A comparative study on seismic stability analysis of 2D and 3D concrete gravity dam

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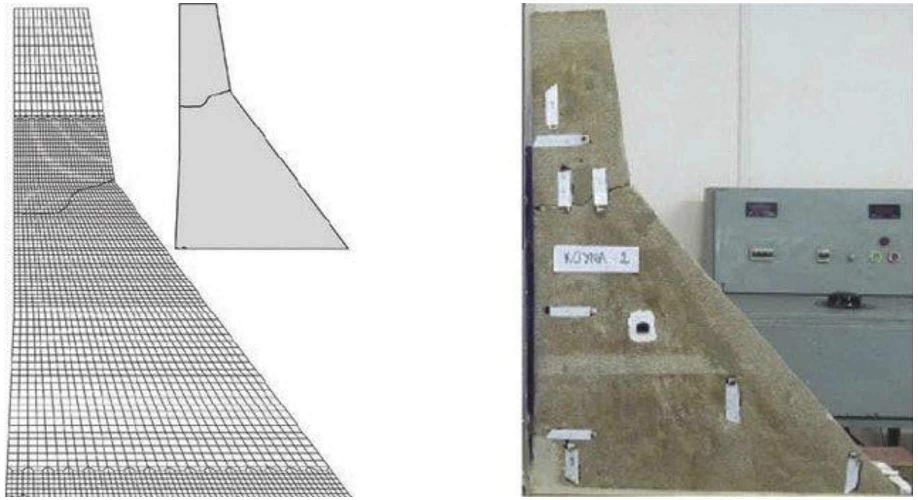
Importance of seismic analysis of dam

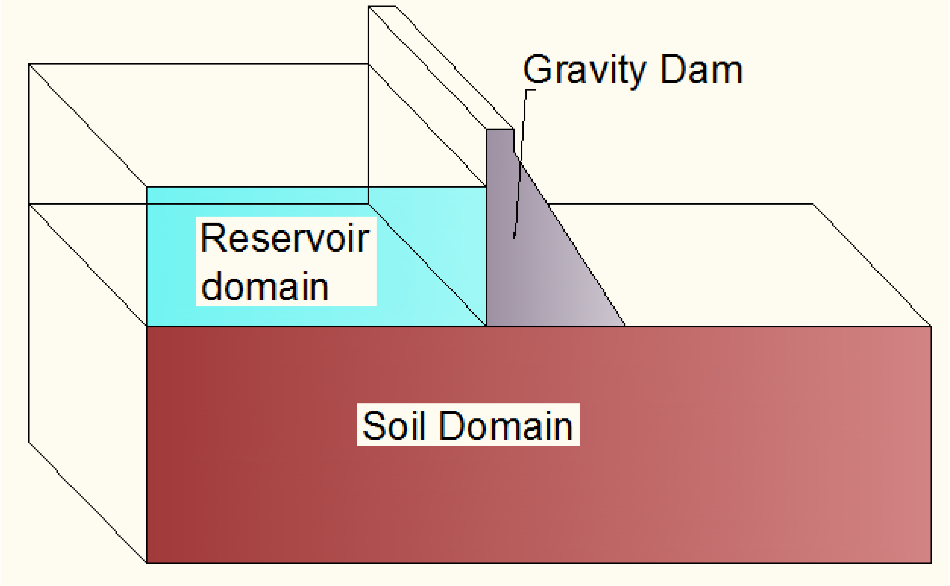
Shih-Kang Dam- Chi-Chi earthquake, 1999



Wang et. al. (2015) "The Influence of Initial Cracks on the Crack Propagation Process of Concrete Gravity Dam-Reservoir-Foundation Systems", Journal of Earthquake Engineering

Modelling of Dam

- 3 phase system
- 2D or 3D domain
- Boundary conditions
- Loading
- Interface property



Loading on Dam

- Self weight
- Hydrostatic Pressure
- Uplift Pressure
- Silt pressure
- Hydrodynamic force
- Inertial load

