DAM ENGINEERING: STATE OF THE ART AND PRACTICE, OBSERVED BEHAVIOR AND FUTURE CHALLENGES

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TOPICS

- INTRODUCTION
- LESSONS DUE CURRENT AND FAILURE SCENARIOS
- EMBANKMENT DAM PERFORMANCE DURING EARTHQUAKES
- BACKGROUND OF EARTHQUAKE EMBANKMENT DAM ENGINEERING HISTORY
- SEISMIC DESIGN
- ANALYSIS OF DAM STABILITY DURING EARTHQUAKES
- RESERVOIR TRIGGERED SEISMICITY
- MONITORING AND INSPECTIONS
- AGEING EFFECTS
- REHABILITATION OF DAMS
- RISK ANALYSIS
- BENEFIT AND CONCERNS OF DAMS
- FINAL REMARKS
- NEW CHALLENGES- LESSONS FOR TOMORROW

20th CHIN FUNG KEE MEMORIAL LECTURE

Professor Chin Fung Kee was a man of prodigious energy and fine intellect. We are indebted for his outstanding contribution for the advancement of knowledge in Engineering Practice, Engineering Research and for his devotion and passion for Education and Public Service.

But it is not sufficient to remember the Master, it is important to follow his example, to give continuity with energy and perseverance to his heritage and to spread his message that:

"The important thing in science is not so much to obtain new facts, as to discover new ways of thinking about them".

Bertolt Brecht

I am very busy
I have already begun with my survey
And I began to write my next error.

LESSONS DUE TO CURRENT AND FAILURE SCENARIOS OF DAMS

- Deteriorations due to hydraulic structures and operation about 35%
- Deteriorations due to cracking and hydraulic fracturing about 30%
- Slope failure odf dams and reservoir about 10%
- Excessive seapage through foundation about 12%
- Inadequate slope protection 7%
- Other situations 6%

LESSONS DUE TO CURRENT AND FAILURE SCENARIOS OF DAMS

- 20 % during the construction phase
- 20 % during the filling of reservoir
- 22 % after the construction phase
- 16 % after the period of five years following the construction phase
- 22% no identified cases

Lesson 1: Differential Settlements of Foundations

- The alluvia foundations with variable thickness can provoke differential settlements, with zones of traction and cracking. It is important to remove this material with poor properties, when its thickness is small

Lesson 2: Foundations Singularities

- The foundation was volcanic, very pervious and with fissures of moderate and high intensity.
- To control the seepage trough the foundations a grounting curtain was proposed.
- The preliminary grounting tests have shown difficulties but the design has not incorporated additional safety measures to incorporate the deficiencies of the grouting curtain
- During the filling of the reservoir the water levels were monitored in a number of observation levels in the vicinity of the dam.
- The rate of rise of water level in the wells was increasing at a greater rate than the rise of reservoir water

Lesson 2: Foundations Singularities

- The Independent Panel performed a finite element analysis using a hyperbolic model to assess the hydraulic fracturing and concluded that the failure was due a pipe forming trough the erodible silt core material in the key trench due the hydraulic facture or by flow of water trough joints carrying silt material.

- The Interior Review Panel has recommended: (i) the major dams project should be reviewed by an independent board
 (ii) the decisions should be documented
 (iii) the design team should
 follow the project
during the construction
phase of the dam

