

Preliminary Analysis of 0206 Earthquake in Southern Taiwan

Kuei-hsiang Cheng*

Kao Yuan University, 1821, Zhongshan Rd., Luzhu District, Kaohsiung, Taiwan (R.O.C.).

*Corresponding author. E-Mail: t40002@cc.kyu.edu.tw; Tel: 886-7-6077750; Fax: 886-7-6077762

Received: 7 March 2016

Revised: 2 August 2016

Accepted: 5 August 2016

Online: 13 August 2016

Keywords:

Source effect; Site effect;
Seismic design specifications and commentary of buildings;
Disaster prevention city renovation; Disaster prevention and rescue system

ABSTRACT.

The incident of Southern Taiwan earthquake on February, 6th 2016 has been divided into two events. The first event occurred in the foothill subduction zone, which is categorized as the interface event; the second event happened in the alluvium located at the front of deformation area of the subduction zone, which is categorized as the intraplate event. Due to the source effect derived from southeast to northwest and the soft alluvium site effect in Tainan area, there were 14 residential buildings collapsing and 117 people killed during the earthquake. Among them, Yonkang District suffered the most damages (3-apartment buildings collapsing killed most of the victims of this earthquake). Besides, the earthquake also cost Taiwan the loss of 13 billion NT Dollars. In Yonkang District, there was a residential building complex which contained 3-apartment buildings collapsed because of faulty design in the beginning and improper construction process with bad quality. By the time when the earthquake struck, the site effect brought stronger shake to this fragile residential building, causing it to sway east and west. The building fundamental pillars were sheared off and then from the 7th to 16th floors had fallen down to the basement. This paper discusses the cause and effect of this earthquake; in addition, it also talks about the strategies, regulations, laws, and systems in order to bring up concrete suggestions to disaster prevention units and governments.

© Transactions on Science and Technology 2016

Introduction

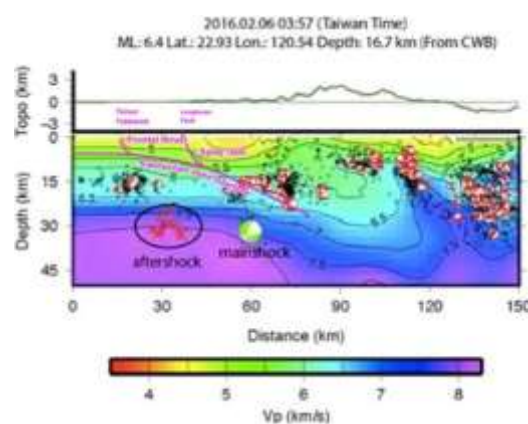
The ML6.4 earthquake occurred at 3:57, Feb. 6th, 2016, hereinafter termed as 0206 EQ, in southern Taiwan caused 14 residential buildings collapsing immediately, 3 having serious tilt, and 117 people lost their lives. Not to mention that Weiguang residential building complex in Yonkang District fell down completely and that made 115 residents dead in this incident. The earthquake parameters of 0206 EQ occurring at 03:57 am on Feb. 6th are displayed in Table 1. These data are obtained from Central Weather Bureau Taiwan, CWB (2016).

Table 1. Earthquake parameters of study event

Parameters	Details
Origin Time	2016/02/06 03:57:27
Lon.	120.54°E
Lat.	22.93°N
Depth	16.7KM
Mag.	6.4

