Rehabilitation of Earthquake affected South Nawin Dam, Myanmar

Presented by

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1. Background

- **Dam Failures** happened **more than 200 notable cases** between 2000 and 2009 worldwide.(*Cannata & Marzochi,2011*)
- Common cases of earthen embankment dam failures are

(a) Overtopping

(b) Slope failure

(c) Piping through dam body failure

(d) Dam crack by seismic load

(a) Overtopping of dam failure

(b) Dam slope failure

(c) Piping through dam body failure

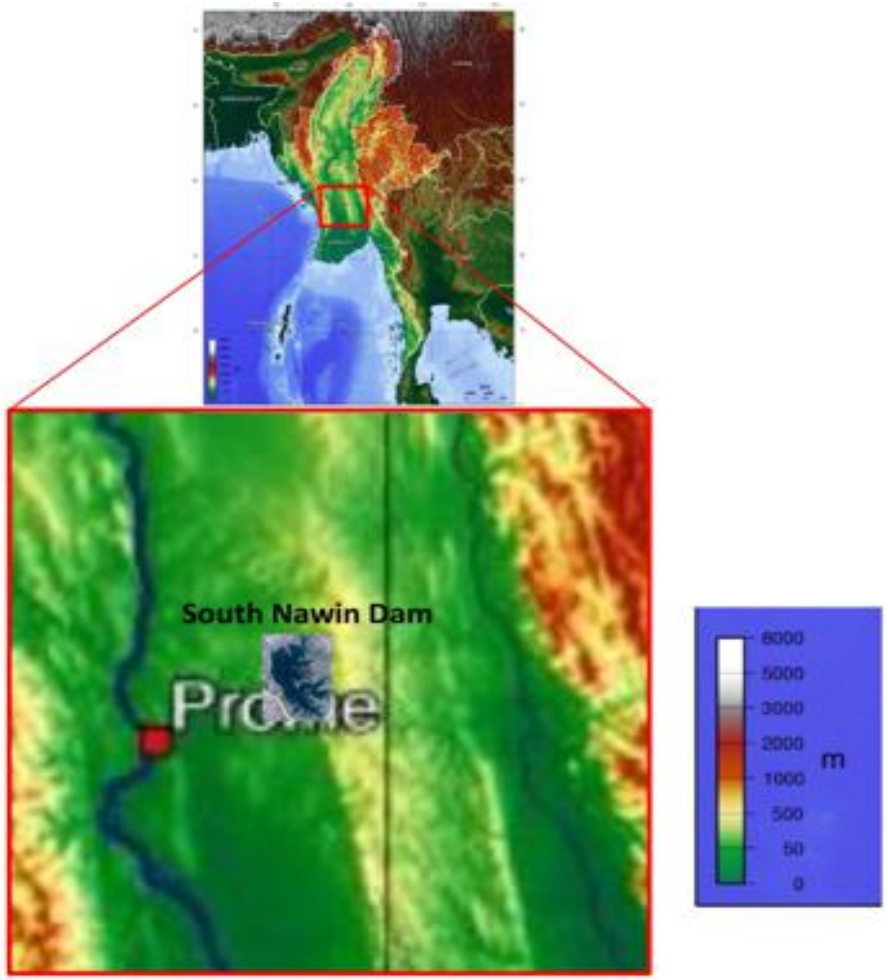
(d) Dam crack by seismic Load

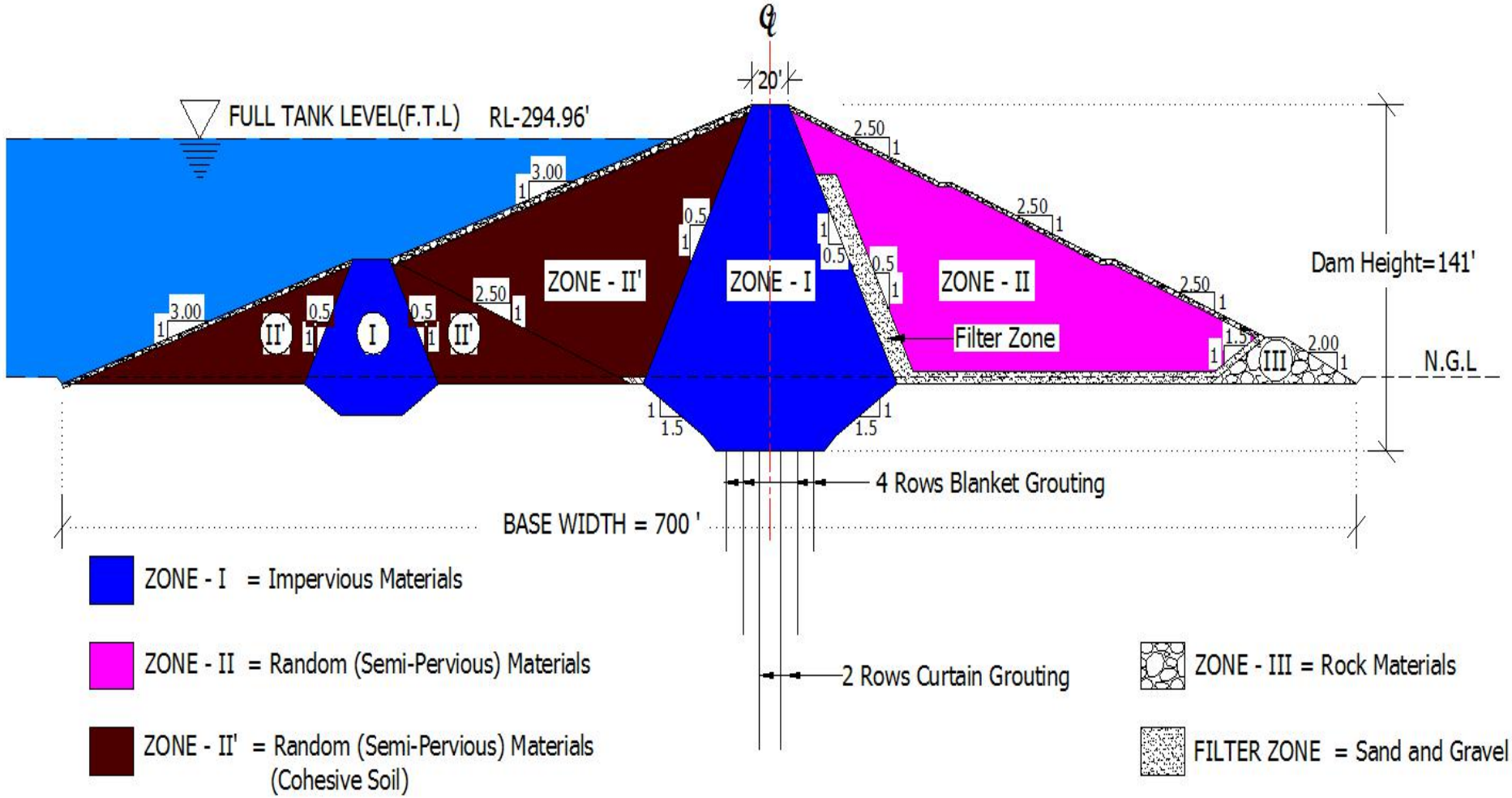
Figures : Common Cases of Embankment Dam failure (NARITA Kunitomo, 2000)

2. Earthquake hit & damages of South Nawin Dam

❑ South Nawin Dam

- Location : Paukkaung township of Pyay District, Myanmar (Latitude 18.918°N and Longitude 95.579°E)
- River : South Nawin
- Dam type : Sloping core earth dam
- Dam Height : 141 ft
- Crest length : 3.16 miles
- Storage Capacity : 287,000 Ac-ft
- Completed year : 1985-1995 (~ 26 years up to now)





Typical cross-section of South Nawin main dam

❑ Occurrence of earthquakes (2005-2018)

Sr. No.` `	Date	Lat.	Long.	Magnitude (M)	Intensity	Focal Depth (km)	Epicentral Distance (km)	Peak ground acceleration (g)
1	6.2.2005	18.862	95.664	4.3	V-VI	33	10.9	0.085
2	20.10.2005	18.913	95.761	4.7	V-VI	10	19.1	0.068
3	30.5.2013	18.840	95.638	4.3	V-VI	66.9	10.7	0.086
4	5.10.2018	18.944	95.584	4.2	V-VI	10	2.8	0.231
5	10.10.2018	19.033	95.608	5.1	VI-VII	10	13.0	0.133
6	27.10.2018	19.086	95.635	4.9	VI	10	19.5	0.078