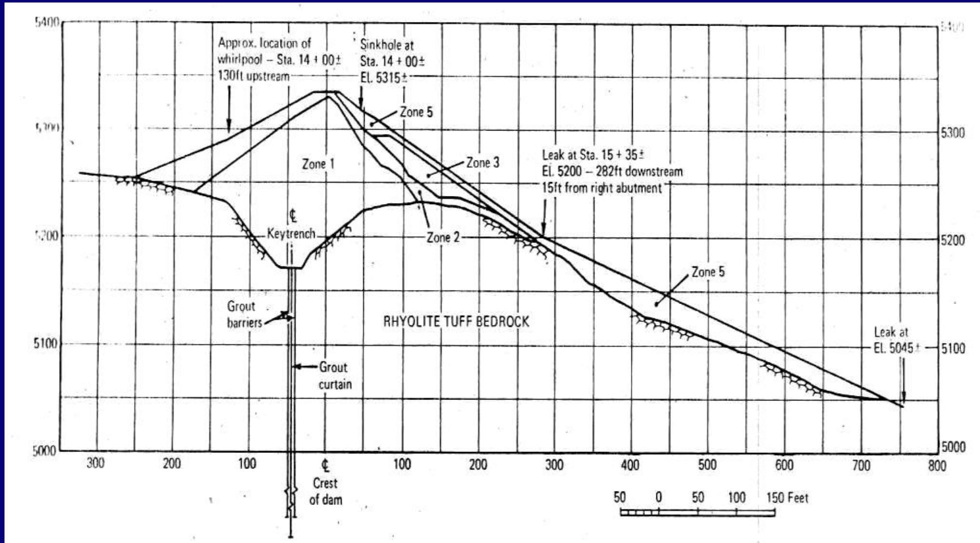


Fig. 4. Section through the dam near the line of failure (from the Independent Panel report)

Figure 1: Teton dam profile

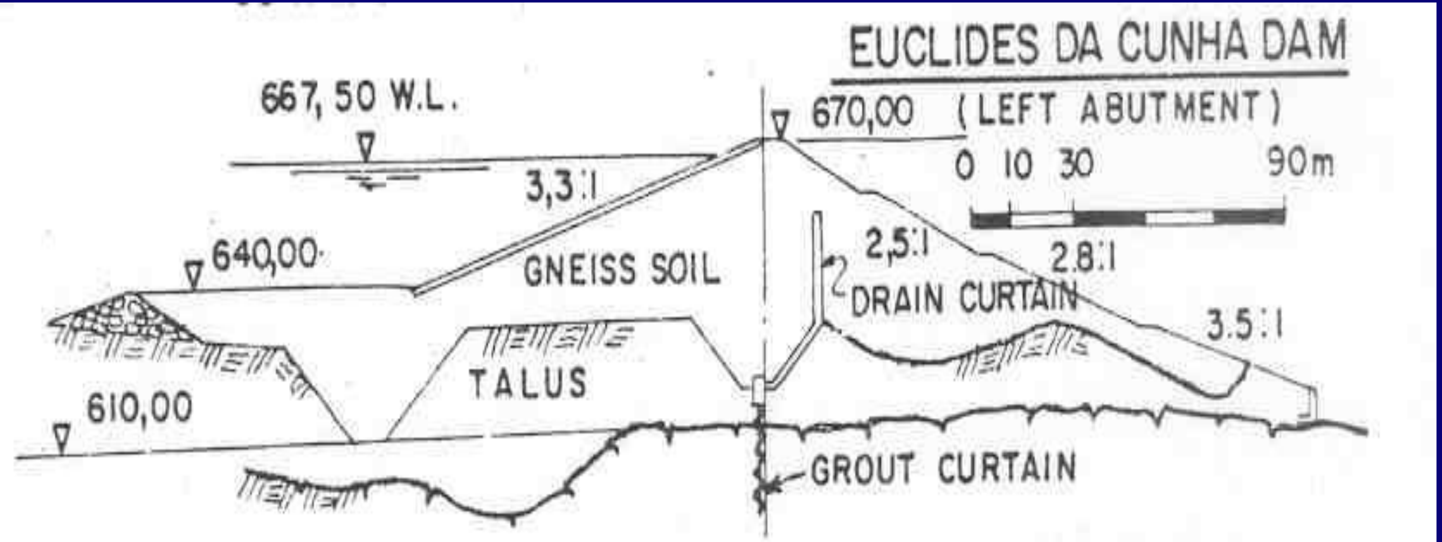
Lesson 3 Dimensions and Shape of the Valley

- Narrow valleys with inclined slopes are favourable to the occurrence of cracks and so the design should incorporate special measures