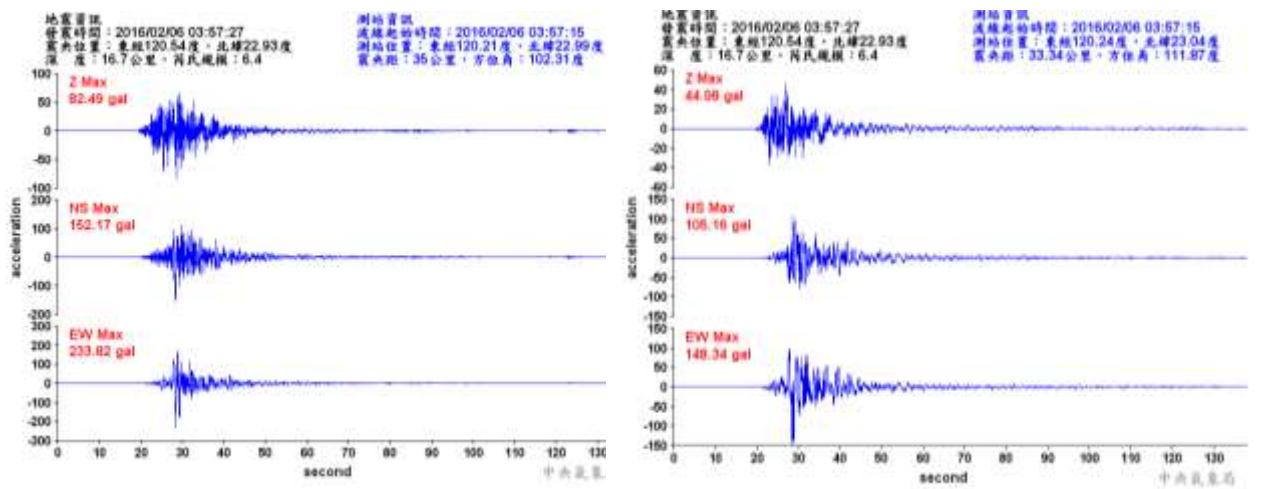
Based on the data from CWB field stations and Taiwan Earthquake Center (TEC, P-alert) stations, we could tell that there were two main shocks occurred almost at the same time. The first one was ML6.2 from a blind fault but near Chishan fault, and 4 seconds earlier. It was located in Meinong Dist., Kaohsiung. P waves of the first EQ moved approximately 6 km per second west to Yonkang Dist., Tainan, 25 km west to Meinong and deduced another blind fault crack. The P waves triggered the second EQ which was ML6.1 and 30 km in depth and that was the primary cause for severe damages to people and buildings.

The hypocenter mechanisms for both events were similar; however, the main shock with east-west strike, while the second one was because of north-south fault, the aftershocks are much deeper, which made the most damages to Tainan area, only 5 km from the second EQ's epicenter. The 2nd event 4 seconds after the mainshock was used to measure the long-period acceleration and velocity (Killer Phase). This is why the data of a P-alert station (Instant Quake Intensity Information, 2016) nearby could be seen moving west first and then north. By mapping on the hypocenter profiles of TEC, we could preliminarily see the first EQ was from subduction zone interface event; the second EQ and aftershocks were from subduction zone intraplate, and it was named intraplate EQ in Japan.

**Figure 1.** Velocity structure of 0206 EQ (Huang, 2004; Structural Seismology Lab, 2016)

According to the acceleration data in Tainan and Yonkang, the wave with 1-2 second cycle is clearly in vertical and keeping for 10 seconds and even more. Its PGA falls to 50-80

cm²/sec (CWB intensity scale 4); however, the shake in EW direction is 5-6 seconds with PGA at 150~230 cm²/sec (CWB intensity scale 5).



(a) Tainan (Intensity 5)

(b) Yonkang (Intensity 5)

Figure 2. Acceleration records of (a) Tainan & (b) Yonkang, 0206 EQ (CWB, 2016)

The strong shake happened in Tainan and Yonkang was due to the seismic waves of this EQ moved from the epicenter to northwest direction. The serious damages in Tainan were related to site effect. The soft alluvium geological structure enlarged the amplitude, which brought much stronger shakes and longer period. The shake of intensity 5 in Xinhua, Tainan lasted for 8.16 seconds. It was much longer than it did in Chishan for only 1.74 seconds. The coseismic displacements in vertical and horizontal directions triggered by the main shock are shown as in Fig. 3.