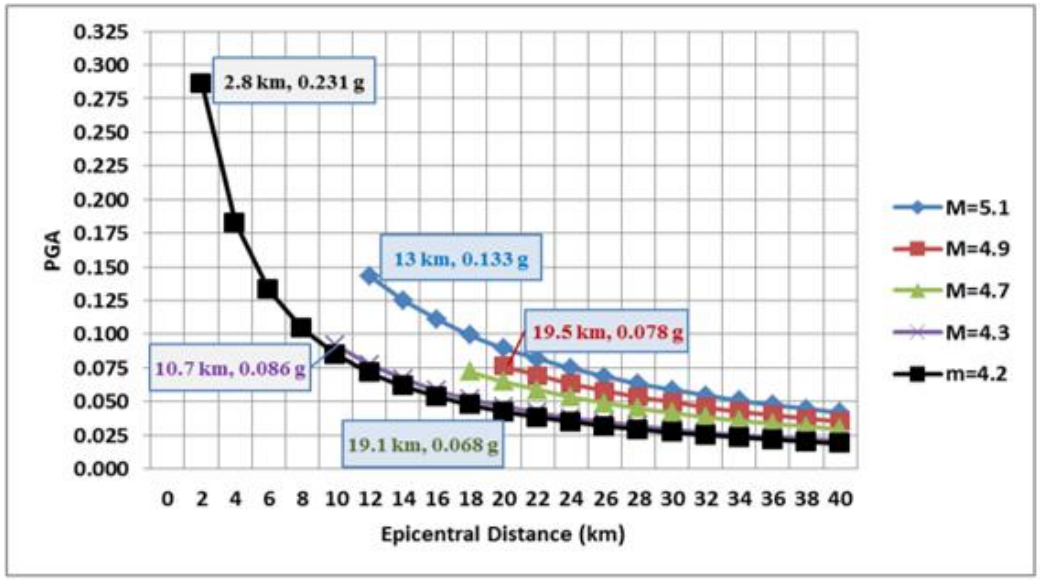


Figure: Location of Earthquake and damage section

❑ Hit of Earthquake on Dam

- On October, 2018 the earthquake occurred at South Nawin dam.
- It caused several streaks of cracks and subsequent settlement of the dam embankment.
- The cracks run in parallel with the dam alignment and triggered the persistent settlement in the section of cracks.

