Introduction of Distinct Element Method (DEM)

Collapsing Process Simulations of Brick Masonry Structures

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Shaking table test in E-Defense, NIED

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Experiment profile

Main features

- Specimens were build in 31 years ago
- One house was retrofitted by brace and plywood
- Japanese Building Code was revised in 1981 (25 years ago)

brace

plywood

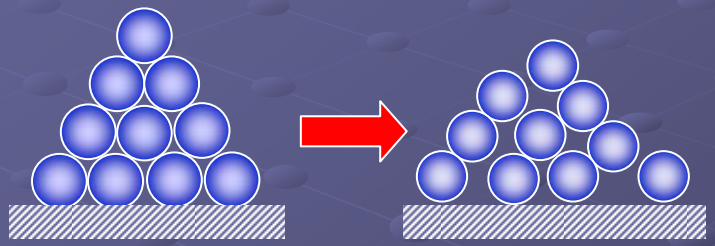
It is important to reinforce existing houses that have not enough earthquake-resistance adequately

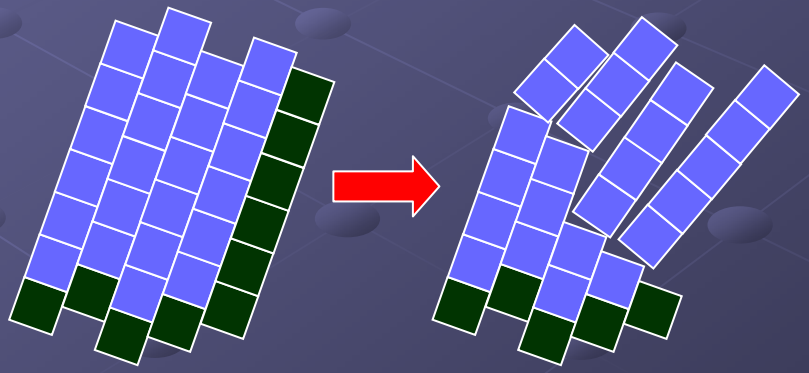
Outline

- Introduction of Distinct Element Method
- Simulation Example
  - Application to Timber Structures
- Trial Simulation of Brick Masonry Structures