- The study of shape valley and the development of tension stress can be performed by 2D or 3D analyses

Lesson 4 Liaison Embankment-Abutment

- The liaison embankment-abutment needs special cares due to the inclination of the slope, as the slope inclination of abutment can provoke transverse cracks due to differential settlements and the rock discontinuities are favorable to the traction zones.
- Two months after filling of the reservoir of Euclides da Cunha dam a seepage has occurred in the downstream slope in the neighbor of left abutment where the rock has exibited some irregularities. The investigations have shown the existence of a crack due the differential settlements due to the abutment inclination



Lesson 5 : Difference of Compressibility between the Core and the Shell Materials

- El Infiernillo dam built in Mexico on 1963 is a zoned dam with a thin central clay core and shells with rockfill materials
- The difference of compressibility and geometry between the core materials and the shell materials favored the occurrence of stress transfer between the core and shell materials. This stress distribution is favorable to the occurrence of longitudinal cracks.

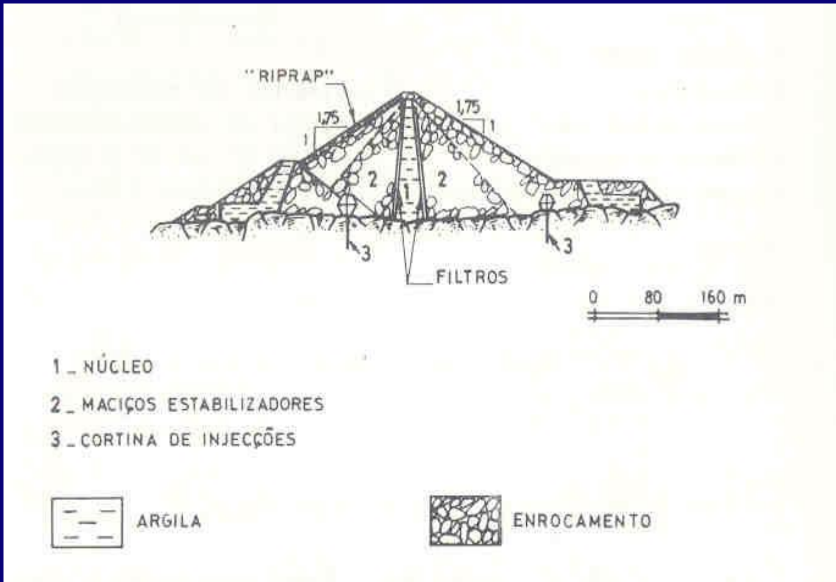


Figure 3. El Infiernillo dam profile

Lesson 5 : Difference of Compressibility Between the Core and the Shell Materials

- Numerical analyses of stress states of El-Infiernillo have shown plasticity areas in the core and filters and transitions zones. The numerical results have reflected field observations data

Lesson 5 : Difference of Compressibility Between the Core and the Shell Materials

- **Due to this situation the following effects have occurred: (i) considered settlements during the first filling; (ii) the development of plastic zones that embrace a considerable proportion of the potential shear failure surfaces in the dam, (iii) a reduction in the relative density of the granular materials**

Lesson 6: Characterization of Fill Materials

- The characteristics of the fill materials are related with cracking. Some soils have high susceptibility to cracking and can not sustain small differential settlements
- Tests to characterize the erodibility of the material, namely flume tests and cylinder rotating tests should be highly recommended.

