Earthquakes and Impounded Dams

P. Loganathan FIGM

In a recent article in the "The Star" (13th October, 2014), Dr Harsh K. Gupta, an Indian authority in the field of seismology, had stated that "the filling of a man-made water reservoir can induce tremors in the earth". He further stated that "there have been at least half a dozen reservoir-triggered earthquakes registering magnitudes 6.0 and larger, causing substantial damage and killing hundreds".

Dr Gupta had pointed out that "When the reservoir is impounded, fluid pressure increases and the accumulated stresses make it possible for ruptures to occur. Globally, there are already more than 150 examples of these provoked earthquakes, such as Koynanagar in India (1967), Xinfengjiang in China (1962), and Kremasta in Greece (1966)".

The Koynanagar earthquake, reported as among the greatest earthquakes of historical times in the Indian peninsula (Berg *et al*. 1969), occurred near Koynanagar town in Maharashtra, western India on 11 December 1967. The 6.2 (average) magnitude earthquake had occurred near the site of the Koynanagar (or, Koyna) hydro-electric dam (installed capacity 1960 MW) and had intensity of VIII (MM) at Koynanagar (Berg *et al*. op cit.).

In this incident, at least 180 lives were lost and over 1,500 injured. Although more than 80% of the houses in the township were damaged, the dam did not suffer any major damage to the dam except for some cracks which were quickly repaired. The earthquake caused a 10 – 15 cm fissure in the ground over a length of 25 kilometres. The Koyna Dam, constructed in an area underlain by the Deccan Traps, a series of basaltic volcanic flows of Cretaceous – Eocene age, at peak storage impounds some 280,337,000 cu. metres of water. The construction began in 1956 and was completed in 1964. The dam is a rubble-concrete dam of 103.2m in height. The lake covers a surface area of 891.78 sq. km (http://en.wikipedia.org/wiki/Koyna_Dam). The Koyna River, which flows southwards into the dam reservoir, is believed to be fault-controlled. As proof of its effectiveness, there have been several earthquakes of smaller magnitude in Koynanagar since 1967.

The Xinfengjiang Dam is a gravity dam, and of 105 m in height, on the Xinfeng River, 8 km upstream of its confluence with the Dong River, and west of Heyuan City in Guangdong Province, China. The underlying rock-type is granite (Chen and Talwani, 1998). The dam's power station has a 292.5 MW installed capacity and its reservoir supplies water for farming along with drinking water to Guangzhou, Shenzhen and Hong Kong. Construction on the dam began in 1958, the first generator was operational in 1960 and the dam completed in 1962. The lake covers an area of 370 sq. km. The dam's reservoir-filling is attributed to several earthquakes within the project area including a 6.1-magnitude (Mw) on March 19, 1962.

The Kremasta Dam is an earth-fill embankment dam, of 165 m in height, on the Achelous River in Aetolia-Acarnania, Greece. It is located downstream of where the the three rivers of the Agrafiotis, Tavropos and Trikeriotis meet to form the Achelous. The Kremasta area is underlain by flysch formation (comprised of alternating sequences of conglomerate, sandstones, siltstone and shales) (Kalkani, 1997). The dam was constructed between 1961 and 1965 and its four 109.3 MW generators were commissioned between 1966 and 1967. Its installed capacity is 437.2MW. Shortly, after the dam's reservoir, Lake Kremasta, was filled a 6.3-Mw earthquake occurred. This has been attributed to reservoir-induced seismicity. Lake Kremasta is the largest artificial lake in Greece and covers some 81 sq. km.

When the causes of these impounding-induced earthquakes were investigated, Gupta found that these earthquake sequences had certain similarities which differed from the normal sequences.

Now how about dams in Malaysia? Did they suffer from similar seismicity?

Research Fellow, Academy of Sciences Malaysia

The classic example is the Kenyir Dam seismicity. The Kenyir Dam, Peninsular Malaysia's largest rock-fill dam, is underlain by granite and is 155 m in height. Construction began in 1978 and was completed in 1985. The lake covers an area of 370 sq. km. In an article by Cik Noorliza Lat (*Warta Geologi*, Vol. 28, No.5, Sept-Oct 2002), she reported that the dam, built in a previously aseismic area, was responsible for several earthquakes from 1984 to 1987. The Malaysian Meteorological Department recorded a total of 28 earthquakes with magnitudes ranging from 2.5 to 4.6. The tremors were felt at a distance of more than 50 km. The area now is again aseismic; a suggestion that the region may have achieved a new, stable stress regime.

In Sarawak, the Bakun dam, a 205-metre-high concrete face rock-fill dam, with a length of crest of 740 metres, a base width of 560 metres and a crest width of 12 metres. This makes it one of the highest rock-fill dams in the world. It will flood 69,640 hectares of land, an area bigger than Singapore (Lau, 2004). Construction began in 1996 and was completed in 2011. The rocks at the Bakun dam site are clastic sediments such as sandstones, siltstones and shales with an argillaceous or siliceous matrix (JMG Sarawak Map). The dam is currently being impounded. Its installed capacity is 2400MW.

The dimensions of the Bakun Dam seem to fit with many other global dams which have had been impacted by the phenomenon known as reservoir-induced seismicity. Will the Bakun dam area also suffer from this phenomenon? Let us see in the next 4–5 years.

REFERENCES

Berg, GV, Das,YC, Gokhale, KVG & Setlur, AV 1969, "The Koyna, India, Earthquake", *Proceedings of the Fourth World Conference on Earthquake Engineering, Santiago, Chile*, vol. 3, pp. J2–44 to J2–57.

Chen, Linyue & Talwani, Pradeep 1998, 'Reservoir-Induced Seismicity in China' *Pure and Applied Geophysics*, vol. 153, pp. 133–149

Lau, Chau Chin 2004, 'A Study on Concrete Faced Rock-fill Dams', unpublished thesis, University of Southern Queensland, Queensland.

Kalkani, EC 1997, 'Geological Conditions, Seepage Grouting, and Evaluation Of Piezometer Measurements' in 'The Abutments Of An Earth Dam', *Engineering Geology*, vol. 46, no. 2, pp. 93–104.

Jabatan Mineral and Geoscience Department Sarawak, Geology Map.

Wikipedia, *Koyna Dam*, viewed 17 Oct 2014, http://en.wikipedia.org/wiki/Koyna_Dam.

Wikipedia, *Kremasta Dam*, viewed 17 Oct 2014, http://en.wikipedia.org/wiki/Kremasta_Dam.