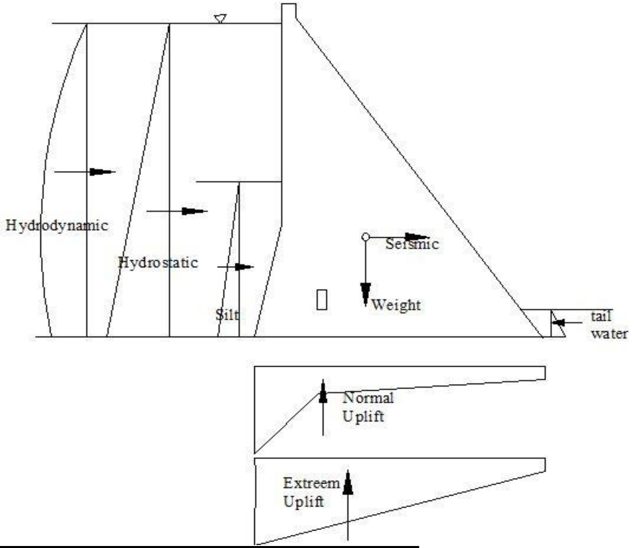
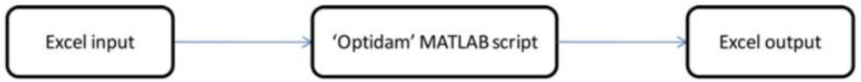


Table 1. Different Load Cases

Case No.	Self weight of dam	Upstream reservoir level	Silt pressure	Tail water level	Ice and wave pressure	Uplift pressure	Earthquake load	Permissible tensile stress
A	Yes	X	X	X	X	X	X	0
B	Yes	Normal	Yes	Normal	Yes	Drained	X	0
C	Yes	Flood	Yes	Flood	X	Drained	X	$0.01f_c$
D	Yes	X	X	X	X	X	Yes	0
E	Yes	Normal	Yes	Normal	X	Drained	Yes	$0.02f_c$
F	Yes	Flood	Yes	Flood	X	Undrained	X	$0.02f_c$
G	Yes	Normal	Yes	Normal	X	Undrained	Yes	$0.04f_c$