- After the first reservoir filling a great concentration of dirty water has appeared in the right bank. From the investigations was concluded that the seepage was due to the differential settlements and the high susceptibility of core cracking

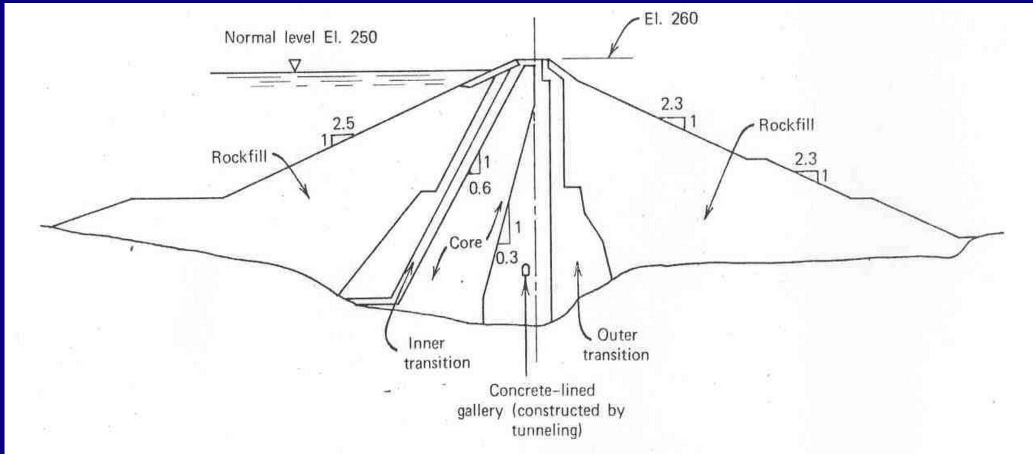


Figure 6. Mathina Dam cross-section

Lesson 7: Hydraulic Fracturing

- During the filling of reservoir due to the seepage and buoyancy forces there is a modification of the stress state. When the water pressure is higher than the summation of the effective stress and the traction resistance of the material tension cracks can occurred
- Hydraulic fracturing is defined as the condition to provoke and propagate a physical separation in a soil or rock mass, due to the excessive pore pressure in comparison with the existent stress in the soil and rock mass

