CORRELATION OF SITE CONDITION - BUILDINGS DAMAGES – AND GROUND RUPTURE OF THE 27 MAY 2006 YOGYAKARTA EARTHQUAKE – CENTER JAVA AND MICROZONATION OF THE AREA DAMAGE

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1. INTRODUCTION

The 27 May 2006 earthquake produced a strike-slip ground rupture about ± 80 Km. long. It stretches along general N 220-245E direction from *Desa* Parangtritis – Distric Kretek-*Kabupaten* Bantul to *Desa* Prajinan, *Distric* Josonalan, *Kabupaten* Klaten. The sense of horizontal movement is left-lateral. Its epicenter lies within "*the District Saden area"* (?), *Kabupaten* Bantul and registered a magnitude of 6.3 (Ms) on the open ended Richter scale. The ground rupture was responsible for part of the damage inflicted by the earthquake. Hardest hit by rupturing are the Kampung Sengir, Piyungan, Srimartani, Derjo, Pathuk, Taji, Prambanan District. Many roads and one bridge were also cracked by the ground rupturing. Vibration triggered landslides and liquefaction and settling. Vibration was widely felt and its intensity varied with local ground conditions. Landslides affected Sengir. Liquefaction and settling damaged mostly the river deposits (flood plain) areas in and near Taji, Prajinan and Srimartani

Post earthquake study of the ground ruptures provides additional insights into the possibilities that might be expected in case the Melange Cretaceous-Tertiary Fault (Kertapati, 1999) and Opak Fault or other faults move again. Future activities of similar magnitudes along the ground rupture will most probably follow the same trace. Structural controls that affected rupture propagation and arrest might provide us clues as to the size of the next earthquake and enable us to identify sites where high frequency energy inducing strong ground-motion might be expected along the trace.

2. LOCATION, STYLE AND PATTERN OF SURFACE FAULTING

The ground rupture is rarely confined to a simple narrow and distinct line. Instead, a complex faults pattern resulted where the main fault zone is complicated by branching and secondary faults of lesser displacements. The main trace at the ground surface can be a single rupture or consist of parallel, branching, or interlacing fractures. The width of the zone of faulting of the main trace may vary from a few centimeters to hundreds of meters.

In the case of the 27 May 2006 Yogyakarta Earthquake ground rupture, this zone is up to several centimeters wide. Maksimum horizontal displacement for the surface rupture is ± 7.5 centimeters. Rupture length, magnitude and maximum ground rupture are within the range of expected values based on worldwide empirical data, such as: Rainbow

Mountain Earthquake (USA-Nevada, 1954 -0.3 centimeters; Chenoua, Algeria, 1989 - in Well & Coppersmith, 1994).

3. PRE-27 MAY 2006 ACTIVITY OF THE MELANGE CRETACEOUS-TERTIARY FAULT

The oldest earthquake felt in Yogyakarta Province is the Yogya-Surakarta Earthquake – Central java, which occurred on July 17, 1865, were 372 houses collapsed or partially collapsed, while only 5 persons lost their lives and MMI Scale of VII – VIII. A similarly strong earthquake occurred on May 12, 1923 in Central Java is believed to be the most destructive and memorable earthquake to have hit Central Java in its entire history. It is highly probable that the earthquake was caused by the movement of the same segment of the Melange Cretaceous – Tertiary Fault that rupture during the 27 May 2006 Earthquake. This earthquake was felt far east in eastern Lombok. Generally in southern part of Central Java causing extensive damage and small cracking occurred in East Java, the worst damage occurred in Yogyakarta. At Klumpit one house was torn a part, one person reported killed. At Prambanan 126 brick/stone houses collapsed. At Klaten 2200 houses sustain damage; at various places underground pipelines were broken. The MMI was VIII – IX. Other earthquake was occurred on December 13, 1926 and the disturbance was most intense along the south coast of Central Java in the distance of 250 km. The deaths of 213 people have reported and about 2096 persons were seriously injured; approximately 2800 houses were damage (Table 1)