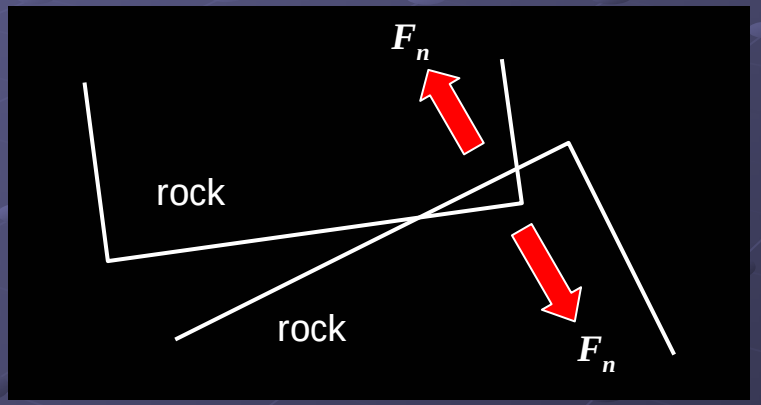
DEM（Distinct Element Method）

Collapsing simulation of rocks （P.A. Cundall）

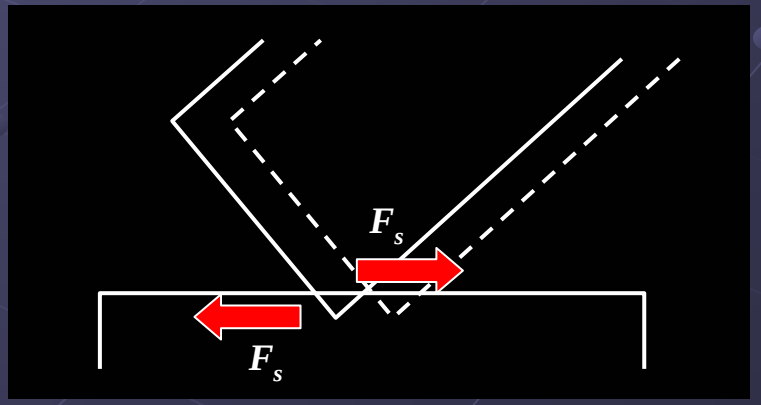




Normal force

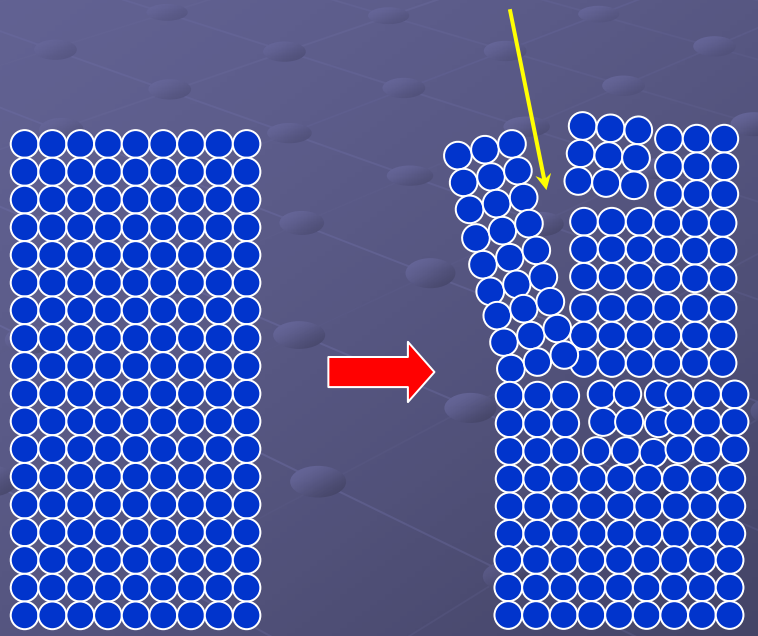


Shear force

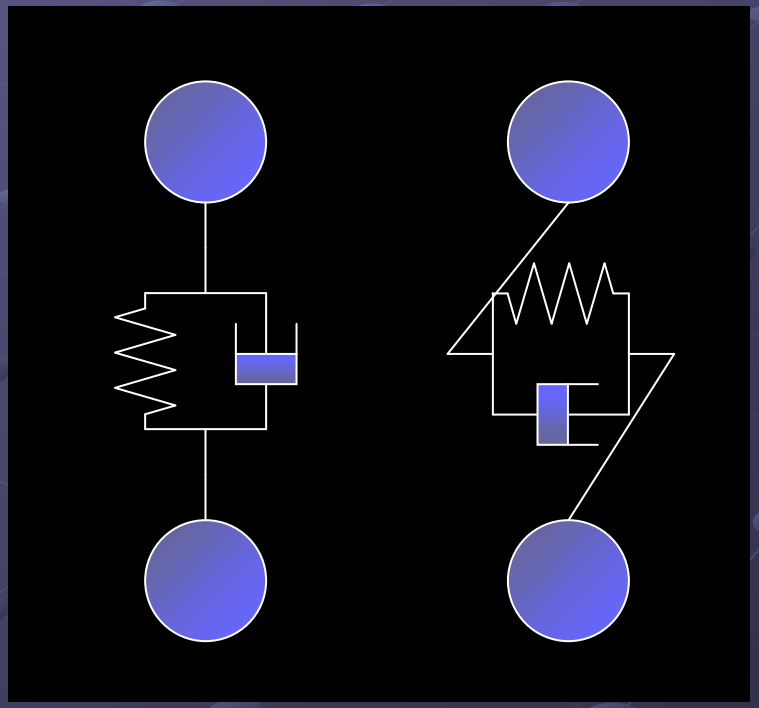


EDEM（Extended Distinct Element Method）

- Fracture simulation of concrete（Meguro, Hakuno）



Pore spring



Why DEM ?

- Non-continuum analysis method.

  → Large deformation analysis can be made easily.

  → Suitable for Brick Masonry Structure.

