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Geological and active fault settings surroundings Tigadihaji Dam of Indonesia

Didiek Djarwadi[1], D.H. Natawidjaja[2], and M.R. Daryono[2]

[1] PT Pamapersada Nusantara, Jln Rawa Gelam I. No.9, Jakarta, Indonesia.
[2] Research Center for Geotechnology, Indonesian Institute of Science, Bandung, Indonesia.

ABSTRACT

Tigadihaji dam was proposed built in the Selabung river, a natural drain of Ranau lake, an ancient caldera in South Sumatra of Indonesia. The dam was a rock fill dam with 122 meter in height above the deepest foundation. The dam was located at high seismically region in Indonesia. The dam was surrounded by several faults which indicated as active faults. The active Kumering segment of Sumatra Fault Zone (SFZ) was located at 18 km from the left bank of the Tigadihaji dam, while small faults of Pauh and Sukarena was located around 1.85 km and 10 km respectively from the right bank of the Tigadihaji dam, which run parallel with Kumering fault. The base rock of the Tigadihaji dam and surroundings was tertiary sedimentary rocks which belong to Air Benakat and Gumai formations. These formations were covered by thick Ranau tuff a product of Ranau volcano eruption which dated back to 31K years ago. This paper discussed the method of probing the thickness of the Ranau tuff in the dam foundation and identification the activity of Pauh fault which very close to the footprint of the dam foundation.

Keywords: Geology; Active fault; Dam Foundation; Paleoseismology trenching

1 INTRODUCTION

Tigadihaji dam was a rock fill dam which will be built on Selabung River, in the South Sumatra province of Indonesia. The dam was located only 18 km from the Komering segment of the Sumatra Fault Zone, which known have a high seismic activity, and has already known as an earthquake sources. The seismic hazard assessment reveal that 2 faults located on the downstream of the dam as secondary faults which parallel to the Sumatra Fault Zone. The Pauh and Sukarena faults named after the nearby village have a distance of 1.85 and 10 km from the dam site respectively.

A study on Sumatra Fault Zone as a major source of earthquake as well as the slip rate was carried out in order to indentify the possibility of earthquake magnitude. Komering segment of Sumatra Fault Zone as the nearest earthquake source were studied. Two major earthquakes on 1933 and 1994 were recorded occurred at Komering segment of Sumatra Fault Zone.

Dams shall be designed to resist the maximum credible earthquake (MCE) which defined as the largest reasonably conceivable earthquake magnitude that is considered possible along a recognized fault systems or within a geographically defined tectonic province, under the presently known or presumed tectonic framework (ICOLD, 2016).

Seismic hazards assessments is compulsory for dam construction, particularly if the proposed dam is located on and around the known active fault zones. Detailed investigations of active faults occurrences including their exact locations, level of activities, earthquake history shall be conducted carefully since the active faults pose three kind of hazards to the dam constructions, there are: strong ground shaking, direct ground deformations related to fault movements during earthquake events and earthquake triggered landslide and liquefaction.

In the vicinity of Tigadihaji dam, detailed geology and active fault studies have been conducted. This includes mapping of the lithology and suspected active fault strands using high-resolution digital topography and latest GIS techniques, documenting geological outcrop data, shallow geophysical imaging using resistivity method, and conducting paleoseismological trenching on suspected active fault strand.

2 GEOLOGICAL AND SEISMICITY OF TIGADIHAJI DAM

Geological regional survey was carried out within radius of 50 km, to include the extent of the Pauh and Sukarena faults, while detail geological survey was carried out surroundings the Tigadihaji dam site in order to identify the fault strands and the activity of the Sukarena and Pauh faults. The basic data in this survey was digital elevation map (DEM) and then processing using GIS (Geographic Information System) software to obtain detail topographic map which may shows the geologic structures and suspected fault location. Tigadihaji dam was built on the Gumai and Air Benakat geologic formation which covered by thick Ranau tuff as product of mega eruption of ancient Ranau volcano, which at present left Ranau lake as their huge crater. Figure 1 shows the project location in Indonesia, while Figure 2 shows the distribution of Ranau tuff as product of mega eruption of ancient Ranau volcano on the surroundings the project. (Natawidjaja, 2017).