We summarize that historic earthquake events was caused by the movement of the Melange Cretaceous-Tertiary Fault (Figure 1). Wichmann (1918) reported those earthquakes occurred in entire of Java correlated to the fault activities (Figure 2)

Table 1 Historic Data of Significant Damage Earthquakes along the Seismogenic Line

Events	Effect	Intensity – MMI
Origin Time: 1865 Jul 17	**Jogyakarta:** Central Java In Jogyakarta and Surakarta 372 houses collapsed or partially collapsed, while only 5 persons lost their lives	VII – VIII
Origin Time: 1923 May 12	**Yogyakarta:** Central Java – Felt as far east as eastern Lombok. In general, south Central Java was badly damage and slight cracks in walls were found in East Java. The region of greatest destruction was in Jogyakarta Province. At Klumpit one house was torn a part, one person reported killed. At Prambanan 126 brick/stone houses collapsed. At Klaten 2200 houses sustain damage; at various places undergtound pipelines were broken	VIII – IX
Origin Time: 1926 Dec. 13	**Jogyakarta:** Central Java the disturbance was most intense along the south coast of Central Java in the distance of 250 km. The deaths of 213 people have reported and about 2096 persons were seriously injured; approximately 2800 houses were damage	VIII – IX
Origin Time: 1937 Sept. 27 Epicenter: 8.7^0 S – $110,8^0$ E	**Jogyakarta:** Central Java – the shock was felt in Jogyakarta and caused small cracks in the walls of the Ambarukmo Hotel. No other buildings or houses damage.	VIII – IX

Source; SEASEE, 1986)

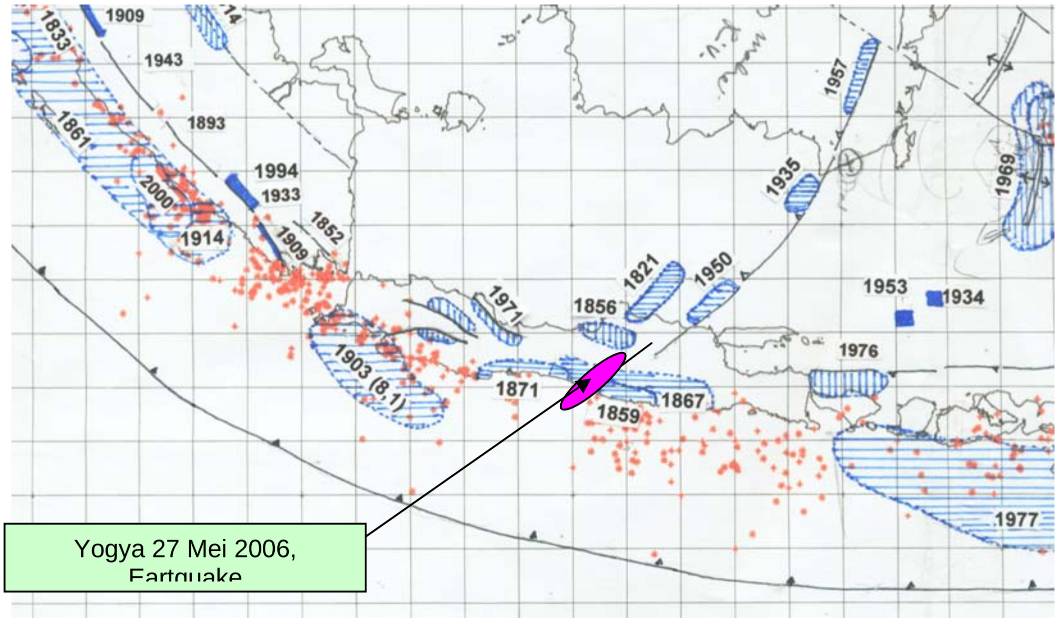

Figure 1 Historic of significant damage earthquakes around Java and vicinity area

