2016/02/06 Meinong Earthquake, Kaohsiung, Taiwan
Main damage area: Tainan

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Changes in ver. 2.0

- General damage condition is updated.
- Building information of King’s Town bank and Weiguan building is updated. Photos were added.
- Google street view photos of some sites before earthquake were added.
- Six damage sites were added.
- Two areas of soil liquefaction were added.
Earthquake information

- Epicenter: 22.93N, 120.54E
- Depth: 16.7 km
- Richter magnitude scale: 6.4

(Courtesy of CWB, Taiwan)
Earthquake information

- Detailed information:
  Link to
  Central Weather Bureau, Taiwan

(Courtesy of CWB, Taiwan)
Earthquake information

- Maximum PGA at Caoling, Yunlin (120.68E, 23.60N)

(Courtesy of CWB, Taiwan)
Earthquake information

- Yongkang dist., Tainan (area with the collapsed residential building)

永康 (TAI1) 震度：5 級

地震資訊
發震時間：2016/02/06 03:57:27
震央位置：東經120.54度，北緯22.93度
深　度：16.7公里，芮氏規模：6.4

測站資訊
波動起始時間：2016/02/06 03:57:15
測站位置：東經120.24度，北緯23.04度
震央距：33.34公里，方位角：111.87度

(Courtesy of CWB, Taiwan)
Earthquake information

- Downtown area, Tainan City

**台南市 (TAI) 震度：5级**

地震資訊
發震時間：2016/02/06 03:57:27
震央位置：東經120.54度，北緯22.93度
深 度：16.7公里，芮氏規模：6.4

測站資訊
波緣起始時間：2016/02/06 03:57:15
測站位置：東經120.21度，北緯22.99度
震央距：35公里，方位角：102.31度

Z Max 82.49 gal
NS Max 152.17 gal
EW Max 233.82 gal

(Courtesy of CWB, Taiwan)
Earthquake information

★：Main shock
●：Aftershocks
★★：Main shock of Jiasian EQ, 2010/03/04

 Courtesy of NCREE Taiwan (link to pdf file)
General damage situation (preliminary)

- **Buildings**
  
  Collapse: Eight RC buildings known, several URM buildings
  
  Inclined due to soil liquefaction: Three areas known so far:
  1) close to Yansuei River, 2) Hsinshi distric., 3) 72-84 Wenhe Str.
  
  Moderate damage: no accurate number yet
  - Most of the buildings look intact. The damaged buildings scatter in the east area of Tainan (Yongkang, Sinhua, Rende, Gueiren, Guanmiao, Yujing, Shanshang)

- **Casualties** (2016/02/12)
  
  96 deaths (94 in Weiguan building)
  
  28 missing
  
  550+ injuries
Collapsed Buildings

■ King’s Town Bank
Hsinhua (23.036246, 120.301128)

11 stories with 1-story basement
About 20 years old
1F-3F collapsed and inclined to the street side

1F-3F: Bank and office
Above 4F: rental suites
(not occupied so no casualties reported)
Collapsed Buildings

- King’s Town Bank
Collapsed Buildings

- King’s Town Bank

Before earthquake from Google street view
Collapsed Buildings

- King’s Town Bank
  
  Before earthquake from Google street view
Collapsed Buildings

- King’s Town Bank
Collapsed Buildings

- King’s Town Bank
  The building is being demolished to protect the opposite gas station.
Collapsed Buildings

- Weiguan building - Yongkang (23.005026, 120.261198)
Weiguan building

17 stories with 1-story basement
About 23 years old (licensed in 1992)
Collapsed and overturned to the street side

1F-2F: commercial (big electronic store)
Above 3F: residential
Collapsed Buildings

- Weiguan building
  Before earthquake from Google street view
Collapsed Buildings

- Weiguan building
Collapsed Buildings

- Weiguan building
Collapsed Buildings

- Weiguan building

- It seems there were no walls at the base floor
Collapsed Buildings

- Weiguan building

It appears the rebars in the beam were neither anchored in the column nor extended into the next beam.
Collapsed Buildings
Collapsed Buildings

- Weiguan building

Failure at the steel coupler?
Collapsed Buildings

- **Weiguan building**

  90-degree bend hooks were allowed to use before Chi-Chi earthquake. However the hooks drew the attention of the public opinion and is blamed for the collapse.
Weiguan building

Used oil cans embedded in the concrete were used as inside formwork of non-structural façade to reduce the weight. Some local media mistook this for jerry-building.
Collapsed Buildings

- Weiguan building

An interactive rough 3D model was built by Dept. of Geomatics, NCKU with photo taken by drones. [click here](#)
Collapsed Buildings

- **Street Building**
  - **Rende** (22.989766, 120.267397)

3 stories +1-story rooftop additions
37 years old
Collapse at the ground floor

The upper stories were intact. It was demolished for safety reason.
Collapsed Buildings

- Street Building
Collapsed Buildings

- Street Building
  Before earthquake from Google street view
Collapsed Buildings

- Street Building

The 2+1F buildings at the left side were built at the same time and they are intact.
Collapsed Buildings

- Street Building

The intact neighbor buildings are lower and have partially confined masonry panels (behind the closet and adjacent to the stairs) at the base floor.
Collapsed Buildings

- Tachi Market
  Tainan City (22.962476, 120.229978)

4 stories
About 31 years old
Collapse at the ground floor

1F: market
Above 2F: residence
Collapsed Buildings

- **Tachi Market** - Soft ground floor
Collapsed Buildings

- Tachi Market
  Before earthquake from Google street view
Collapsed Buildings

- **Tachi Market** - The building (left) next to the market was mildly damaged.
Collapsed Buildings

- Tachi Market - The building arcade was originally cantilevered. Columns were added at the corner at 2013.
Collapsed Buildings

- **Tachi Market**
  - The column bases and the original cantilever beam ends were damaged.