Fig. 1. Location of the project in Indonesia

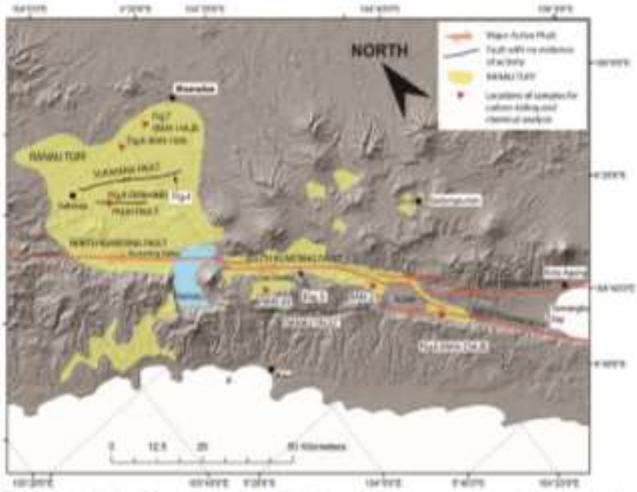

Fig. 2. Distribution of Ranau tuff surrounding the present Ranau Lake (Natawidjaja, 2017).

The Gumai and Air Benakat formations were tertiary sediment rocks which composed of massive of shale-limestone interbedded with tuff-sandstone and sandy limestone. Outcrop of this tertiary rocks found along the Selabung riverbed. Pauh fault characterized by the straightness of the hills that extends towards the northwest southeast and becomes the limit of surface texture morphology changes that express two different rock formations. Ranau tuff laid unconformity above the tertiary rock formation of Gumai and Air Benakat.

During field survey, we confirmed that these faults are indeed presence, marked by topographical breaks, fault-water falls and lineaments of scarps and streams. We also conducted Electric Resistivity Tomography surveys to ascertain the locations of the faults. Similar to the Ranau fault, however, the geomorphological evidences of fault movements have been subdued and unclear. Luckily, on the main road between Ranau lake and Muaradua town, we found a fresh cut of road cliffs exposing the southern end of Sukarena fault outcrop as shown in Figure 3 (Natawidjaja et al, 2017). It shows that Sukarena fault which found on the Gumai Formation did not cross the Ranau tuff layer which found on the above the Gumai formation. Since the Ranau tuff was deposited around 31.000 years ago, it means that there was no movement of the Sukarena fault for the last 31.000 years. It can be concluded that the Sukarena fault was inactive at present time.

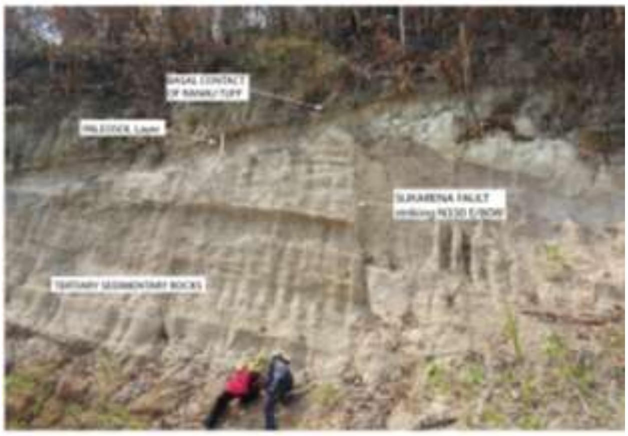

Fig. 3. Road cut exposure between Muaradua town to Ranau Lake exposed the Sukarena fault (Natawidjaja et al, 2017).

Ranau tuff blanketed a wide area about 70-km radius around its center of eruption. Clearly the voluminous Ranau ash flows reset the previous landscapes by effectively buried the pre-existing topography upon its emplacement. Then, it was followed by the fast creation of a new network of drainages. In the proximal area, south of the lake, the tuffs filled the Liwa Basin, which then has been incised 40 to 80 meter deep by wide river canyons forming a plateau-like landscape. Away from the center, the Ranau tuff bed becomes thinner and then dissapears.