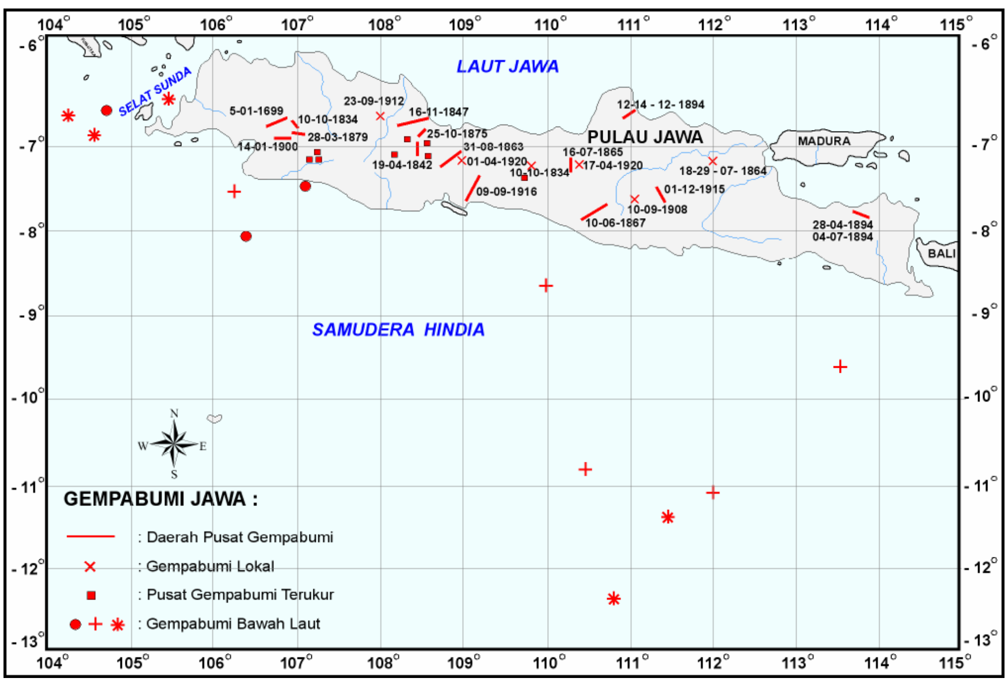

Figure 2 Distribution of historic damage earthquakes around Java (Wichmann, 1918)

4. Variation In Amount of slip along the Fault.

The amount of surface displacement along the fault rupture varies greatly in short distances. Table 2 shows the displacement data for the whole stretch of the ground rupture. Commonly, displacement is not symmetrical along the fault traces but may show several high points in offset along the fault trace.

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Table 2 Ground ruptures due to Yogyakarta earthquake, 2006

No	Location	Ground Rupture Direction	Width	Length	Collateral hazard - Disaster
1	Perajinan: 7^{0}45'48.4" LS; 110^{0}32'54.7" BT	N 80^{0}E	1 – 5 centimeter	15 meter	liquefaction, diamter 10 meter, silty sand
2	Sengir: 7^{0}49'3.6" LS; 110^{0}30'24.6"BT	N 175^{0}E	2 – 6 meter	± 75 meter	Landslide and subsidence along tensional zone – fanglomerate soil
3	7^{0}50'16.4" LS; 110^{0}29'9.4"BT	N 230^{0}E	1 –2 centimeter	± 5 meter	Left lateral displacement 1 centimeter
4	7^{0}49'32.9" LS; 110^{0}29'4.9"BT	N 200^0 E - N 270^{0}E	1 – 5 centimeter	12 meter	Liquefaction: , diamter 8 meter, slity sand
5	7^{0}48'54.6" LS; 110^{0}29'49.3"BT	N 170^{0}E	30 centimeter	30 meter	Liquefaction, diamter 7 meter, silty sand along small river,
6	7^{0}50'13.6" LS; 110^{0}30'9.3"BT	N 270^{0}E	3 centimeter	15 meter	Fracturing along scarp.
7	Jetis: 7^{0}52'26.8" LS; 110^{0}22'28.4"BT	N 270^{0}E	3 centimeter	15 meter	Fracturing crossing road and rice field
8	7^{0}54'57.9" LS; 110^{0}22'34.8"BT	N 220^{0}E	3 centimeter	10 meter	Fracturing cross. road
9	Bukayang: 7^{0}51'12.8" LS; 110^{0}13'57.6"BT	-	-	-	Limestone

