Preliminary Reconnaissance Report on Building Damage
(2016 Kumamoto Earthquake)

Date: April 16 and 17, 2016
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Objective: Preliminary reconnaissance of reinforced concrete (RC) buildings damaged by the 2016 Kumamoto Earthquake
Site: Kumamoto city, Mashiki town, and Uto city in Kumamoto prefecture
Target: The heavily damaged RC buildings reported by media, as well as the damaged ones found on the way.

Route:

4/16  10:10       Arrival at Fukuoka Airport
         12:00       Departure from Fukuoka by car
         14:30       Investigation in Kumamoto city and Uto city (No.1-8)
         19:00       Investigation ends

4/17  6:40        Investigation in Mashiki town (No.10-19)
         12:40       Investigation in Kumamoto city (No.20-24)
         15:15       Investigation ends
         19:00       Arrival in Fukuoka

Notice:
The damage described in this report has been judged by visual inspection only.

We would like to express great sympathy to the people affected by Kumamoto Earthquake and them wish a rapid recovery. We deeply appreciate the people who helped our investigation.
1.
Location: Nishi-ku, Kumamoto city
Structure: 7-story reinforced concrete, without basement, setback on the top floor
Building use: Apartment
Damage outline: Story collapse of 1st story

- Built on a plateau.
- L-shape floor plan with stilt first floor.
- 5 bays in the longitudinal direction and 4 bays in the transverse direction.
- 1st story collapsed due to formation of plastic hinges at the top of the columns in the main shock.
- Shear cracks in non-structural panels on 2nd story and above.
- Tombstones overturned in north and south direction at a surrounding cemetery. The maximum aspect ratio (Depth/Height) of the overturned tombstone is 0.40, and the minimum aspect ratio of survived tombstone is 0.39. This indicates that the maximum acceleration in this area is about 0.4g.
Column damage in the north frame

Crushed column in the south frame
2.

Location: Nishi-ku, Kumamoto city
Structure: 7-story reinforced concrete, without basement, setback on the top two floors
Building use: Apartment
Damage outline: Shear cracks in 1st story columns

- Located diagonally opposite to the previously reported collapsed apartment.
- L-shape floor plan with stilt first floor.
- 6 bays in longitudinal direction and 4 bays in transverse direction.
- Shear cracks in first story columns in the transverse direction with maximum residual crack width of 1.6 mm.
- Flexural cracks on the first story beams in the longitudinal direction.
- Vertical cracks at the middle span of the beams in first story
- Surrounding reinforced brick walls overturned by the earthquake.

South elevation of the building  Shear cracks in a first story column
Flexural cracks in a first story beam  Vertical cracks at the middle span of a beam
Overturned reinforced concrete brick wall
4. Kumamoto castle
Location: Chuo-ku, Kumamoto city

- Stone retaining wall and two of the turrets of the Castle suffered damage
- The turrets are located on the east boundary of the castle
- Wooden structure of the castle turret came down as the stone wall underneath collapsed
- Partial collapse of the stone retaining wall also observed at other turret-less locations

Overview before earthquake
(from Google maps)

Collapsed Higasi-Jyuhakken turret and the surrounding stone retaining wall

Collapsed Kita-Jyuhakken turret and the surrounding stone retaining wall
6.
Location: Minami-ku, Kumamoto city
Structure: RC 3-story building
Building use: Office
Damage outline: First story collapse

- 4 bay by 2 bay building structure
- West and south facade at the first floor had no walls due to shop windows.
- Longitudinal and transverse reinforcements of column found to be round bars.
- First story collapsed with the south side of the second floor touching the ground.

West view
North view
South view
East view
Axially crushed column
Damage to corner column
7.
Location: Uto city, Kumamoto prefecture
Structure: Five-story reinforced concrete frame
Building use: City hall
Damage outline: Local collapse at fourth story

- The structural system above the second floor consists of three frames with two bays in both directions.
- Local collapse at fourth story was observed in exterior frame.
- Failure of beam-column joints was observed at the top of columns in the third and fourth stories.
- Columns in second floor were damaged at the column base.
- Columns in the top story (fifth story) failed in flexure at the top end.
- Ornamental column strips at the tip of cantilever beams were fell-off or broke down at many places.
Flexural failure at the top of an interior column in fifth story

K-net Uto Site
8.
Location: Minami-ku, Kumamoto city
Structure: Two-story reinforced concrete frame
Building use: Office
Damage outline: Shear failure of one of the columns

- Building frame consists of three bays in the longitudinal direction and one bay in the transverse direction. Exterior frames on the south and west are infilled with concrete shear walls with small windows.
- Shear failure was observed in a first story column on the side facing the road.
- No other damage was observed in the structural system otherwise.