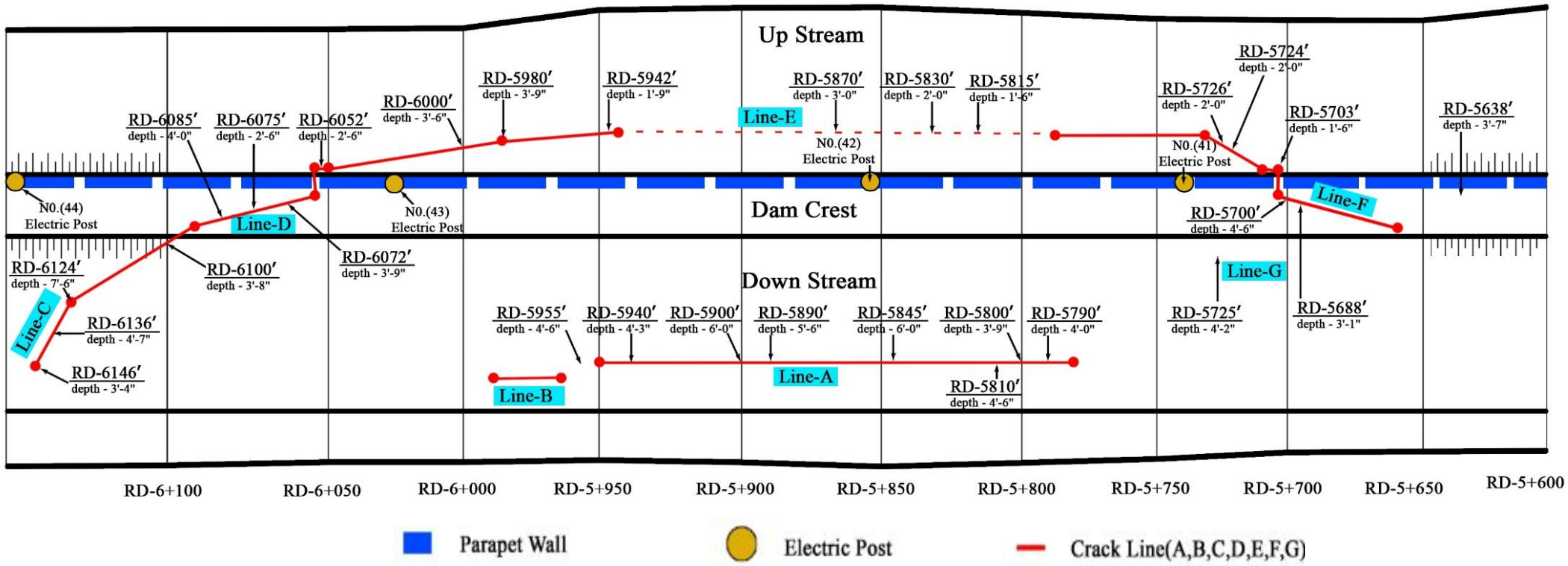
Photo: IWUMD

❑ Assessments of the damage situation

- Earthquake survey
- Field reconnaissance survey
- Geophysical survey
- Drilling survey
- Trench survey
- Laboratory test

Photo: IWUMD

❑ Crack map



- Between RD-5650 ft to 6150 ft
- Surface cracks were traced up to the middle of the embankment with two directions of vertical and oblique to the downstream of dam.

❑ Weak zone (Geophysical, Drilling survey)