(continued Table 2)

10	Kampung Pathuk:	N 40^0 E - N 60^0E	30 centimeter	± 1 km	Ruptures along scarp and small landslicde and it potential in the heavy rinny seasson
11	Kongklangan-Prambanan	N 180^0E	5 centimeter	300 meter	Ruptures cross road and sutllement , liquefaction occurs, dry wells.
12	Pantai Trisik – Brosot	N 105^0E	1 meter	50 meter	Lateral spreading and liquefaction.
13	Kampung Siluk	N 190^0E	3 centimeter	10 - 15 meter	Fructures cross road beisde Oyo River, Zone fructures is ± 15 meter and down to the east 1 centimeter.
14	$7^0$57'10" LS; $110^0$23'17.6"BT	N 240^0E	2 centimeter	10 meter	Fructures and down to east 2 centimeters.

The pattern of horizontal displacement may be described as wavy with sharp increase and sudden decrease along a relatively short distance. There is however a general decrease in horizontal displacement as the rupture is trend from NE – SW except near the terminii where both horizontal and vertical displacement approach zero values. Likewise, net slip variation from NE – SW show a similar pattern owing to the predominatly strike – slip nature of the ground- rupture.

5. Propagation, Termination of the ground Rupture and Seismic microzonation the damage area

The southwest extension of the fault with respect to the epicenter was more restricted, indicating that this part of the fault must have been more resistant to breaking.