Hinged connection
Collapsed Buildings

- **Shanshang Market**
  Shanshang (23.102771, 120.354864)

2 stories
About 30 years old
Collapse at the ground floor

1F: market
2F: residence
Collapsed Buildings

- Shanshang Market

Before earthquake from Google street view

Updated 2016/02/12
Collapsed Buildings

- Shanshang Market
Collapsed Buildings

- Shanshang Market
Damaged Buildings

- **Shanshang District Office**
  
  **Shanshang** (23.103282, 120.352408) (close to the Shanshang market)

- 3 stories
- About 30 years old
- Moderate damage

- Shear cracks appeared on almost every column at 1F and some at 2F
- Ceilings and shelves damaged
Damaged Buildings

- Shanshang District Office
Damaged Buildings

- Shanshang District Office
Intact Buildings

- Shanshang Junior High School
  Shanshang (23.103836, 120.357748) (close to the Shanshang market)

3 stories
30-50 years old
(built in several periods)
no damage
Intact Buildings

- Shanshang Junior High School

Standard plan with cantilever corridor and larger span. Similar buildings have been found severely damaged or collapsed in Chi-Chi earthquake, but....
The building has partially confined masonry wing-walls in the back frame. This is also the reason that it rated a high score in the preliminary seismic assessment and has not been put in the waiting list for retrofit.
Collapsed Buildings

- Old URM building
  Shanshang (23.102672, 120.354467) (next to the Shanshang market)

Single story house

At least 40 years old (estimated)

The gable and the side wall separated from the roof and collapsed on the car.
Collapsed Buildings

- Old URM building

Before earthquake from Google street view
Collapsed Buildings

- **Old URM building**
  
The roof was supported with bamboos.
Collapsed Buildings

- **Old office building**
  
  Yongkang (22.994894, 120.260433)

4 stories

About 30-40 years old (estimated)

All floors collapsed.
Collapsed Buildings

- Old office building

Before earthquake from Google street view
Collapsed Buildings

- Old office building
Collapsed Buildings

- Old office building
Collapsed Buildings

- Xinfu Building
  - Gueiren (22.967340, 120.297689)

7 stories with basement

1F and 2F collapsed and sank to the basement

1F & 2F: Store and office
Above 3F: residence
Collapsed Buildings

- Xinfu Building
  Before earthquake from Google street view
Collapsed Buildings

- Xinfu Building
  The residents were all rescued through the windows.
Collapsed Buildings

- Xinfu Building

90-degree bend hooks and lap splicing at the same place indicate that the building was constructed before 1999.
No detailed information and no casualties.

It appears that the hotel inclined due to collapsed base floors.
The URM bell tower was made of stone. It was moved once and rebuilt with some new parts.

The entire tower collapsed and has been removed.
Collapsed Buildings

- Bell tower of the Wind God Temple

Before earthquake from Google street view
Collapsed Buildings

- Bell tower of the Wind God Temple

The drum tower identical to the bell tower was rebuilt with new materials.

It did not collapse and has been reinforced with temporary braces.
Collapsed Buildings

- Bell tower of the Wind God Temple
  The removed bell tower parts.
Collapsed Buildings

- Bell tower of the Wind God Temple
  The remained foundation shows that the stone columns broke by bending at the base.
Non-structural Damage

- High-rise residential building A

  Anping (22.992092, 120.169012)

26 stories with 4-story basement
20 years old

- Inclined cracks appeared on the non-structural outer walls at 1, 2, 3F. Tiles dropped.
Non-structural Damage

- High-rise residential building A
Non-structural Damage

- High-rise residential building B
  Anping (22.991193, 120.168873) (opposite to high-rise residential building A)

24 stories with 4-story basement
20 years old

- Inclined cracks appeared on the non-structural outer walls at 2, 3, 4F. Tiles dropped. Similar cracks happened during former earthquakes.
Non-structural Damage

- High-rise residential building B
Soil liquefaction

- Three areas are known so far. I have visited two of them.
- RC buildings inclined or sank into the ground. URM walls broke.

1) North coast of Yansuei River
   A large area between Fu’an Rd., Hui’an St. and Bei’an Rd.
Soil liquefaction

2) 72-84 Wenhe Street

A small area not close to the river. The residents said there seems to be a buried old water channel under the street (Wenxiang street).
Soil liquefaction

- Lane 169, Sec. 4, Fu’an Road  \((23.024693, 120.207316)\)

Updated 2016/02/12
Soil liquefaction

- No. 22 & 24, Lane 161, Hui’an Street (23.025618, 120.207835)
Soil liquefaction

- No. 14 & 16, Lane 161, Hui’an Street  (23.025629, 120.207524)
Soil liquefaction

- No. 6 & 8, Lane 161, Hui’an Street  (23.025634, 120.207248)
Soil liquefaction

- No. 1, Lane 32, Sec. 2, Bei’an Road (23.025379, 120.205504)
Soil liquefaction

- No. 72-84, Wenhe Street  (23.003376, 120.191716)