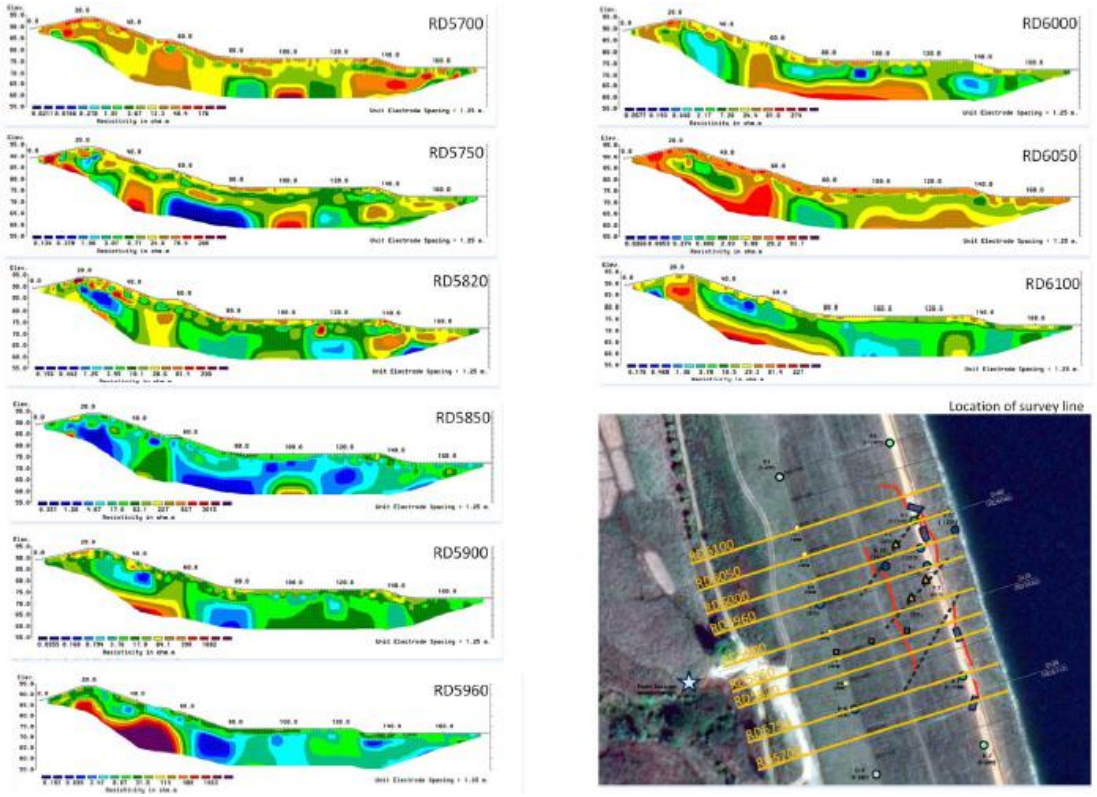


Fig : 2D resistivity survey for tracing cracks