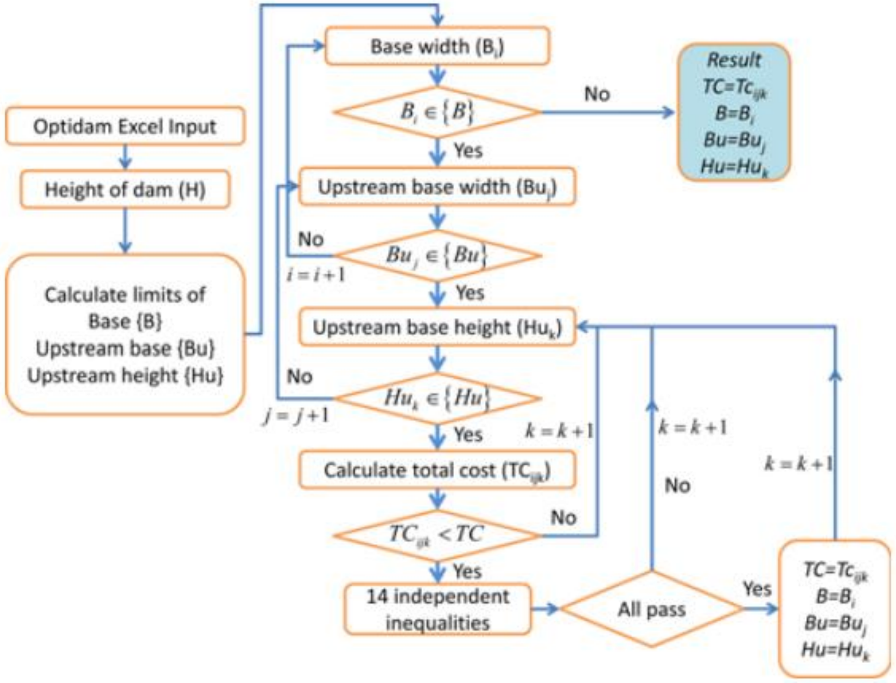
Obtaining a section of a Dam

- An in house MTLAB based optimization code



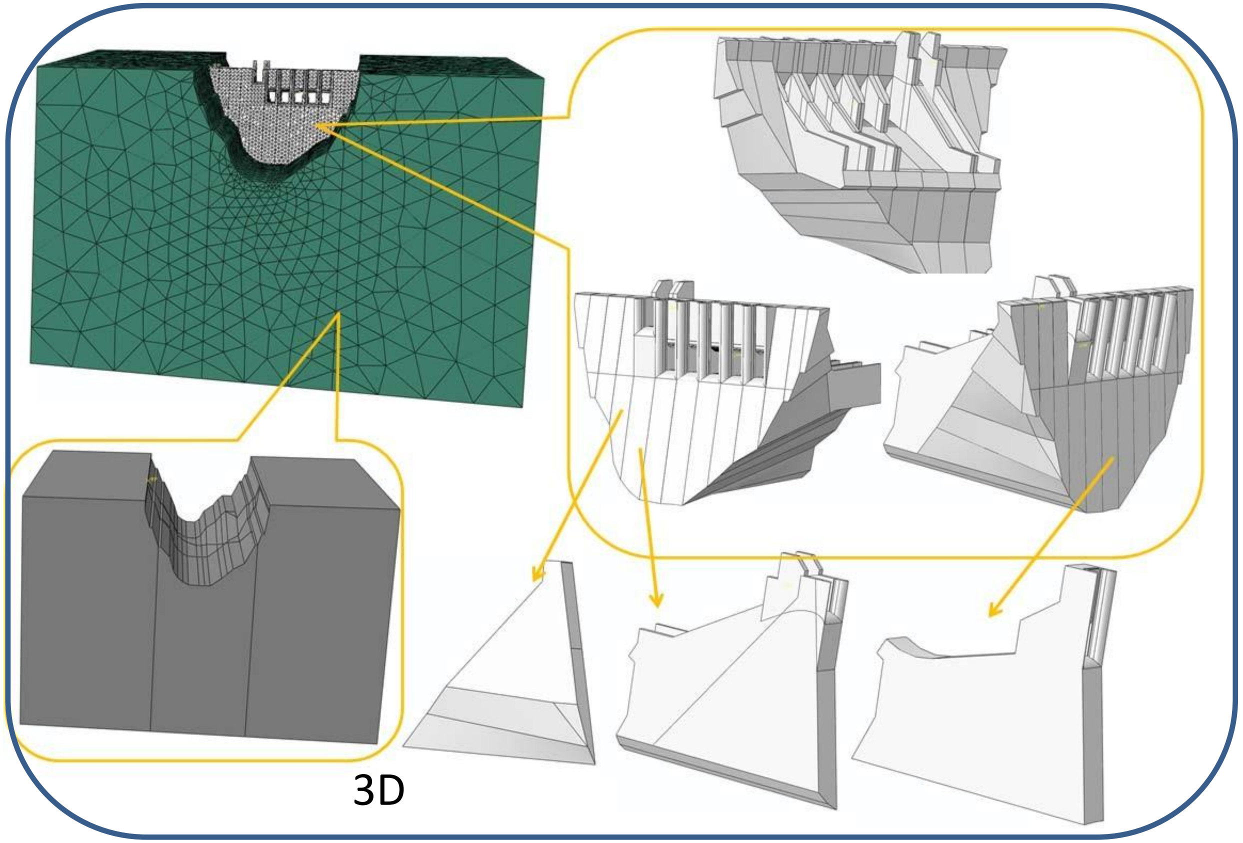
Dam parameter		
Height	240	m
Cohesion of dam-foundation interface	20000	kg/m^2
friction angle	35	degree
concrete unit weight	2400	kg/m^3
crest width	10	m
crest depth	10	m
Cost parameter		
1m3 Concrete	10000	
1m excavation	1000	
Grade of concrete	15	Mpa
Seismic Zone		
Z	0.36	
Reservoir Parameter		
Normal reservoir level	228	m
Flood reservoir level	234	m
Normal Tail water level	0	m
Flood tail water level	0	m
Silt or spillway height	100	m
unit weight of silt	1440	kg/m3