- DEM don’t need to solve total stiffness matrices as in FEM.

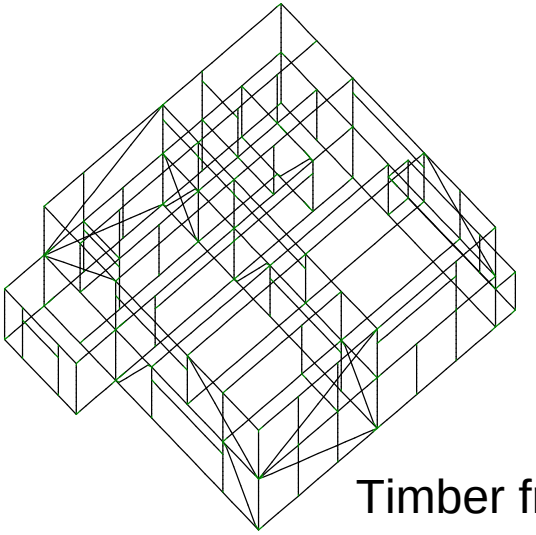
  → The calculation cost is reduced.

Target specimen for numerical simulation

Non-retrofitted house

- Specimens were build in 31 years ago in Hyogo
- Mud wall, mortar finish
- Scores in seismic capacity evaluation = 0.5
  (1F Y-direction)

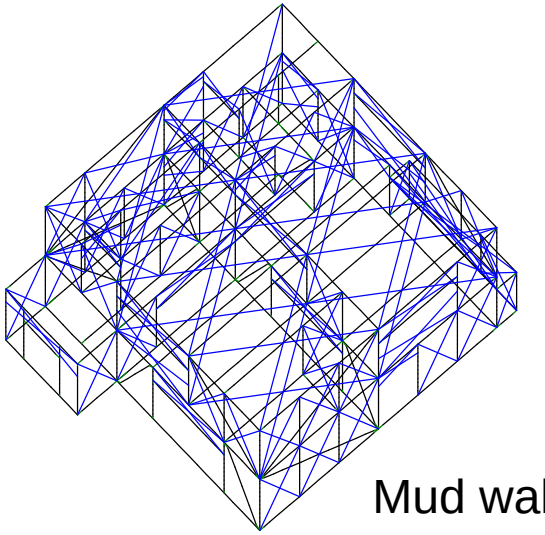
Simulation model



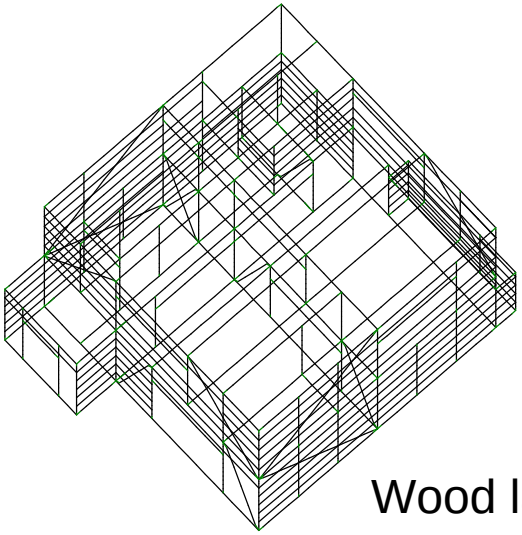
Timber frame

Number of Nodes
4,604
Number of DOF
27,624

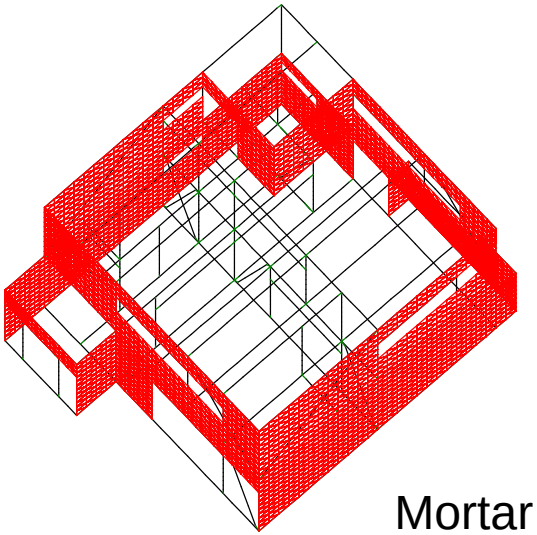
Calculation Time
About 2.5 hours
=15 sec. simulation
(Pentium4 PC)