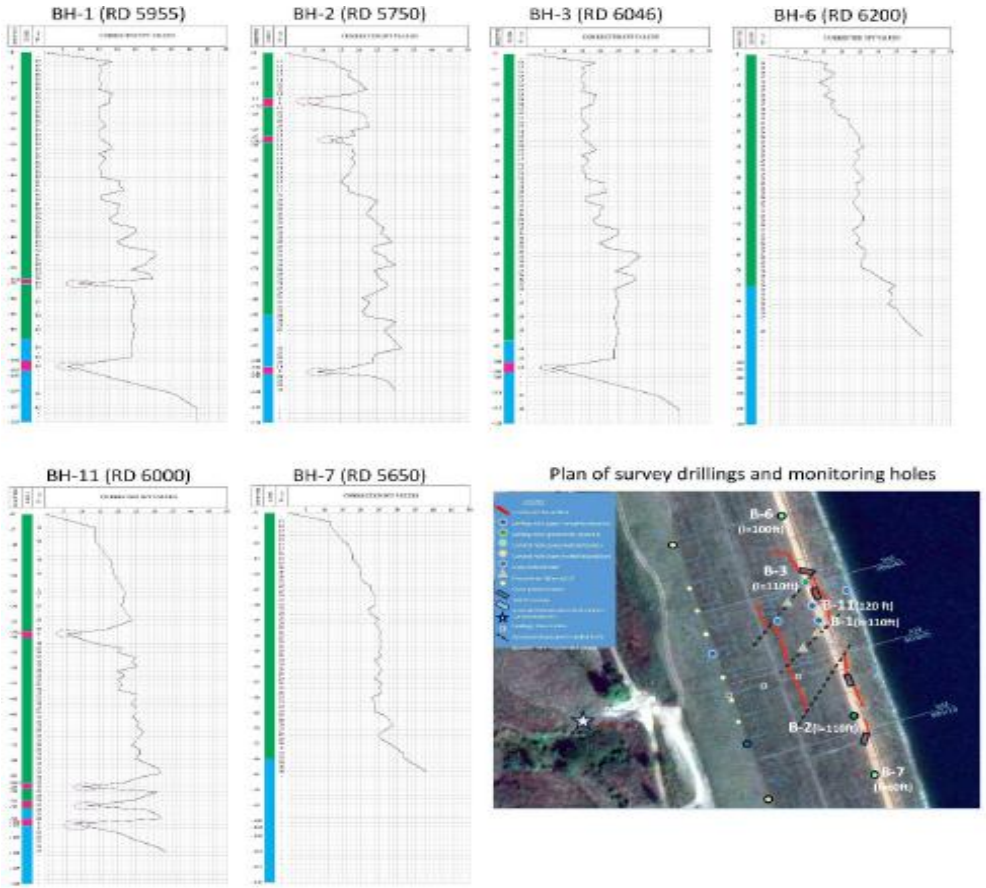
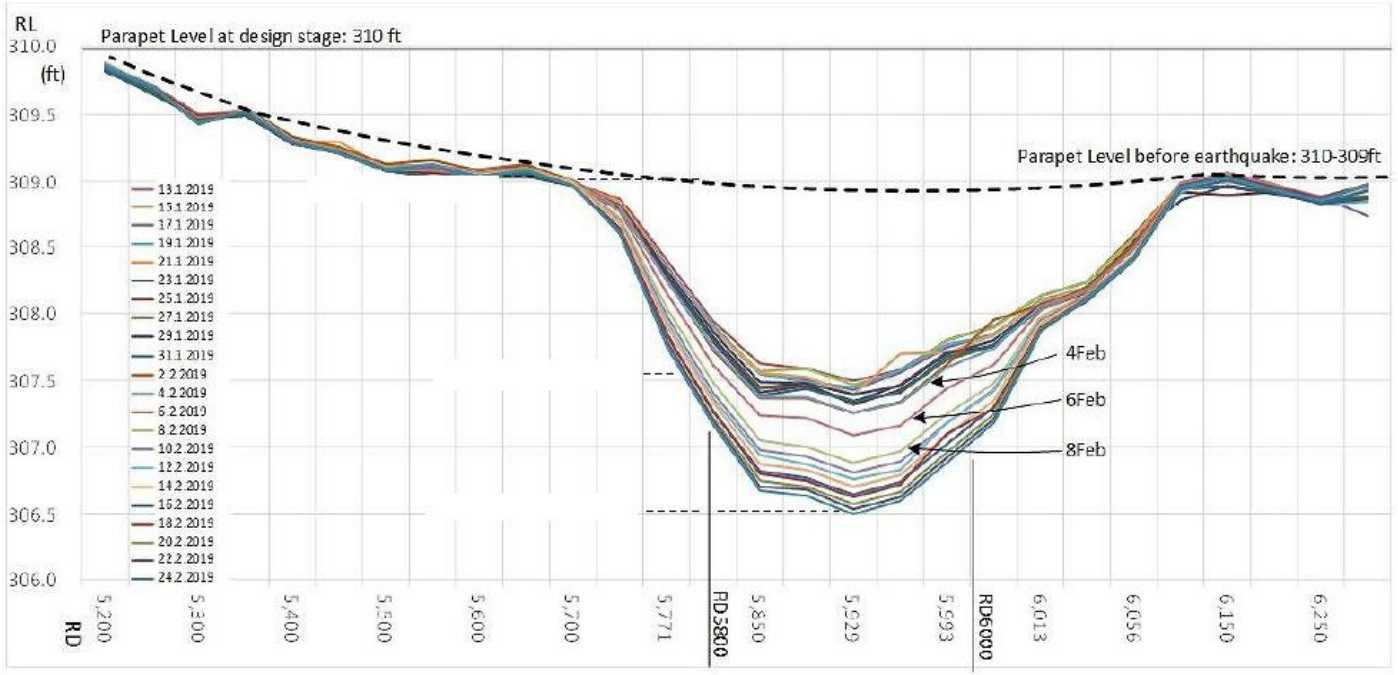