Overall view from the east of the building
Shear failure in a column
10.
Location: Mashiki town, Kamimashiki district, Kumamoto prefecture
Structure: 3-story RC building
Building use: city hall
Damage outline: ground deformation, causing damage to a connecting corridor

- Building appears to be built on a banking.
- Surrounding ground deformed extensively at many places.
- Building was retrofitted with an outer frame on the south side.
- Shear cracks were observed on the connecting beams of the outer frame.
- Flexural cracks were observed on the third floor which was not retrofitted with any outer frame.
- Damage was observed at the top and bottom of columns supporting the connecting corridor.
Settlement around the outer frame

Surrounding ground deformation
11. KiK-net Mashiki
Location: Mashiki town, Kamimashiki district, Kumamoto prefecture

- Surrounding ground surface is very soft. Adjacent public lavatory subsided and inclined as result of the ground deformation.
- Installation is located at the edge of a small embankment next to the peripheral road.
- A number of wooden houses collapsed in this area.
12.
Location: Mashiki town, Kamimashiki district, Kumamoto prefecture
Structure: Five-story RC frame
Building use: Training facility
Damage outline: Failure at base of columns, failure at beam-column joints

- Structural system above the third floor consists of a single bay moment resisting frame in both directions.
- Building is inclined to the west due to large residual inter story drift at the third and fourth stories.
- Flexural failure at the column base in third story and failure of the beam-column joints at fourth and fifth floors are prominent.
- According to the hearing from a staff, only cracking and spalling of concrete at the bases of the third story columns were observed after foreshock (on April 14th) while severe crushing of concrete at the column base and significant inclination appeared after the mainshock on April 16th.
13.
Location: Mashiki town, Kamimashiki district, Kumamoto prefecture
Structure: 3-story reinforced concrete with reinforced concrete chimney
Building use: Disposal facility
Damage outline: Falling-off of ceiling and exterior wall panels

- Damaged exterior wall panels observed in the orthogonal direction.
- Ceilings appeared to have fallen off and incinerators stopped by the earthquake.
- No damage was observed at the bottom of the chimney.
14.
Location: Mashiki town, Kamimashiki district, Kumamoto prefecture
Structure: Two-story RC frame without basement
Building use: School
Damage outline: Minor cracks in the building

- Stilt first story for 3 longitudinal bays in the south elevation
- Laminated timber classroom building and reinforced concrete gymnasium exist adjacently. No obvious damage observed in either of the buildings.
15.
Location: Mashiki town, Kamimashiki district, Kumamoto prefecture
Structures: Two-story RC building (south part), Three-story RC building (north part)
Building use: School
Damage outline: Minor cracks in the school building, flexural failure of the first story columns of connecting corridor, and buckling of the braces in gymnasium

- Two parallel school building are joined by two connecting corridors. This connecting structure exhibits flexural failure at the top and bottom of columns, and is inclined largely in transverse direction. Residual drift ratio is 6% in the west corridor, and 20% in the east corridor.
- South building consists of 8 bays in longitudinal direction and 2 bays in transverse direction. No obvious damage was observed.
- North building consists of 9 bays in longitudinal direction and 2 bays in transverse direction. Two central spans are braced on the first and second story. Cracks observed in the concrete mortar connecting the brace to the RC frame.
- Shear cracks in a mullion wall (residual crack width 2.5 mm) and flexural cracks in columns and spandrels also observed in the south part of the north building.
- All the steel braces in the second story of the gymnasium show buckling.

North elevation of the building  South elevation of the building
Elevation of the east corridor
Story drift of the east corridor
Elevation of the west corridor
Story drift of the west corridor
Inside of the gymnasium
Buckled brace
Top of the damaged column (connecting corridor)
17.

Location: Mashiki-machi, Kamimashiki district, Kumamoto prefecture
Structures: Four-story and three-story RC buildings separated by an expansion joint
Building use: Hospital
Damage outline: Inclination due to ground deformation

- Considerably displaced soil and asphalt observed around the periphery of the building
- Adjacent parking space also found to have deep ground openings
- Movement appears to have happened at the expansion-joint connecting the front and back potions of the building. Latter portion found to have tilted 1.9% to the south as the retaining wall at the back of the building failed.
- Diagonal cracks observed in the wall panels at the first floor. However, no significant damage observed in the building frame.

Overall building view from southwest
Displacement across the expansion joint
Crack in non-structural wall
Broken asphalt around the building
Ground opening in the parking

Ground displacement at the back of the building
18.
Location: Mashiki-machi, Kamimashiki district, Kumamoto prefecture
Structures: Three-story RC building (No.1) and two-story RC building (No.2)
Building use: Hospital
Damage outline: Flexural cracks in columns, Shear cracks in short columns

(No.1)
- Flexural cracks observed in the columns of stilt first story. Beams connected to these damaged columns was a wall girder.
- Shear cracks on non-structural panels and damage at the expansion joint due to the subsidence of supporting ground were observed.