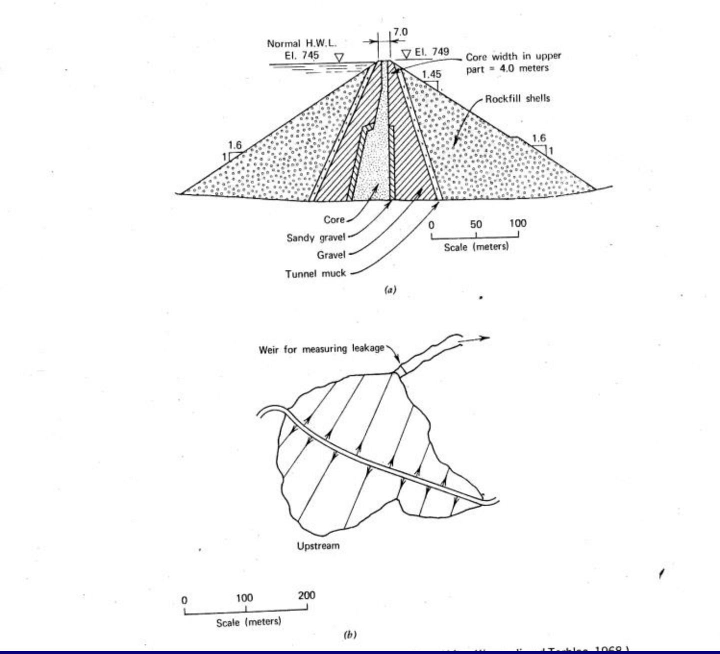


Figure 7. Hyttehuvet dam profile

Lesson 7: Hydraulic Fracturing

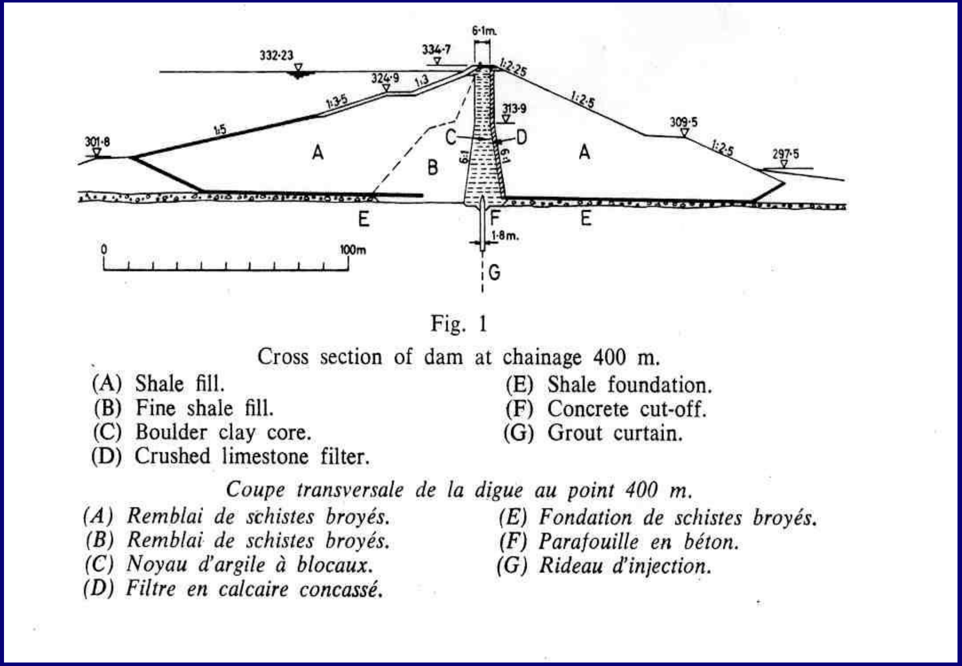
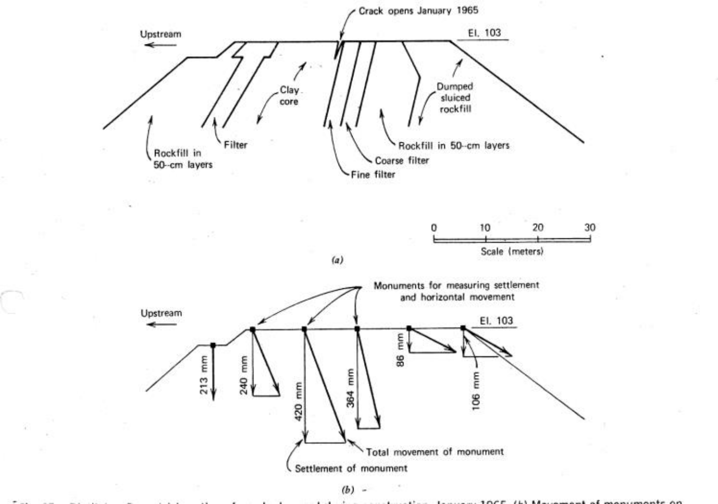


Figure 8. Balderhead dam profile

- **In 1967, two years after the filling of reservoir caverns have occurred in the dam crest. The investigations have concluded that the cracks and the seepage trough them have provoked piping of a considerable part of the core**



Lesson 8: Connection of Fills of Different Ages

- The schedule of the works sometimes creates situations with a discontinuous construction of the fills
- In 1969 high seepage was detected in the neighbouring of the left embankment of Hills Creek dam and the explanation was connected with the circulation of the engines and the filling and compaction of this zone was not done adequately and core segregation has occurred