Fig : Drilling Logs for embankment and foundation

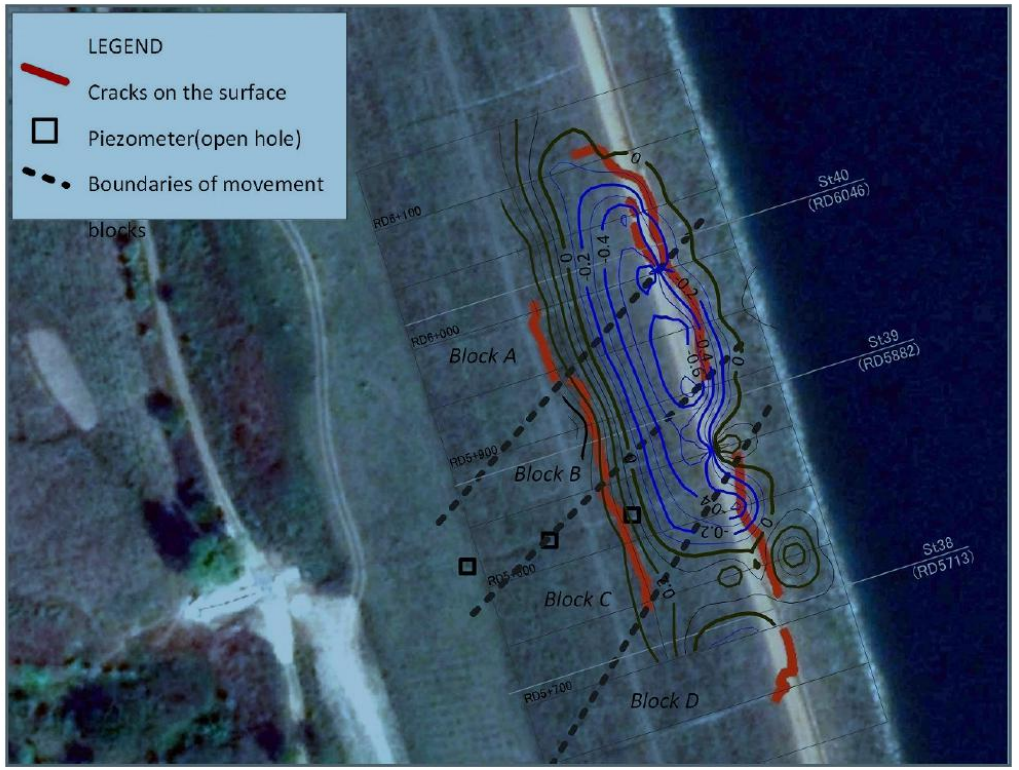
- A very low resistivity zone was seen in several locations of dam crest and was traced to the middle of the embankment with downstream dipping.
- Weak sections indicated Standard Penetration Test (SPT) value < 15