(No.2)
- Amount of wall section is considerably larger compared to the building area
- Two short columns in each story show shear cracks. Maximum width of the observed cracks is 1.7mm.
19.

Location: Mashiki town, Kamimashiki district, Kumamoto prefecture
Structures: Two three-story RC buildings connected by two corridors
Two-story structural steel gymnasium
Building use: School
Damage outline: Inclination of a part of the school building due to ground deformation

- South part of the building is divided by an expansion joint. Furthermore, an extension has been built on the east side
- Both the north and south school buildings were retrofitted seismically by steel-braced frames in the longitudinal direction.
- Middle part of the south school building inclined 1.9% to the east. Ground displacement was also observed around the buildings
- Movement appears to have happened at the expansion-joints connecting the school buildings and the stilt-type corridors. Damage was also observed at the base of columns.
- Gymnasium was retrofitted with braces and no buckling appears to have happened. However, cracking in the concrete foundation of the braces was observed.
Inclination of the school building

Ground displacement around the school building

Corridor connecting the school buildings

Damaged column of the corridor

Cracks at the end of spandrel wall in the corridor

Displacement at the expansion joint between the corridor and the school building
Steel braces in the first story of the gymnasium

Cracking in a concrete foundation of the brace
20.
Location: Higashi-ku, Kumamoto city
Structure: Three-story RC building
Building use: Store
Damage outline: Total collapse

- Building separated by an expansion joint.
- West part of the building collapsed due to failure of the columns at the entrance hall with open ceiling.
- Main reinforcement bars in the columns were round bars.

![Building leaning against the columns of the arcade](image1)

![Overall view from the northeast](image2)

![Overall view from the south](image3)

![Collapsed first story](image4)
Collapsed column in the first story

Failure of a beam-column joint at the top of a second story column
21.
Location: Higashi-ku, Kumamoto city
Structure: Four-story RC building, without basement, with 1-story penthouse
Building use: Complex building with shops and apartment
Damage outline: Shear failure of the stilt first story columns

- Shops on first story, and apartment houses on second story and above
- 4 bays in the longitudinal direction and 1 bay in the transverse direction
- Wall frame in the south and east face, and moment frame in the north and west face for first story.
- Two columns show shear failure at the lapping of reinforcement, and the corner column shows residual axial deformation.
- Moment frame section are heavily damaged due to the eccentric floor plan.
- Shear failure of the beam in transverse outer frame.
- Shear cracks on wall frames

![Overview of the building](image1)
![Shear failure at the lapping of reinforcement](image2)
![Shear failure of a beam](image3)
![Shear cracks on a wall](image4)
22.
Location: Higashi-ku, Kumamoto city
Structure: Six-story RC building
Building use: Residential building with a grocery store in the first floor
Damage outline: Story collapse at the first or the second floor

- Building is a 6-story building, but appeared to be a 5-story building because of the story collapse of one of the lower stories. It appeared as if the collapse happened on the first floor in the east side and the second floor in the west side.
- Main shock on April 16 caused the building collapse.
- No one lived in this building ahead of the impending demolition and reconstruction.
23.
Location: Higashi-ku Kumamoto city
Structure: Five-story RC building
Building use: Commercial and residential complex
Damage outline: Collapse at the first story

- First floor of the building is for office use and above floors are for residential use.
- Frame consists of four bays in the longitudinal direction. Outside staircases are located at the both gable ends of the building.
- Main shock of April 16th caused the collapse.
24.
Location: Chuo-ku, Kumamoto city
Structure: Three-story RC building
Building use: Hospital (dental office) with a penthouse
Damage outline: Collapse of the stilt first floor

- Building is supported on stilts, having a parking area and an entrance hall at the first floor.
- Walls are arranged at an angle from the span direction.
- Walls at the first floor are located on the north side eccentrically.
- South side of the first floor collapsed completely resulting in an inclined building.
- Quick inspection had already been conducted and it resulted in a red tag.
25. Other damages observed:
(1) Damage to non-structural members in reinforced concrete buildings
(2) Falling off of exterior panels in steel structures

Chuo-ku, Kumamoto city

Higashi-ku, Kumamoto city

Higashi-ku, Kumamoto city

(3) Collapse of wooden houses

Mashiki town

Mashiki town
(4) Inclination of wooden house due to ground displacement
(5) Damage to the road

Minami-ku, Kumamoto city

Mashiki town

(6) Failure of retaining wall

Mashiki town