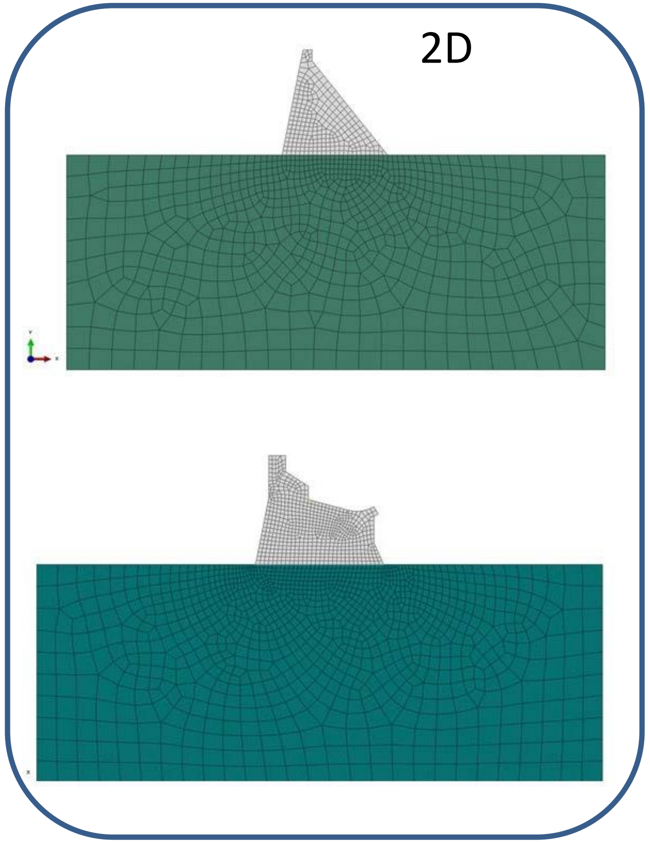
Height	240					
Base	243					
Base_up	67					
Height_up	167					
crest	10					
crest_dept	10					
Upslop	0.397436					
downslop	0.763636					
Cost	2.66E+08	INR/m thickness				
FOS			stress			
Case-B	1.215607		Sig-B	-180982	-1.80982	Mpa
Case-C	1.158056		Sig-C	-166380	-1.6638	Mpa
Case-D	4.551867		Sig-D	-285630	-2.8563	Mpa
Case-E	1.000825		Sig-E	-112784	-1.12784	Mpa
Case-F	1.468921		Sig-F	13995.33	0.139953	Mpa
Case-G	1.013526		Sig-G	59516.76	0.595168	Mpa



Banerjee et. al. (2014), "Optimization and Safety Evaluation of Concrete Gravity Dam Section", KSCE Journal of Civil Engineering

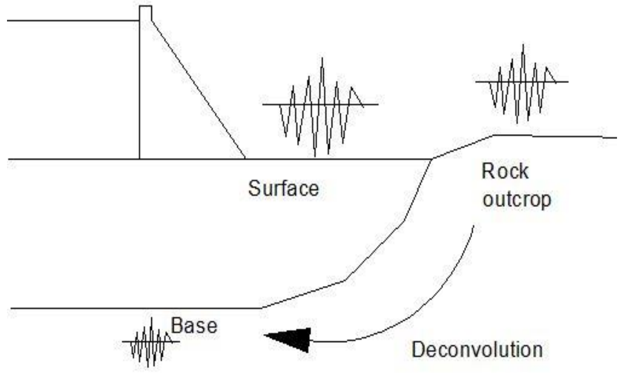
Finite Element model

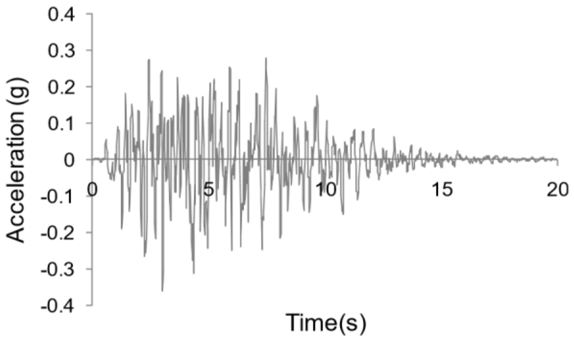


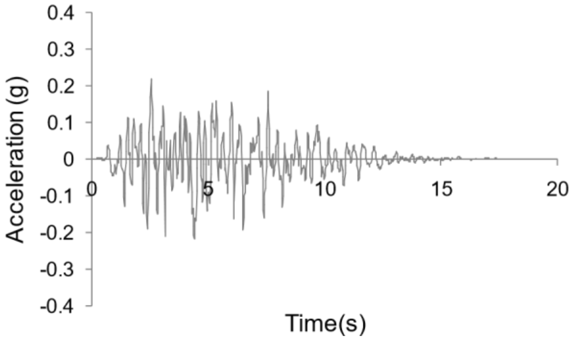


Ground motion

- From micro-zonation study we can get the site-specific ground motion at rock outcrop.
- It needs to be deconvoluted for applying at base of the foundation