Ref: Geology report (IWUMD)

❑ Settlement



Settlement measured along parapet

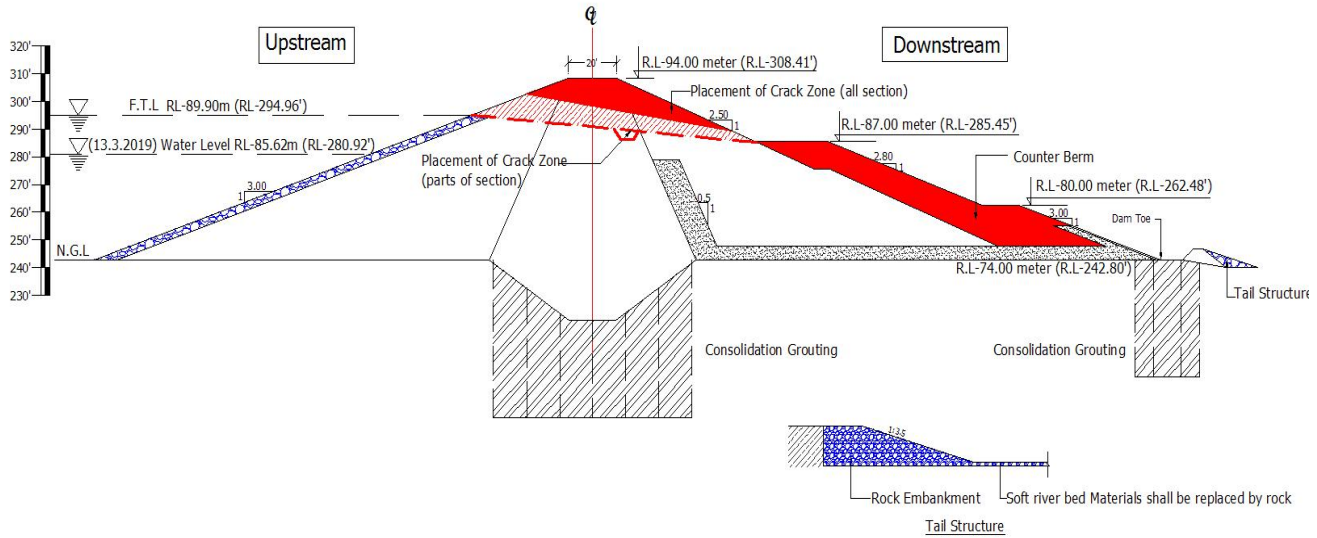


Areal distribution of settlement of cracked section

- Total settlement : 2.5 ft in 4.5 months
- Average settlement rate : 0.16 ft/day in 4.5 months
- Maximum settlement rate : 1.02 ft/day (6.2.2019) along with a rapid change of water level in the reservoir

Ref: Terminal report (Sanyu consultants)

3. Rehabilitation works on South Nawin dam



Case	Earthquake factor	Minimum safety factor
Case 1: current condition	k=0.23	Fs=0.971
Case 2: counter-weight embankment (CWE)	k=0.23	Fs=1.018
Case3: CWE + foundation treatment under core zone	k=0.23	Fs=1.201
Case 4: CWE + foundation treatment under core zone and downstream	k=0.23	**Fs=1.222**