On the cliff exposures along the main road near Muaradua town , 80 km northeast of Ranau Lake, 4-5 meter-thick Ranau tuff bed lies on the moderately dipping tertiary sedimentary rocks, nicely showing an angular unconformity contact. Along the boundary a few tens of cm organic-rich paleosoils had been developed on the upper surfaces of the tertiary rocks. We carefully digged and selected part of this organic sample for radiocarbon dating to avoid possibilities of any modern-carbon contaminations from nearby modern plants and roots. The Accelerator Mass Spectrometry (AMS) analysis of this sample (RAN-014) yields a conventional carbon age of 26,830 ±140 BP, or the corrected calendar-year age of Cal BP 31085 to 30805 (95% probability)(Natawidjaja et al, 2017).

Southeast of Ranau lake, Kumering segment of

Sumatra Fault Zone straightly runs through the thick, flat-top Ranau-tuff filling Liwa basin, marked by linear alignment of Way Robok deep canyons and major deflections of major river canyons crossing the fault line. Five major river canyons are right-laterally offset about the same amount along the single major traces of Kumering fault indicating they are formed isochronously or nearly so. Three of the displaced canyons are across the fault at right angle, thus give excellent measures for fault offset of about 320 to 380 meters, as shown in Figure 4. Uncertainty of the amount offset are appoximated by the width of displaced river canyons. We do not include the other two offsets since the river cut at low angle to the fault, so they yield less accurate measure of the offsets. The average of these three river offsets is 350 ± 50 meter, thus yields a sliprate of 10.4 ± 2.4 mm/year for the Kumering fault segment.

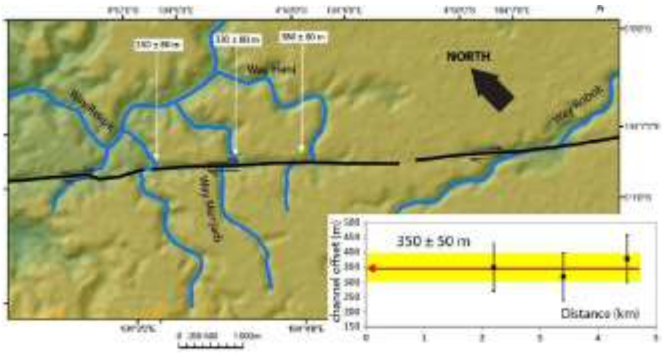

Fig. 4. Consistent right lateral offsets of isochronous river channels deeply incised into Ranau tuff near Liwa. The total offset is estimated from three channels that across the fault at high angle.

3 IDENTIFICATION OF PAUH FAULT

Since the Sukarena fault has been identified as inactive fault by interpretating the road cutting that run through the Sukarena fault as shown in Figure 3, the Pauh fault need to be identified whether it was active or inactive fault and the influence to the Tigadihaji dam.

Geoelectric survey across the Pauh fault at the nearest distance to the Tigadihaji dam was carried out primarily intended to scan underground structures of the Pauh fault. The result of this scan will be used to pinpoint the location of the trench excavation for palaeoseismology study. Figure 5 shows the geoelectric result which across the Pauh fault.

Scanning results indicated that the decomposed top soil have a thickness more than 5 meter, interpreted from the resistivity less than 200 Ohm.m. This soil layer probably young alluvial deposit and decomposed of Ranau tuff. Below the decomposed soils, the Ranau tuff layer with high resistivity found up to 80 meters except at the suspected Pauh fault.

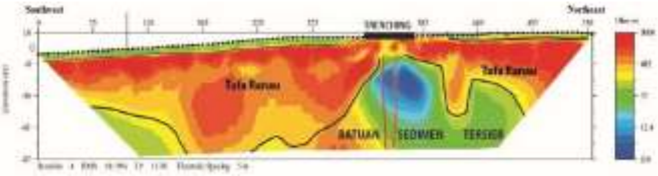

Fig. 5. Scanning result of line 1 with indication of Pauh fault.

Below the Ranau tuff, the tertiary sedimentary rock was found indicated from low resistivity which range from 2 to 100 Ohm.m. The most important from line 1 scan result was the capture of the suspected Pauh fault.

Palaeoseismic trench usually carried out to prove the existence of a fault structure that has been identified from morphological analyses or geoelectric scanning. It can be use also to evaluate the fault activity and look for traces of past seismicity recorded in the soil layer (Yeats, 1996). Palaeoseismic trench was a method that has widely used in the earthquake research. This method became popular following the successfully study of palaeoseismology in Pallet Creek, California (Sieh et al, 1989., Sieh, K , 1977).

