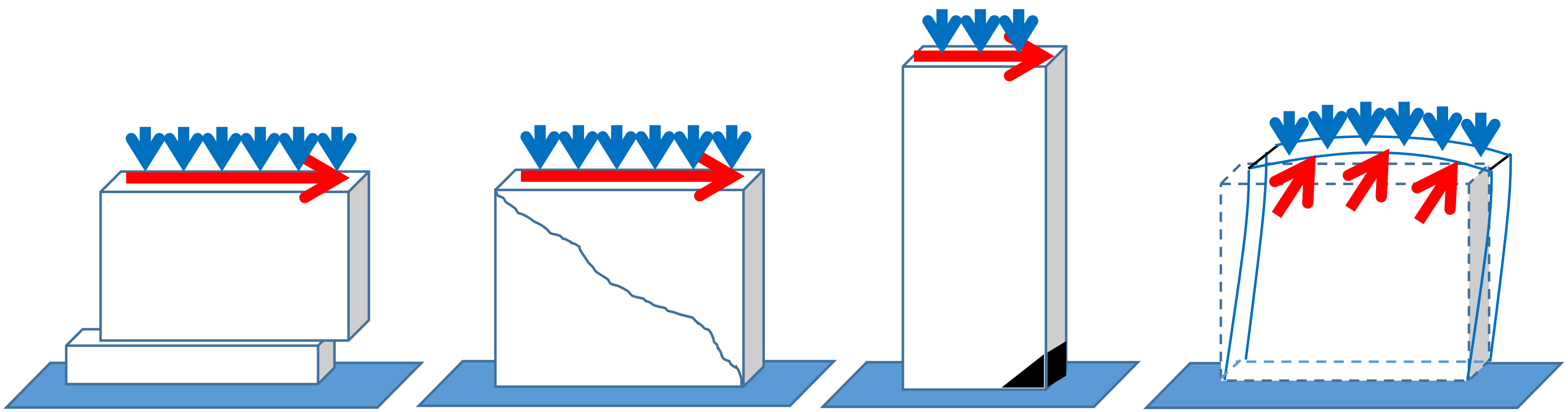
- Propose seismic design method for soft first story buildings
- Propose construction guideline and details of bar arrangement of soft first story

Improve seismic safety of buildings in Nepal

1. Non-structural wall

1-1. Objectives of research

- Investigate size and strength of masonry materials
- Conduct structural test to assess the strength of the brick wall



Sliding failure   Shear failure   Flexural failure   Out of plane failure

1. Non-structural wall

1-2. Roadmap

Items Year	1	2	3	4	5	6	7	8	9	10
Field survey on construction method, brick size, material strength	→									
Literature survey on masonry wall strength	→	→								
Structural test on cracking and ultimate strength of **in-plane direction**			→	→	→					
Structural test on ultimate strength of **out-of-plane direction**					→	→				
Strength of **multi-story brick wall**							→	→		
Development of **design formula** of ultimate strength of brick wall					→	→	→	→	→	→
Proposal of **retrofitting techniques**				→	→	→	→	→	→	→

1. Non-structural wall

1-3. Required equipment

Loading system in Romania donated from Japan

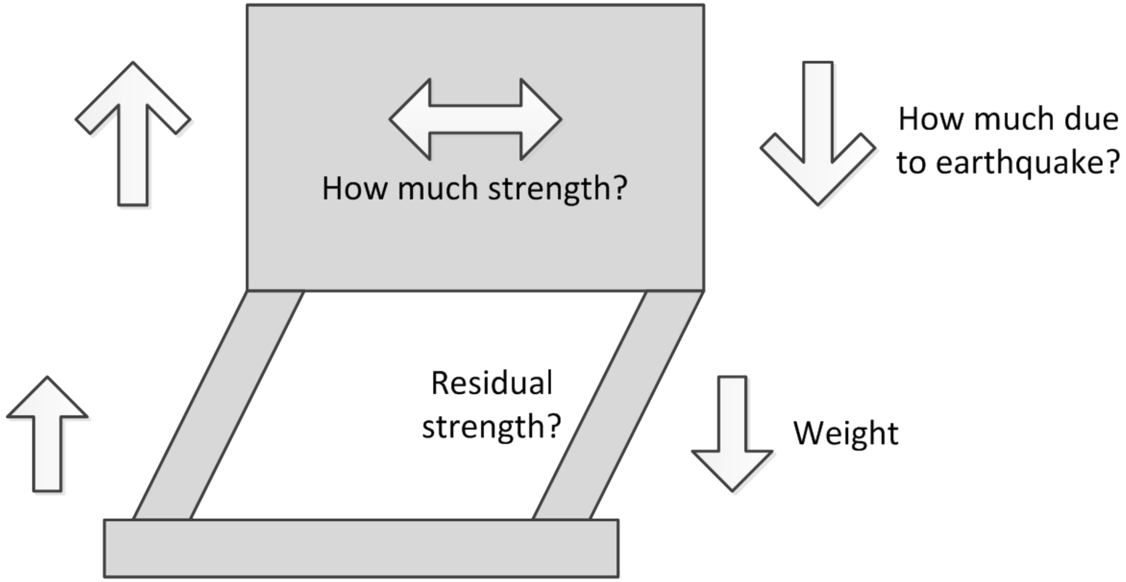
Bi-directional lateral loading system

- Hydraulic oil jacks
- Hydraulic pump
- Pantograph system to prevent out-of-plane deformation
- Transducers
- Data logger
- Switch boxes
- Strain gauges
- Data acquisition software
- Notebook computer for data acquisition

2. Soft first story

2-1. Objectives of research

- Investigate design details of soft first story
- Conduct structural test to assess the ductility of soft first story



2. Soft first story

2-2. Roadmap

Items Year	1	2	3	4	5	6	7	8	9	10
Field survey on size of column, common material properties, nominal stress	→	→								
Structural test on **shear and flexural strengths** of column			→	→	→	→				
Structural test on **ductility demand** of soft first story.				→	→	→	→			
Development of **design formula** of shear strength of column					→	→	→	→	→	→
Proposal of **design methodology** soft first story.						→	→	→	→	→

2. Soft first story

2-3. Required equipment (same as the equipment of nonstructural wall test)

Loading system in Romania donated from Japan

Bi-directional lateral loading system

- Hydraulic oil jacks
- Hydraulic pump
- Pantograph system to prevent out-of-plane deformation
- Transducers
- Data logger
- Switch boxes
- Strain gauges
- Data acquisition software
- Notebook computer for data acquisition

Concluding remarks

- Our Team investigated and discussed to tackle with Damages of
  - non-structural walls
  - Soft-first-story
- An example of a seismic screening method to consider the effect of brick non-structural walls is proposed.

Concluding remarks

- Difficulties and problems in the structural engineering field, however, cannot be solved in only one year with limited budged.
- Roadmaps to achieve the goal are the main outputs from our team.
- They can contribute to find the shortest way to the goal for researchers, officers, stakeholders, and funding agencies

- This wrap-up workshop is not a goal to overcome the earthquake disaster…
- We are just standing on the starting point with brand-new maps.

Let’s start together to the goal!

Thank you for your kind attention…