Mud wall

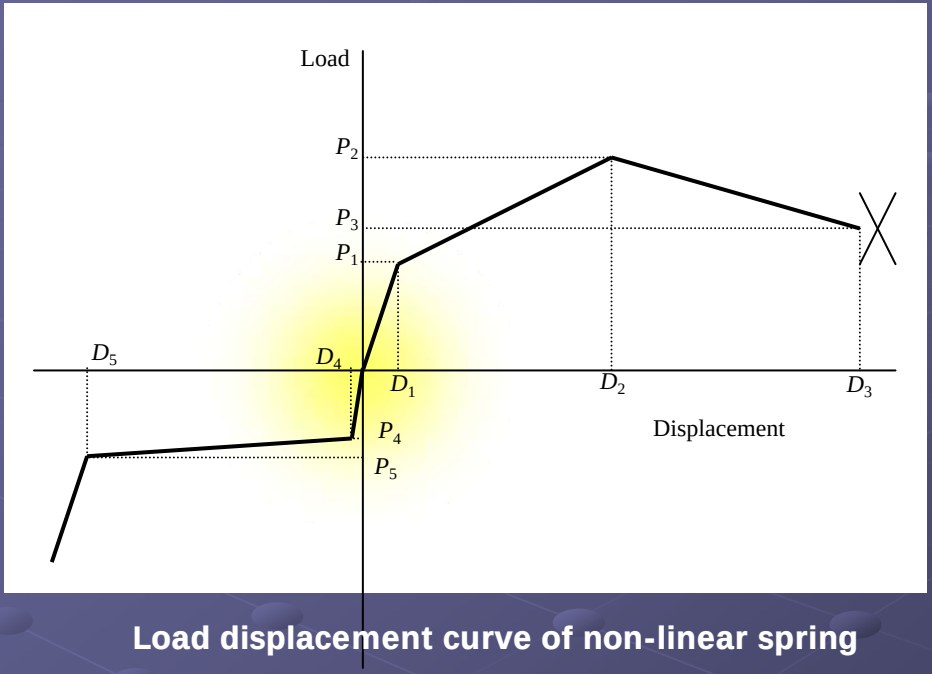


Wood lath



Mortar

Parameters of frame connection



Load displacement curve of non-linear spring

Corner fastener
（CP-T）

Iron cramp
（C120）

Hold down faster
（S-HD20）

Representative data of non-linear spring

	Load (kN)					Displacement (mm)				
Type	P_1	P_2	P_3	P_4	P_5	D_1	D_2	D_3	D_4	D_5
S-HD20	21.51	41.44	40.00	1.2	2.5	5.19	25	40	2.0	16
CPT	8.16	14.19	10.00	1.2	2.5	0.69	10	30	2.0	16
C120	3.20	8.50	6.00	1.2	2.5	0.50	13	18	2.0	16