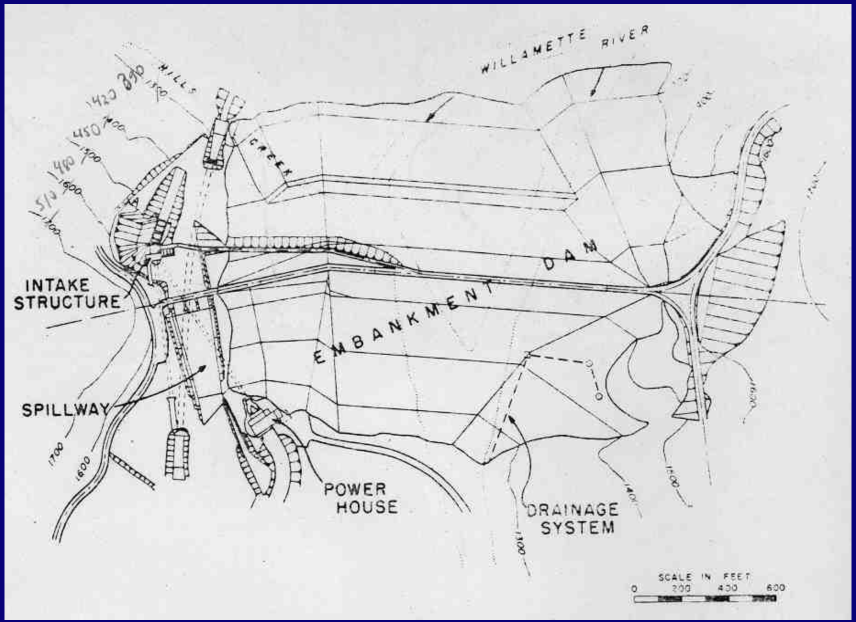


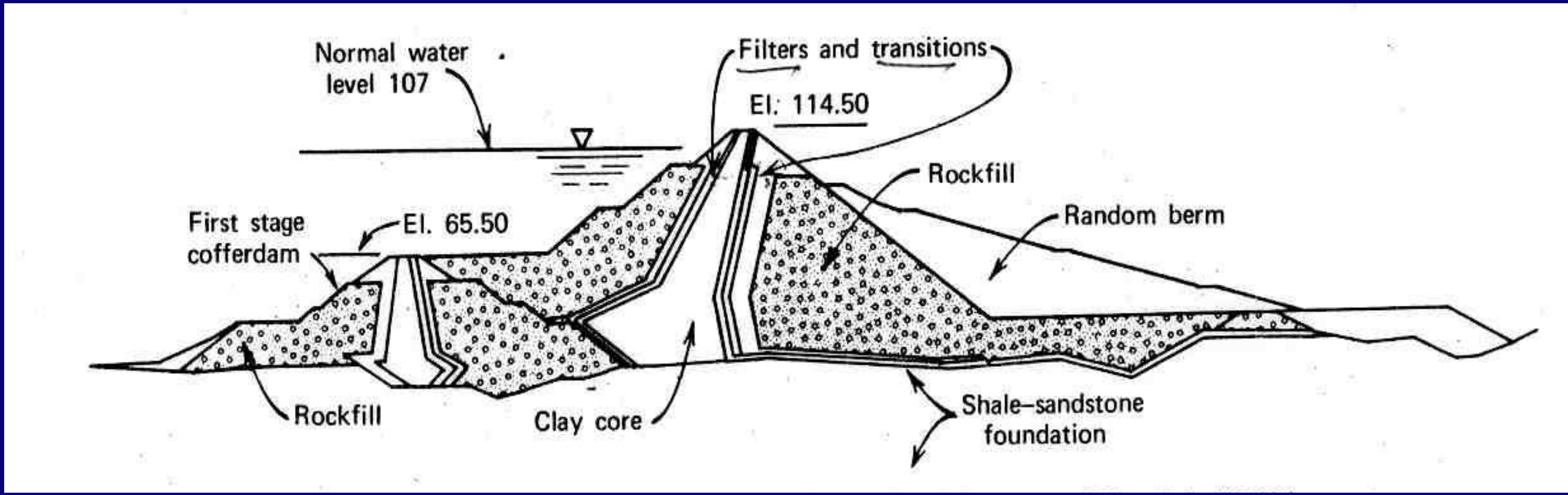
Figure. 10 Hills Creek dam plan

Lesson 9: Drying of the Material

- Long dry periods can provoke the occurrence of cracks. If the fill surfaces are exposed for high temperatures during long periods, need to be covered by an layer of sand material, with a thickness of 0.50m, to avoid the cracking of the fill material