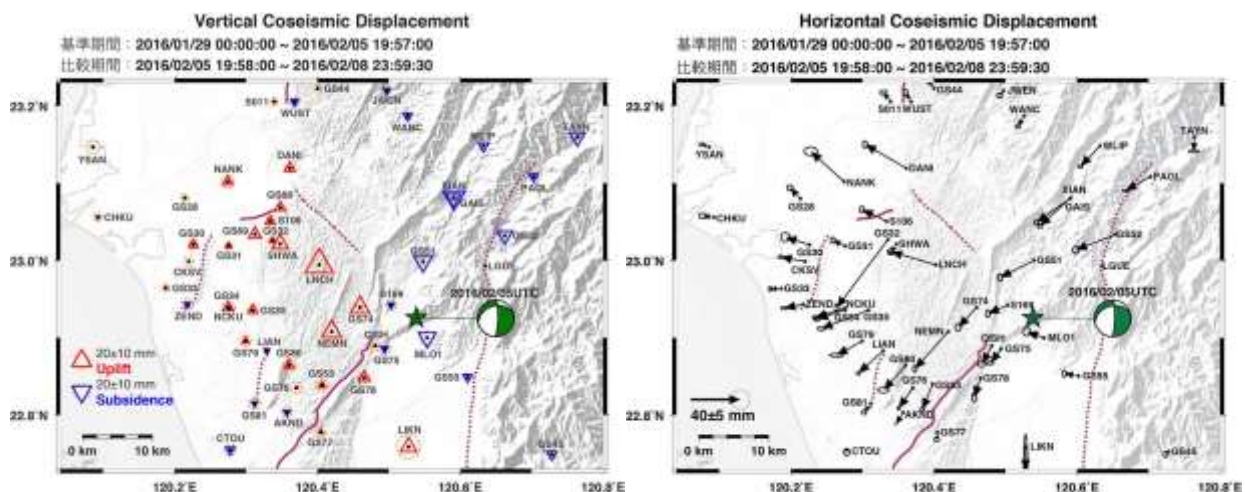


Figure 3. The coseismic displacement in vertical and horizontal directions of 0206 EQ (CWB, 2016)

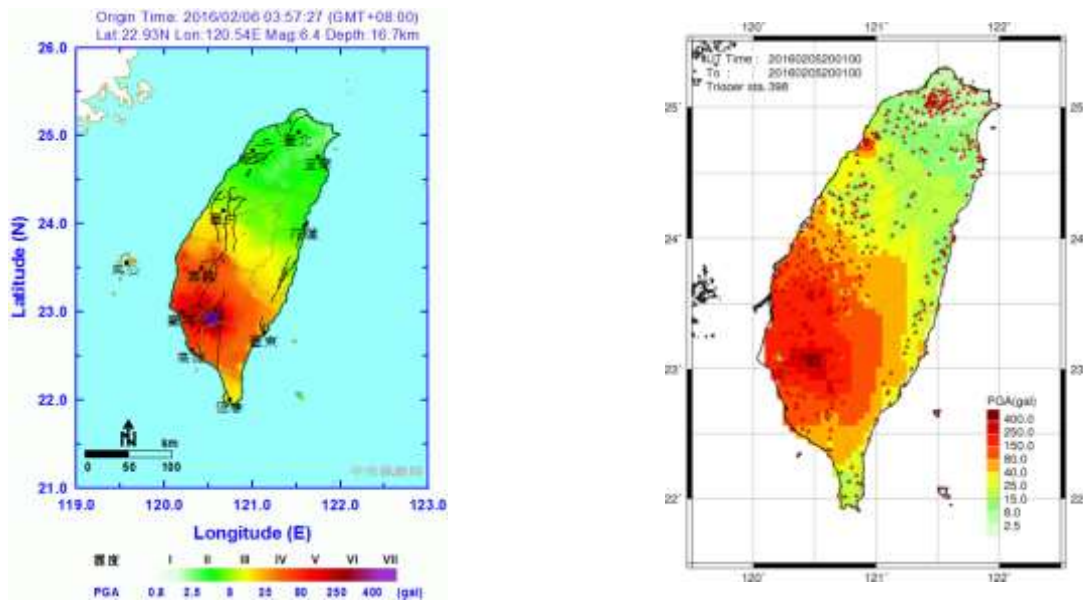


Figure 4. CWB shakemap & P-alert (TEC) 1-min shakemap (CWB 2016; TEC-CEO, 2016)

Figure 4. shows the CWB shakemap (left) and P-alert (TEC, right) 1-min shakemap. From the statistics of CWB Earthquake Center, there have been 12 events larger than ML5.5 within 30 square KM from the epicenter of 0206 main shock dating back from 1900. Among them, 5 events reached ML6.0 and they are listed in Table 2. This tells us that events have been occurring more and more in the 21st century.