Simulation

Input wave: JR Takatori 100%

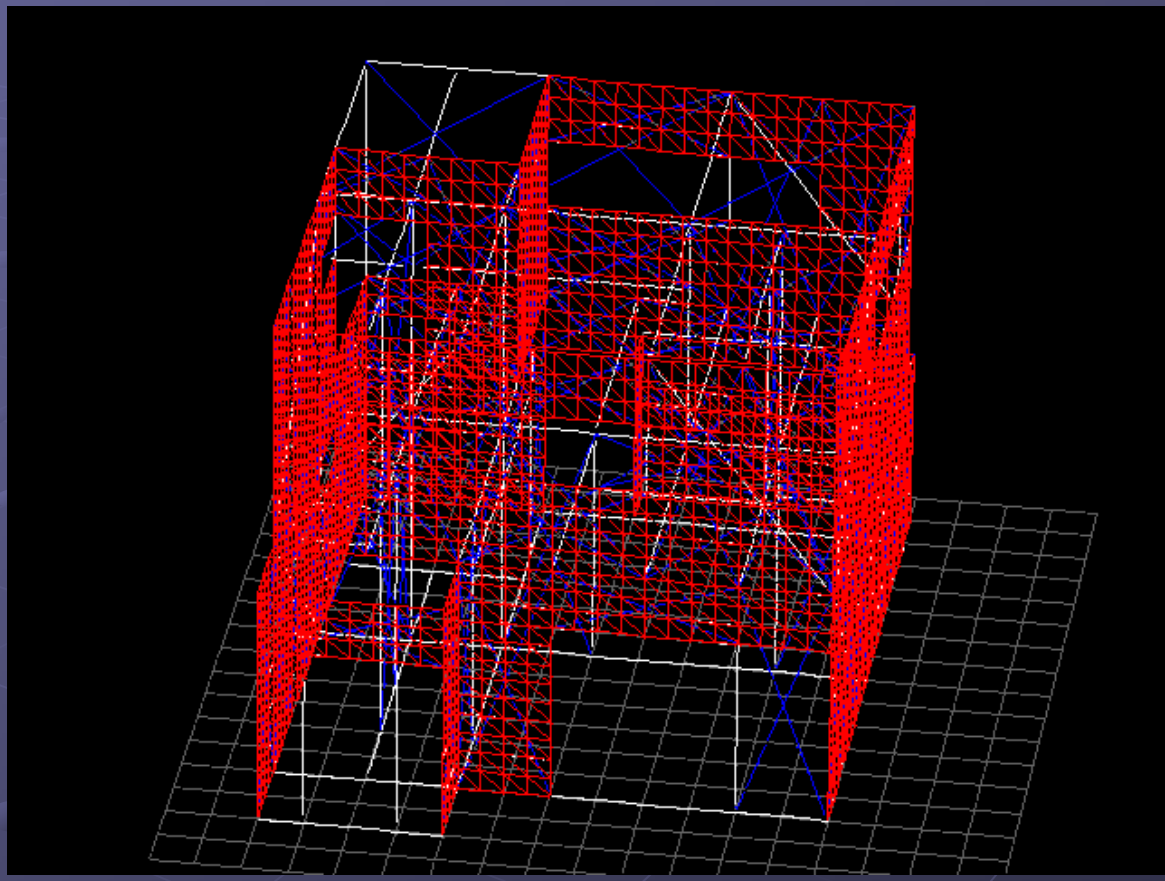
(KOBE Earthquake)

	Acceleration	Velocity	Displacement
NS	641.7gal	149.2kine	86.33cm
EW	666.2gal	117.0kine	37.78cm
UD	289.5gal	16.5kine	11.15cm

