April 24, 2016

Preliminary Reconnaissance Report on Building Damage
(2016 Kumamoto Earthquake)

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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

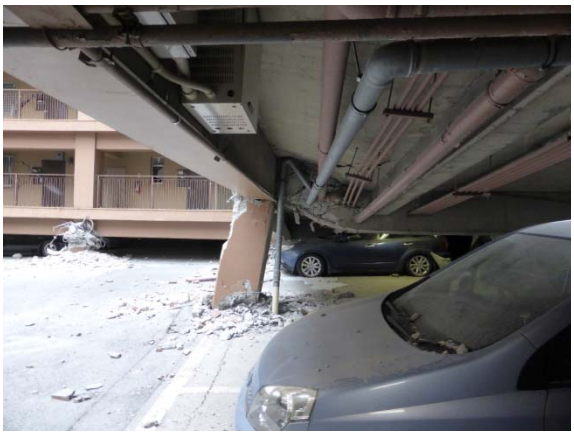
Damage outline: Story collapse of 1st story

- 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.

South elevation of the building

East elevation of the building

Soft 1st story collapese in north east frame



Bending of the tarnsverse beam in north frame

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.

Overall view of the building from soutwest end

Collapsed fourth story

Failure of an interior beam-column joint
at the fifth floor on west side of the building

Failure of an interior beam-column joint
at fifth floor on south side of the building

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.

East view

South view (retoroffited with an outer frame)

Damaged connecting corridor

Damage to the column of 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.

KiK-net Mashiki

Inclined public lavatory

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.

Overall view from north

Flexural failure at the base of third story columns

Failure in the beam-column joint at fourth floor

Failure in the beam-column joint at fifth floor

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.

South elevation of the building

Damage to exterior wall panels

No damage 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.

South elevation of the building

Cracks at the top of second story columns

Overview of the gymnasium

Damage to the exterior walls

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

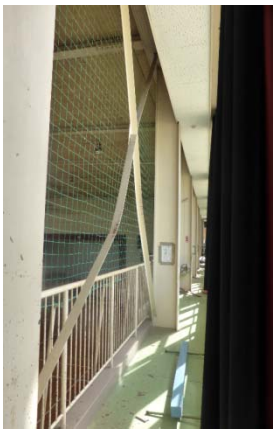
Elevation of the east corridor

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 (connectiing 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 subsidance 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.

Overview of the builing

Shear cracks in the nonstructural panel
(due to subsidance of the supporting ground)

Shear cracks on a short column

Flexural cracks on a stilt story column

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.

Overall view of the north school building

Overall view of the south school building

Seismic retrofitting by steel-braced frames

Seismic retrofitting by steel-braced frames

Inclination of the school building

Ground displacement around the school building

Coriddor connecting the school buildings

Damaged column of the coriddor

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 gymmnasium

Cracking in a concrete foundation of the brace

20.

Location: Higashi-ku, Kumamoto city

Structure: Three-story RC building

Building use: Store

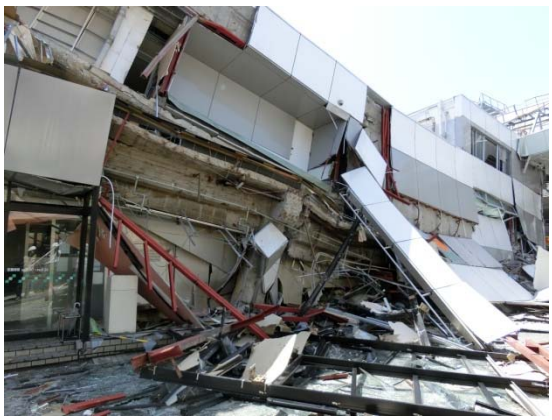
Damage outline: Total collapse

- 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

Overall view from the northeast

Overall view from the south



Collapsed first story

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 builiding

Shear failure at the lapping of reinforcement

Shear failure of a beam

Shear cracks on a wall

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.

South view

East view

View of the damage from inside the building in the first floor. (The upper floor collapsed down)

Shear failure in a beam

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.

Overall view from the east

Collapsed first story

Failure of the gable wall at the south side

Collapsed column at the northeast corner

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.

North-east view

Axially crushed south columns

Axially crushed north columns

Quick inspection result (Red tag)

River next to the building

25. Other damages observed:

(1) Damage to non-structural members in reinforced concrete buildings

Chuo-ku, Kumamoto city

Chuo-ku, Kumamoto city

Chuo-ku, Kumamoto city

Nishi-ku, Kumamoto city

Chuo-ku, Kumamoto city

Chuo-ku, Kumamoto city

(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

Mashiki town

Mashiki town

Mashiki town

(4) Inclination of wooden house due to ground displacement

Mashiki town

(5) Damage to the road

Minami-ku, Kumamoto city

Mashiki town

Mashiki town

(6) Failure of retaining wall

Mashiki town