Palaeoseismic trench was carried out on the approximate the Pauh fault line. Trenching was made over the line 1 of the geoelectric survey, cut the Pauh fault perpendicularly. The dimension of the trench are; 20 meter in length, 1.50 in width and 2.00 m in depth. Logging on the both (left and right) walls were made using different colours to identify the soil layers and fault structures. Logging were made to identify colour, texture, type or nomenclatures of soils. Trenching in Pauh faults have five (5) different soil layers and described as follows:

Layer 100 was the first soil layer, identified by black colour was top soil consists of sandy silt soils, dark brown in colour, many roots found.

Layer 200 was the second layer, gravelly sandy silt with some lithic fragment up to 4 cm, brown in colour.

Layer 300 was the third layer, coarse sand from Ranau tuff, with some lithic fragment up to 2 cm, yellowish brown in colour.

Layer 400 was the fourth layer, coarse sand from Ranau tuff with some sand layers interbedded, greyish brown.

Layer 500 was the bottom layer, coarse sand from Ranau tuff with some sand layers interbedded, grey colour.

On the trench walls there is an indication of fracture and fault plane that shear the soil layers with the parallel direction of the Pauh fault. Although the fault structure did not appear on the surface, indication of Pauh fault found at least on the soil layer 400 that shear the soil layer, so that the existence of possible tectonic fracture structures deforming this soil layer is classified as an active fault. Figure 6 shows the logging of the east and west walls of the palaeoseismic trenching, while Figure 7 indicated the Pauh fault in the palaeoseismic trenching wall.

Logging of the left wall

Logging of the right wall

Fig. 6. Logging of the palaeoseismic trenching walls

Fig. 7. Indication of Pauh fault on the palaeoseismic trench wall.

Geological observation, geo-electric survey and data evaluation on the paleoseismic trenching as shown on Figure 7, indicated that Pauh fault was still active, even there was not clearly exposed on the ground surface. The Ranau tuff layer as a product of mega eruption above the Gumai formation indicated a shifting in vertical direction (left lateral normal fault). Carbon dating results on the soil samples taken from the soils on the fault location indicated that the age of the soils was 114 to 249 years. This indicated as the last earthquake resulting from the Pauh fault, even there was no historical record was found. The calculation on the Mmax based on the length of the fault based on several GMPE (ground motion prediction equation) resulting the possibility Mmax 6.4 earthquake may occurred from the Pauh fault. Based on this result, the earthquake which may occurred from Pauh fault shall be included in the Seismic Hazard Analysis for Tigadihaji dam.

This founding will change the Seismic Hazard Analysis which has been made previously. In the previous Seismic Hazard Analysis of the Pauh fault considered as inactive fault, and the Seismic Hazard Analysis were made based on Probabilistic Seismic Hazard Analysis (PSHA). But considering that Pauh fault was an active fault and the distance to the proposed Tigadihaji dam was very closed, and also the length of Pauh fault was already known, the new Seismic Hazard Analysis was made based on the Deterministic Seismic Hazard Analysis (DSHA).

4 CONCLUSION

The identification of active fault nearby the foot print of the Tigadihaji has been presented. The presence of the Sumatra Fault Zone, the sliprates along the fault and paleoseismic on the Pauh fault has been carried out to study the condition of the fault. The conclusions of the investigation are summarized as follows;

1. The Tigadihaji dam location was covered by Ranau tuff as a product of mega eruption of Ranau volcano which have an age of around 31.000 years,
2. Pauh fault which located at 1.85 km in the downstream of the dam with 14 km in length shall be accounted as an active fault,
3. The Seismic Hazard Analysis for Tigadihaji dam shall included the Pauh fault in the analysis.
4. There was a change in Seismic Hazard Analysis for proposed Tigadihaji dam, where before Pauh fault was considered as inactive fault, the Seismic Hazard Analysis was made based on Probabilistic (PSHA), while after the Pauh fault was consedered as an active fault, the Seismic Hazard Analysis was re-calculated based on Deterministic (DSHA).

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