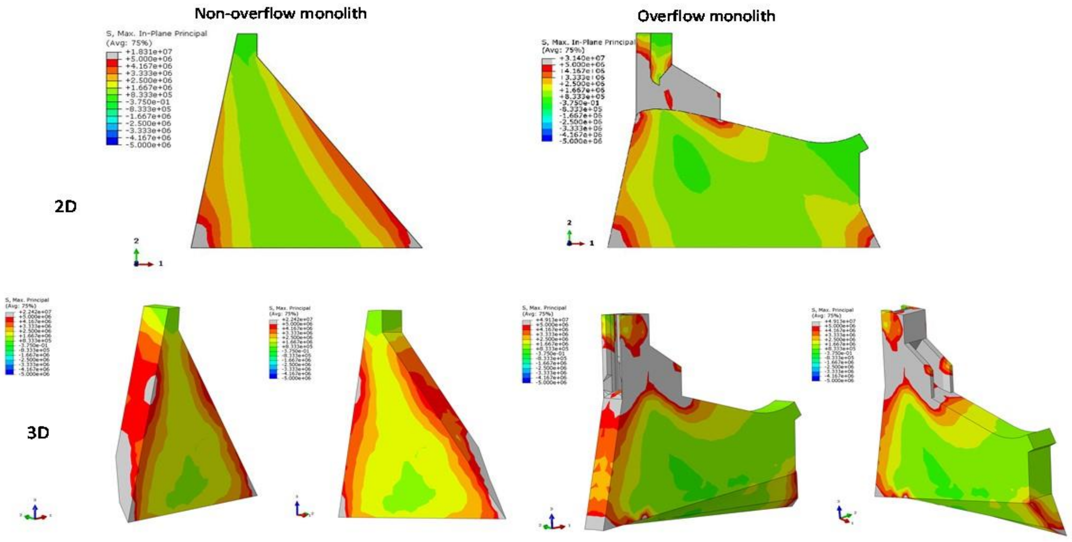


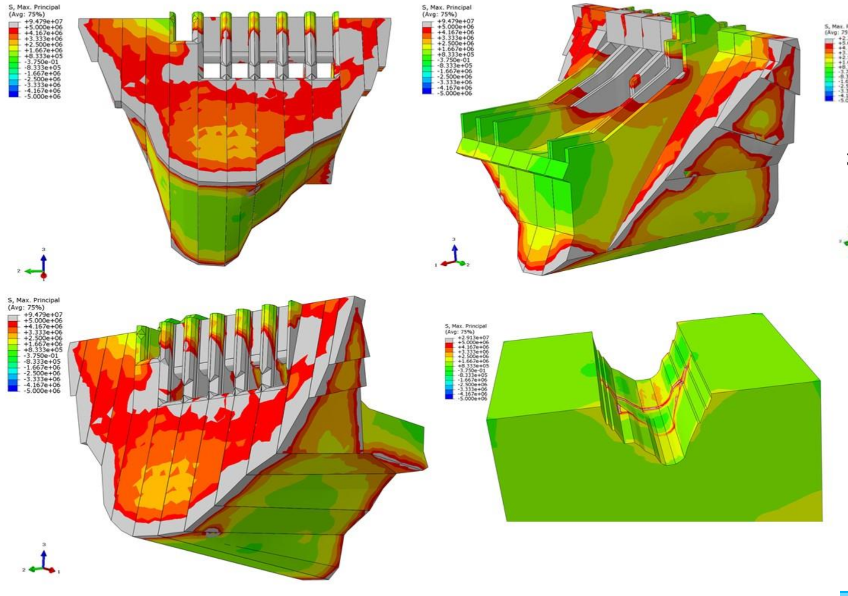


Boundary condition

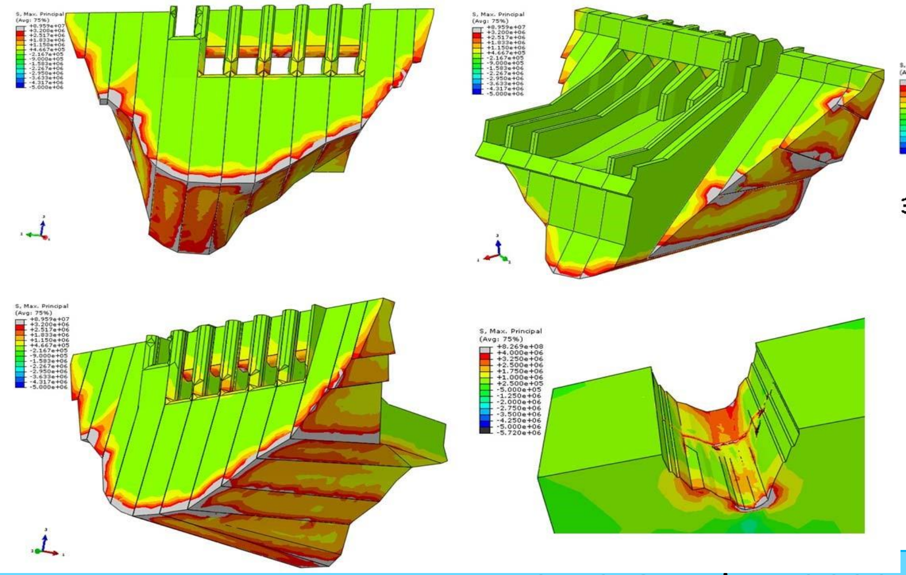
- Non-reflecting Boundary condition

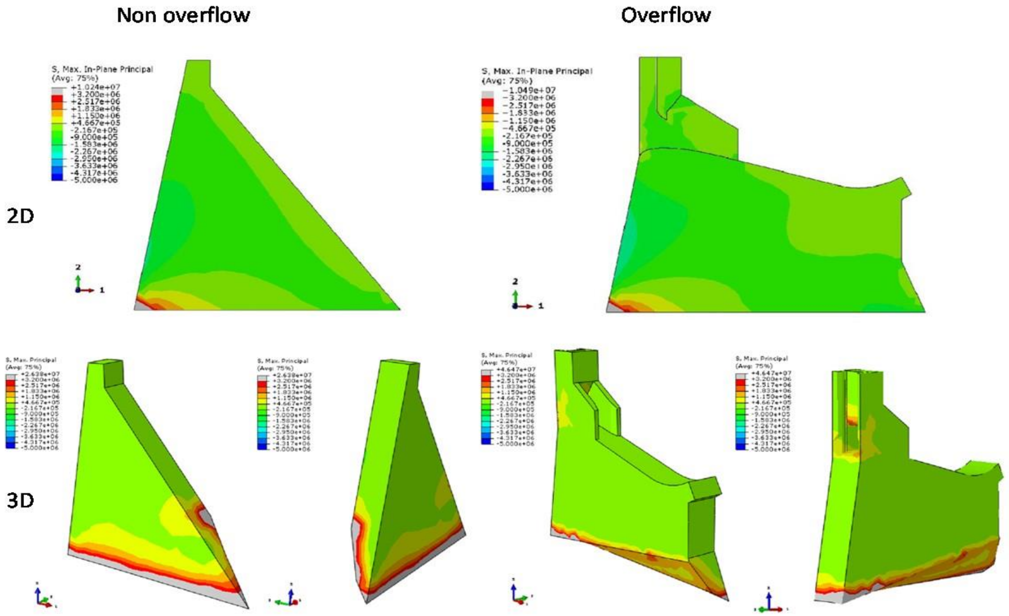
Response Spectrum analysis 2D vs 3D





Time-history analysis 2D vs 3D





Results of displacement

Monoliths/ Blocks	Analysis Method	Direction Horizontal (in mm)	Vertical (in mm)
Non Overflow Block	3D–Time history Method	31	51
	3D–Response Spectrum Method	63	17
	2D–Time history Method	117	75
	2D–Response Spectrum Method	113	25
Overflow Block	3D–Time history Method	34	53
	3D–Response Spectrum Method	117	34
	2D–Time history Method	136	83
	2D–Response Spectrum Method	160	47

Conclusions

1. The time period of the 2D and 3D model are comparable.
2. The result of the response spectra analysis of 2D and 3D dam is also analogous.
3. The response of the response spectrum is much more than that of time domain method,
    1. Effect of radiation damping and
    2. the dissipation of energy due to the contraction joints opening and closing in case of 3D time history analysis which can’t be simulated in response spectra analysis.
4. In case of response spectrum analysis, the effective damping ratio as developed by Chopra shall be used to get comparative stress output as in case of time history analysis.

Conclusions

5. The 2D idealization of 3D dam are always conservative, provided there is no tapered or unsymmetrical base of dam monoliths.

6. The monoliths situated on the steep slope must be investigated carefully, because the asymmetric base shape may induce stress concentration at the sharp corner.

7. The steep slope of the dam foundation need to be thoroughly analyzed and stabilized to counter stress generated due to dynamic dam-foundation interaction.

- Finally, 2D idealization is valid if the slope of the canyon is flat and all the monoliths has flat base. However, in case of narrow steeped riverbed profile 3D analysis of concrete gravity dam is highly recommended

Acknowledgement

Authors would like to acknowledge **Late Prof. D.K. Paul** for guiding several portions of the simulations and perceiving the idea

Thank you