Table 2. EQ catalogue of Southern Taiwan ($ML \geq 6.0$)

EQ	Date	Mag.	Depth	Death	Building collapsing
1902 Tainan	0320	6.0	-	-	-
1946 Xinhua	0205	6.1	5	74	1954
2010 Jiashian	0304	6.4	22	-	-
2012 Wutai	0226	6.4	26	-	-
2016 Meinong	0206	6.4	16	117	17(38 re-built)

Seismic Hazards

The event of 0206 EQ caused total casualty of 117 people and 551 were injured. Besides collapse of 14 residential buildings and 3 in serious tilting, there are at least 38 (HouseFun News, 2016) more needing to be torn apart and re-build immediately. In addition, this EQ also resulted in power failure of 173,163 families and water outage of 400,300 families. Among them, more than 50,000 families did not have water supply for 9 days, which happened to be Chinese New Year Holiday (Feb. 8 was the CNY Day).

The rescue period lasted for 180 hours in Yonkang District, Tainan. The total visits of rescuers for Tainan area were 12,250, fire engines were 1,127 and rescue dogs were 127.

According to Ministry of Internal Affairs, the total visits of rescuers from the whole Taiwan were 24,449, helicopters were 11, vehicles were 4,850, and rescue dogs were 147 (National Fire Agency, 2016).

Regarding to economic loss, high precision technology companies had a loss of 3 billion NT Dollars, Taiwan High Speed Rail had a loss of 194 million NT Dollars (CN Yes.COM, 2016), the loss of agriculture was 170.73 million NT Dollars (NOW News, 2016), 420 schools had a total loss of 130 million NT Dollars (NTDTV News, 2016), and a 250-million-NT-Dollar compensation was given to 148 insurers (Central News Agency, 2016). The estimated total loss for this earthquake was more than 13 billion NT Dollars.

Yonkang Dist. 3-Apartment Buildings Collapse Analysis

This earthquake caused 14 buildings collapsed where among them the 3-apartment building complex was the most serious incident with 115 residents lost their lives. This residential building complex was an RC based building and 22 years old before it collapsed. Its construction was completed in 1994 after its construction admission was given in 1992. Right before its completion in 1994, the design of it was modified (the partition walls of 1F to 4F were cancelled). The floor plan and collapse illustration are shown in Fig. 5.

