Learning from Earthquakes

The June 3, 1994 East Java Earthquake - Tsunami Takes Its Toll on Local Villages

At 1:17 a.m. Java time on June 3, 1994, a $M_w = 7.2$ (Harvard CMT solution) earthquake occurred in the Indian Ocean at a depth of 15 km, near the east end of the Java trench. The earthquake generated a large tsunami that struck the southeastern coast of Java and the southwest coast of Bali. In contrast with the Flores earthquake of December 12, 1992, the tsunami was reported immediately by the news media in the west and preliminary information was posted in *tsu-nica*, the tsunami e-mail bulletin board operated by NOAA-PMEL in Seattle. Using a very coarse topography grid, a numerical prediction for tsunami heights was posted by the University of Southern California on the evening of June 3 and by Tohoku University on June 7. Both predicted runup heights ranging from 1 m to 3 m.

An international team met in Denpassar, Bali, on June 19, where a plan to survey the earthquake and tsunami damage was developed. The group split into five smaller teams. The survey was carried out between June 20 and 26 and covered a coastal area of approximately 500 km, from Denpassar, Bali, to southwest of Malang in Java.

The teams measured runup heights on the basis of watermarks, and recorded arrival times and information on the tsunami waveform, such as number of waves and arrival times, from interviews with eyewitnesses. Runup heights ranged from 3-5 m in sparsely populated west Bali and 3-13 m in more densely populated southeast Java; tidal corrections now underway will adjust these numbers by less than 1 m. As in earlier tsunamis, the hydrodynamic models predicted qualitatively correct runup height distributions, but not the absolute magnitude of the runup heights. The latter is a function of the quality of the bathymetry and topography data available at the time of computation. Mercalli intensity ratings ranged from 3-4 in Bali to 1-3 in East Java. No evidence of liquefaction or crustal movements was observed.

The coastal villages of Pancer, Lampon, and Rajekwesi in East Java were almost completely wiped out by the tsunami. More than 200 people died, more than 400 were injured and more than 1000 houses were swept away. Extensive damage was observed in Sumber, Agung, Pesangarran and Saarongun. Interestingly, the shaking was not felt at all in East Java where the tsunami damage was extensive, but it was felt in Bali, where the damage was minimal. Therefore, the teams had the opportunity to record tsunami damage without collateral damage from earthquake induced shaking. Equally interesting was the fact that damage was observed in fairly western style single story masonry houses; in previous tsunamis in Indonesia and Nicaragua, most of the tsunami-damaged structures were considered of poor construction by western criteria.

Most of the damage was concentrated in pocket beaches fronted by tidal flats. Villages fronted by relatively wide and long beaches suffered comparatively less damage. At the time of the tsunami attack the tidal level was at its approximately mean position. All three hardest hit villages were located next to river mouths with the houses built on wide sand bars. Overflow clearly occurred and the tsunami attacked from both the seaside and the river side, allowing little opportunity for evacuation. In two of the villages, the relatively small number of casualties was attributed to the residents attending a performance of traditional Indonesian shadow theater far inland.

Findings and recommendations were presented in a formal meeting at the ministry of Communication, the parent organization of BMG (Indonesian Meteorological and Geophysical agency). The teams emphasized the importance of civil defense education in remote areas, such as the preplanning of escape routes, and the implementation of some form of tsunami warning system, particularly since damage from local tsunamis without the residents experiencing any ground shaking is a possibility. Other recommendations consistent with the local realities of life included building the houses fronting the coastline stronger so that they do not become battering rams for the houses behind, tying wooden structures to their foundations, providing cross-bracing, mooring fishing boats and planting large trees next to every house in vulnerable areas.

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