(3.1) Consolidation grouting

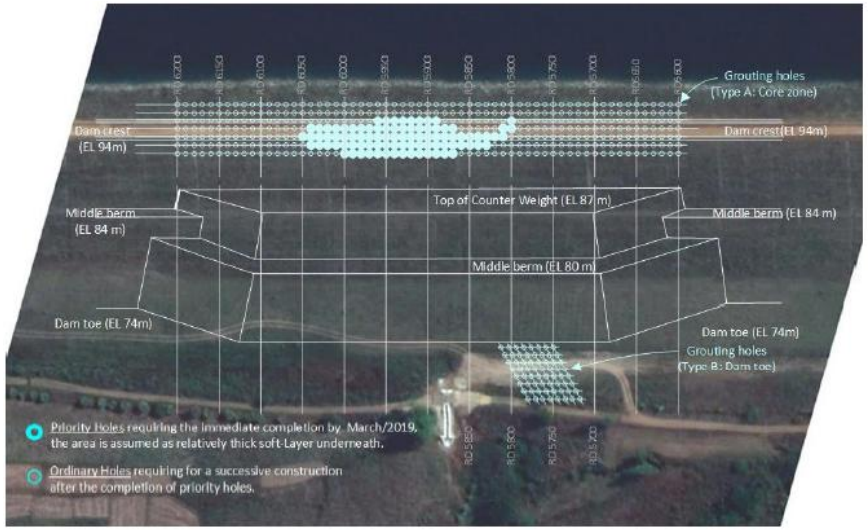


Figure: Grouting holes arrangement

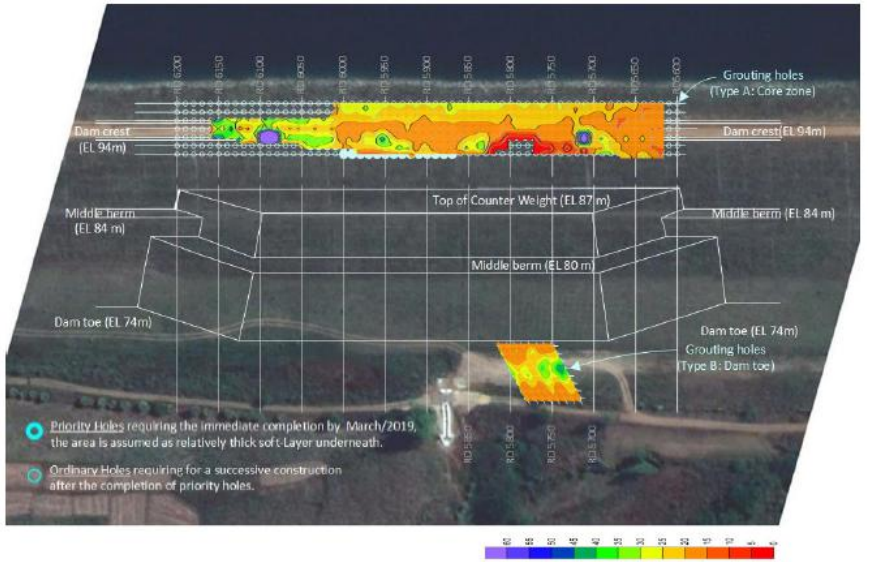


Figure: Distribution of cement injection volume at two areas

Ref: Terminal report(Sanyu consultants)

- 427 holes along the dam crest
- 64 holes near dam toe
- Average cement injection rate 22 kg/m

Photo: IWUMD

(3.2) Replacing crack zones




(3.3) Strengthening embankment section (counter-weight embankment)




Photo: IWUMD

(3.4) Monitoring system

Monitoring facility	Measurement	During 6 months after installation & rainy season	Routinely measurement after 6 months
Open holes	Ground water level	Daily	Weekly
Piezometer hole	Ground water pressure	Daily	Weekly
Inclinometer	Displacement of embankment	Twice a month	Monthly
Leakage observation facility	Leakage amount	Daily	Daily
Control point for topo survey	Surface deformation of dam	Weekly	Monthly
Water level recorder	Reservoir water level	Daily	Daily
Rain gage	Rainfall	Daily	Daily

Bird's-eye view of the South Nawin dam after repairment

Photo: IWUMD

4. Conclusions

- The earthquake damages occurred not only at the South Nawin Dam but also at houses and local pagoda that the nearest places of epicenter.
- It could estimate the peak ground acceleration of 0.23g which was beyond the criteria at the time of design.
- Lessons learned from that situation, the safety of the existing old dams should be evaluated and need to be rehabilitated if they are unsafe according to the current code of practice.
- In addition, design, construction, operation and maintenance works need to be upgraded when the new methods, guidelines and criteria are available.

Thank you for your Attention

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