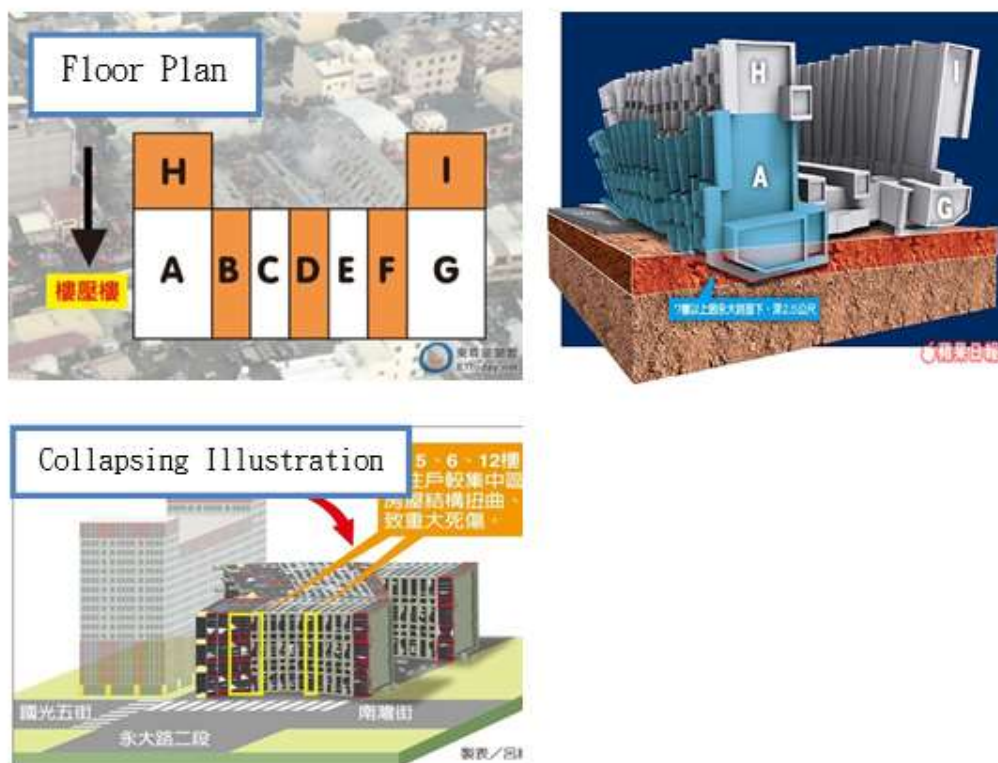


Figure 5. Floor plan and collapsing illustration (ETtoday 2016; Appledaily 2016; Udn News, 2016)

Yonkang Dist. reached CWB intensity 5 in 0206 earthquake. There was no soil liquefaction but the source and site effects imposed a big impact to this weak building complex. We divide this into two aspects: design failure (NEXT Magazine, 2016) and improper construction process.

(a) Design failure:

1. The building complex was a “ Γ ” shape. This shape easily forces too much strain concentrated on the outer corners and caused weak earthquake-resisting capacity on A and G buildings.
2. It is the law that buildings which are over 50m high are required a substantial examination by the government. Weiguang buildings were only 49.9m, which was doubted that the constructor was on purpose to avoid this examination.
3. There were no partition walls from the first to the fourth floors in A、B、C buildings. The insufficient quantity of pillars made these floors weaker than others.
4. In 1994 the design was modified. In buildings B to F, the four load-bearing walls were eliminated so the earthquake-resisting capacity became weak.
5. With 16 stories above the ground and only 1 floor of basement, the lack of foundation in Weiguang was an improper design which resulted in this tragedy.
6. The first floor was next to the road so the arcade was designed for business reason but this led to the unbalance of the buildings and caused them to fall down to this side which had less pillars.
7. It is not correct about the lap joint of girder (crossbeam).

(b) Improper construction process:

1. The stirrup of pillars was only 90 degrees which was less than the new law with 135 degrees after 921 earthquake in 1999 (see Fig. 6). This resulted in weaker structure to earthquakes.

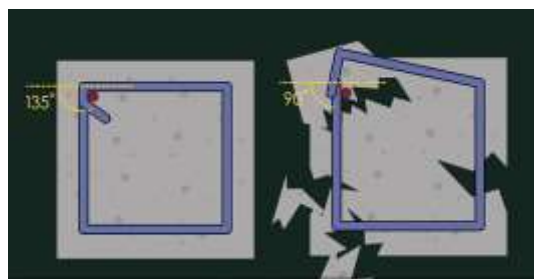


Figure 6. Schematic of beam-column joints (Chinatimes, 2016)

2. The density of stirrup was insufficient among beam-column joints, which did not

match the 5-10-cm regulation.

3. The quantity of stirrup from the first to the fifth floors was near 50% less than it was in the structure calculation sheet. Therefore, the joints had less strength against earthquakes.
4. The construction of rebar in columns was not applied in split-level lap but in block format. This also made the strength weaker.
5. The visible rebar on site was very clean, which may indicate the insufficient bondability.

Figure 7 shows the schematic diagram of Weiguang building collapse. The collapse of the building was due to improper design firstly and bad construction process with the site effect of 0206 earthquake. The earthquake had it swing from east to west and then the foundation was squeezed repeatedly which made the complex fall down to the road ahead.



Figure 7. Schematic of Weiguang Building Collapse (Appledaily, 2016)