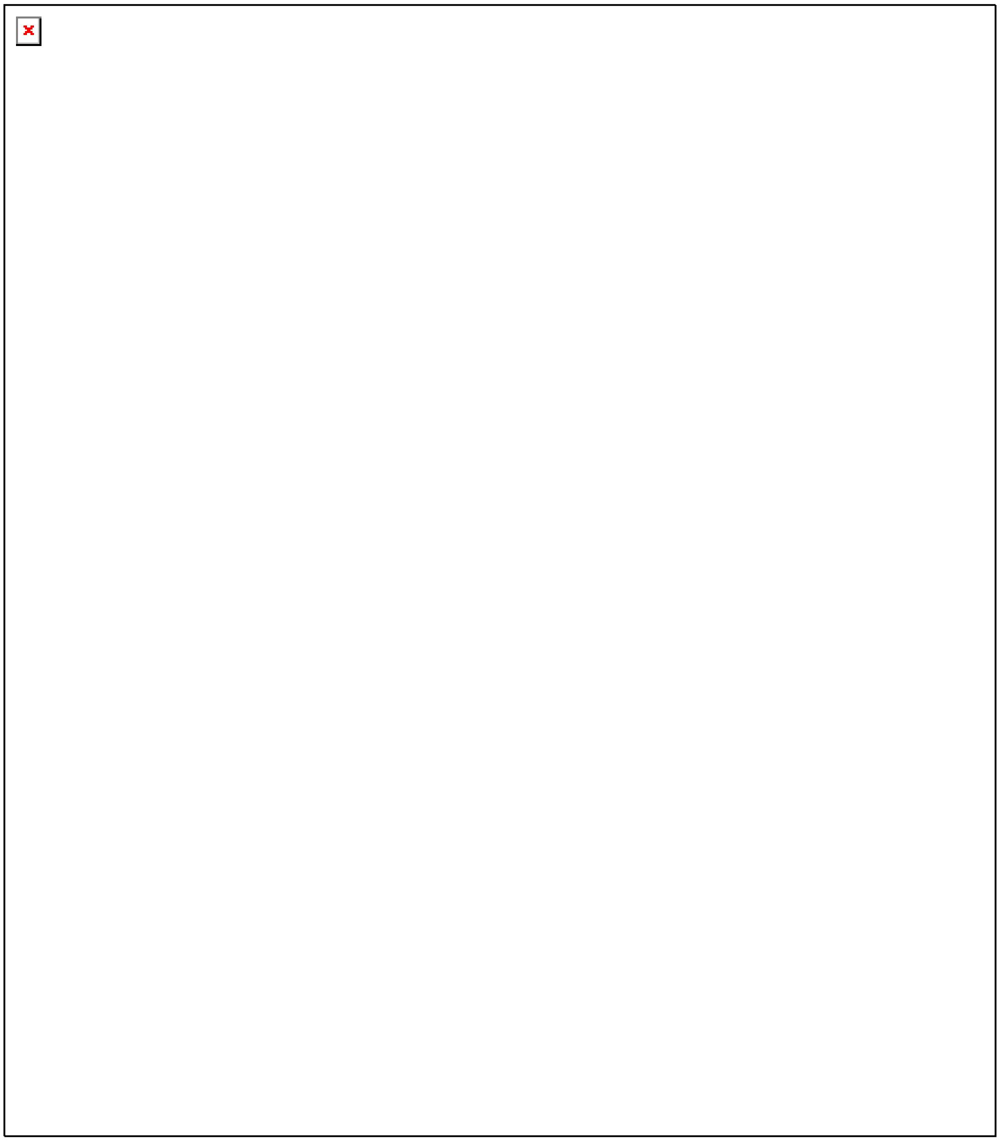

Figure 3 The ground rupture and collateral hazards map due to the Yogyakarta Earthquake 2006

The shorter length of the southwestern portion of the fault suggests that there must be a barrier or a series of barriers. And the ground rupture have extended only a few millimeters to one or two meters (Table 2). The present barriers along the fault especially at the southeast of the epicenter, made rupture propagation irregular. These might have also caused the slowing down of the propagation and caused it to proceed in a series of jerks as barrier or irregularities are encountered along the way.

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This barrier could be in the form of irregularities along the fault plane as manifested by bends/jogs, a geometrical barrier near southwestern terminus, inhomogeneous barriers, or combination of all of the above. Within the two basic classes of irregularity transverse to the direction of rupture propagation (i.e. fault jogs and bends), the structures are usually classified as dilational or anti-dilational. Dilational jogs are associated with small pull-apart basins and anti-dilatational jogs with pop-up structures.

Local ground conditions substantially affect the characteristics of incoming seismic waves during the earthquakes. Flat area along and surrounding of the Opak rive generally consist of thick layers of fine sand, sandy clay and clay.

The microtremor measurements show that the sites with severe damage located near and along the river banks have a considerably long predominant period more than 0.4 s. This matches quite well with the variation of damage distribution (Figure above), which suggest that the thickness of sand, sandy sand and clay in those area are deep. The predominant period decreases towards the north and southeast and the period reduces to below 0.2 s.

According to the variation of the predominant period of the ground, the Yogyakarta damage area due to Yogyakarta earthquake 2006 is classified into five zones as follows:

(a) Zone I - period less than 0.1 s

(b) Zone II - period ranging from 0.1 s – 0.2 s

(c) Zone III – period ranging from 0.2 s – 0.3 s

(d) Zone IV – period ranging from 0.3 s – 0.4 s

(e) Zone V – period more than 0.4 s

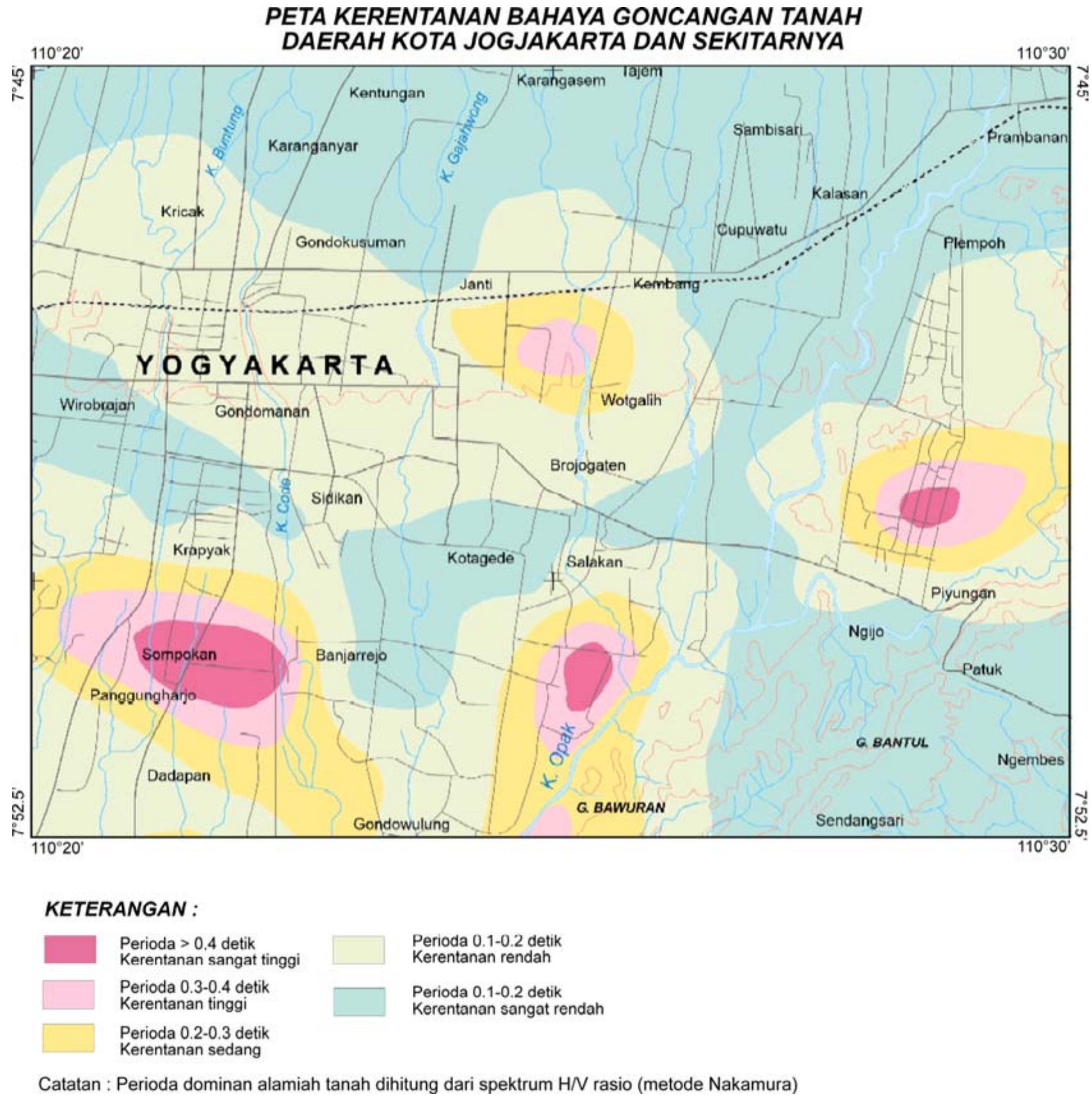

Figure 4 Microzonation of the Yogjakarta Damage area on the basis of variation of the predominant period

6. CONCLUSION

We summarize the Yogyakarta earthquake 2006 event was caused by the movement of the Melange Cretaceous-Tertiary Fault

Flat area along and surrounding of the Opak river generally consist of thick layers of fine sand, sandy clay and clay were severe damage of buildings occurred.

Commonly, displacement is not symmetrical along the fault traces but may show several high points in offset along the fault trace.

The predominant periods obtained from microtremor observations are also found to correlate well with characteristic site geologic condition were severe damage occurred, and contain of sand, sandy clay and clay of river environment. This study shows that there is a possibility of long period ground vibration in Yogyakarta, especially in the

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areas along the river bank or near the beach. This could cause severe damage to the long period structures such as high-rise buildings. Hence, special attention should be given towards the seismically resistant design of such structures.

7. References

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