Peak

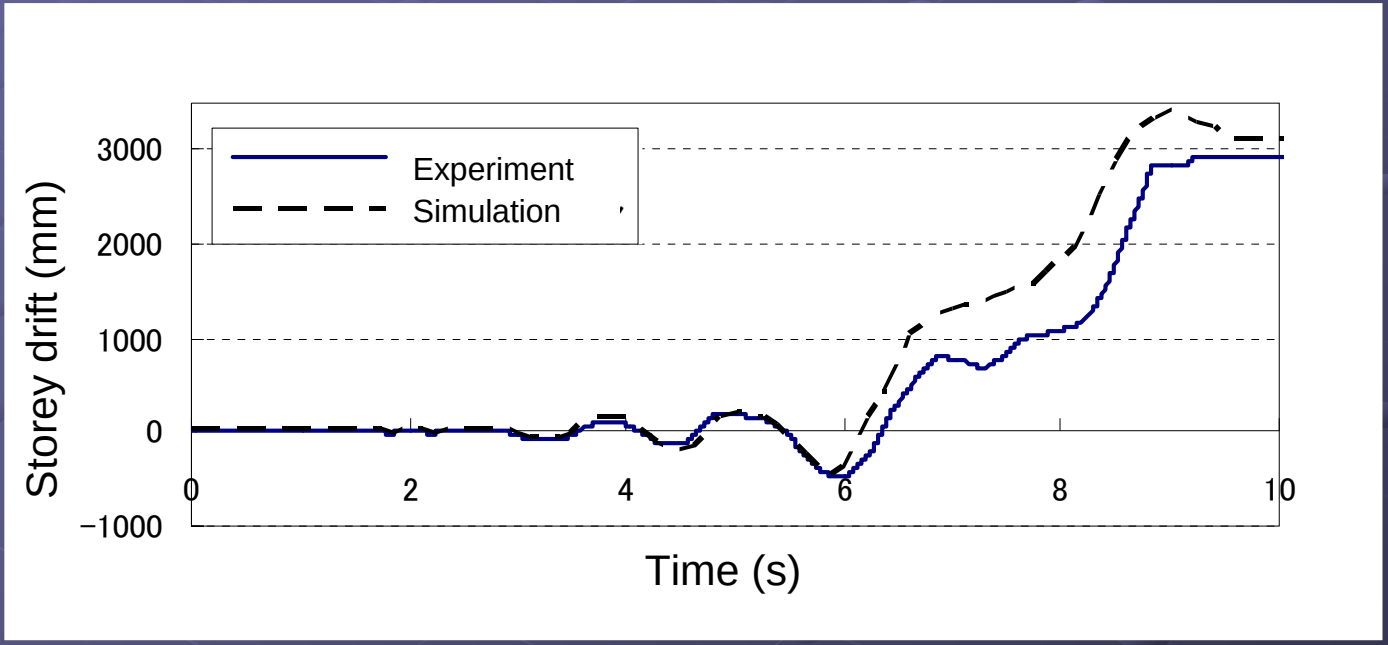
Comparison of collapsing process

Experiment



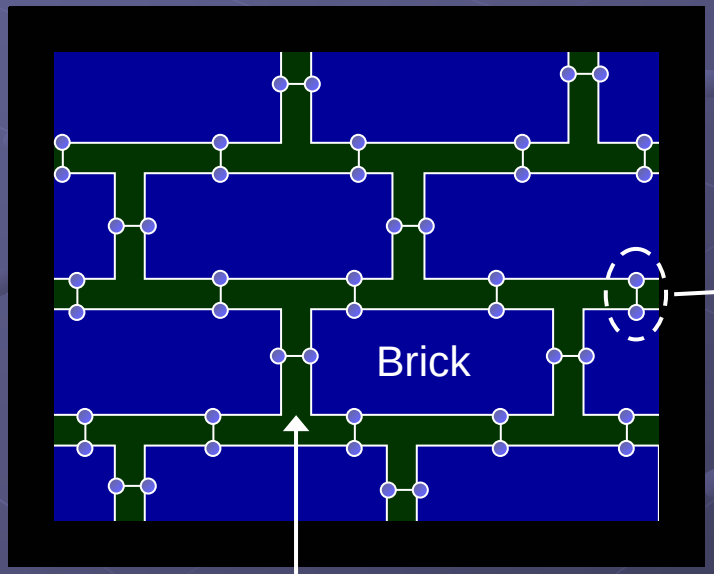
Simulation

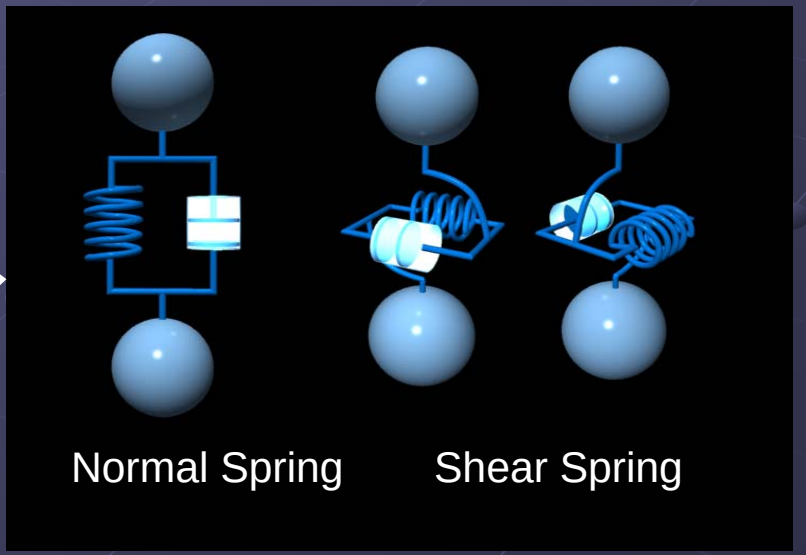
Comparison of storey drift at first floor