Metro Disaster Prevention Strategies and Concluding Remarks

The event of 0206 Southern Taiwan Earthquake has brought us 3-level disaster prevention experiences and lessons. From the law aspects, aseismic design and construction regulations are flexible to improve in design, construction and monitoring, especially when the design is modified. In addition, applications in Geology Act and information of disaster prevention should be released to public as soon as possible. From the policy, homeland plan has to be focused on disaster prevention and should choose old buildings near faults or on the top of soil liquefaction areas as the top priority. From the disaster prevention including construction management, disaster prevention, understanding of natural disasters and many others, people in Taiwan are lack of the knowledge of the above issues. Even though the 0206 earthquake had just crossed the threshold and was a single event, the society still paid a lot in the loss of

lives and economy. The insufficient of disaster prevention education, the incorrect information on the website, and the indifference of escape routes and safe zones has led to hideousness within the society. Although there is no official design from our government, however, according to “Disaster Prevention and Response Act”, the reaction toward 0206 earthquake still looked like a mess. The government and people should be bound together in disaster prevention and preparation. To facing the compound disasters, temporary mobilization is not sufficient instead preparation beforehand is the only strategy to decrease the damages brought by disasters. “Prediction, Pre-warning and Prevention” is always the main policy of disaster management.

References

- [1] Appledaily (2016). *Terror mad shake 8 seconds*. (<http://www.appledaily.com.tw/appledaily/article/headline/20160207/37055063/>). Accessed on 7, February, 2016.
- [2] Central News Agency (2016). *Earthquake in southern Taiwan. Only 148 insured of earthquake insurance*. (<http://www.cnabc.com/news/aall/201602060379.aspx>). Accessed on 6 February, 2016.
- [3] Chinatimes (2016). *Severely affected area in Yongkang: low bending camber of reinforcement*. (<http://www.chinatimes.com/newspapers/20160207000142-260102>). Accessed on 7 February, 2016.
- [4] cnYes.com (2016). *Taiwan High Speed Rail: Further announcement on the effect of Kaohsiung Meinong earthquake on the company's financial operation*. (<http://news.cnyes.com/Content/20160219/20160219184539155065810.shtml>). Accessed on 19 February, 2016.
- [5] CWB (2016). *Earthquake report*. (http://www.cwb.gov.tw/V7/earthquake/rtd_eq.htm). Accessed on 6 February, 2016.
- [6] ETtoday (2016). *Serious casualties in Weiguang residential building. Construction technician: combined factors*. (<http://www.ettoday.net/news/20160210/646277.htm>). Accessed on 10 February, 2016.
- [7] HouseFun News (2016). *Many condemned buildings in Tainan. Tainan Public Works Bureau: 31 need to be demolished* (<http://news.housefun.com.tw/news/article/194173120771.html>). Accessed on 10 February, 2016.
- [8] Huang, S. T. (2004). Fault activity observation and assessment of potential seismic research, "geological structure and crustal deformation Investigation (5/5): Onshore fault of western Taiwan Foothills area with a comprehensive analysis of the subsurface structure," *The Ministry of Economy geological survey, 2004*.
- [9] Instant Quake Intensity Information (2016). (http://palert.earth.sinica.edu.tw/palert_media/gif/2016/20160205195727_1.gif). Accessed on 5, February, 2016.
- [10] National Fire Agency (2016). *Ministry of the Interior started 0206 earthquake emergency response center*. (<http://enews.nfa.gov.tw/V4one-news.asp?NewsNo=22498>). Accessed on 19 February, 2016.
- [11] NEXT Magazine (2016). *The cover story: six critical defects of Weiguang residential building*. (<http://www.nextmag.com.tw/magazine/politics/20160216/35013908>). Accessed on 17 February, 2016.
- [12] NOW news (2016). *Agricultural disaster caused by earthquake. COA: Losses up to 0.69 billion*. (<http://www.nownews.com/n/2016/02/11/1993523>). Accessed on 11 February, 2016.
- [13] NTDTV.com (2016). *School disaster caused by strong quake. MOE: Losses up to 1.3 one hundred and thirty million*. (<http://www.ntdtv.com/xtr/b5/2016/02/10/a1252014.html>). Accessed on 10 February, 2016.
- [14] Structural Seismology Lab (2016). *Taiwan three-dimensional velocity structure* (<http://140.115.22.221/test/v3a.html>). Accessed on 15 February, 2016.
- [15] TEC-CEO (2016). *0206ML 6.4Meinong earthquake report*. (http://tec.earth.sinica.edu.tw/new_web/upload/news/EQfile/2016-02-06M6.4.pdf). Accessed on 26, February, 2016.
- [16] UDN News (2016). *Why more aftershocks in Tainan? Expert: There are double-main shock* (<http://udn.com/news/story/1/1495753>). Accessed on 9 February, 2016.