Modeling procedure of brick masonry structure by EDEM

- It is assumed that brick elements is rigid body.
- Brick elements are connected each other by mortar springs.
- Parameters of mortar spring are decided by element tests

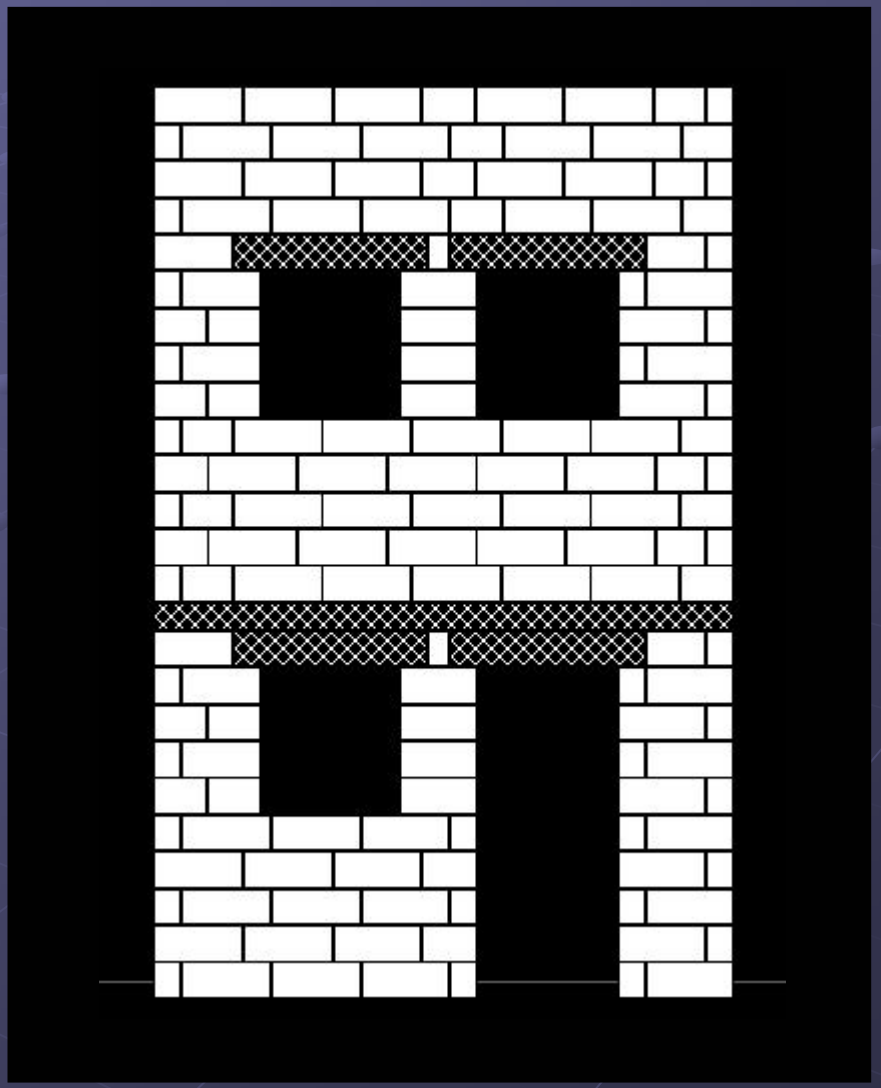




Mortar Spring

Trial Simulation

- Two dimensional model
- 3.3 x 5.2 m
- Concrete Block (50 x 20 x 15 cm)



Input wave: JR Takatori NS