Lesson 10: Opening of boreholes

- The opening of boreholes for the placement of hydraulic piezometers is performed after the construction phase
- There is sufficient experience to conclude that the opening of boreholes can provoke cracking and increase of the permeability. Within this framework the opening of boreholes shall be performed with air pressure, to avoid the occurrence of hydraulic fracturing



Djatiluhur dam cross section

Lesson 11: Concrete Structures Incorporated in the Embankment

- It is difficult to compact the material in the neighbouring of conduits and vibratory plates are used. The conduits located inside the embankment favoured the stress transference and the cracks formation due to the differential settlements. In order to increase the flexibility the placement of wet material in the neighbouring of the conduits is recommended

Lesson 12: Speed of Filling of the Reservoir

- The filling of reservoir can provoke the saturation of the foundation and of the upstream shell and the redistribution of stress can contribute for the occurrence of transverse and longitudinal cracks.
- It is important to control the rate of reservoir filling. Intensive rains have provoked the filling of reservoir of Yard`s Creek with a rate of 3 m by day

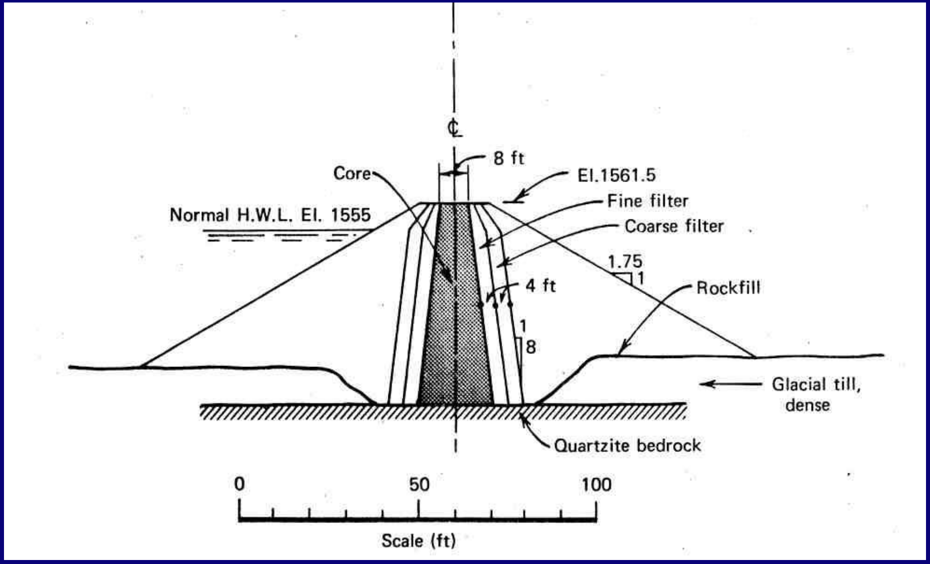


Figure 12. Yard`s Creek dam profile

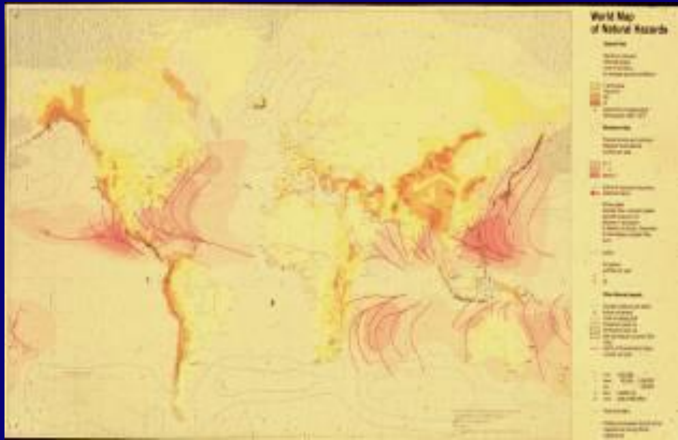
LESSONS FROM DAM BEHAVIOR DURING EARTHQUAKES

- SLIDING OR SHEAR DISTORTION OF EMBANKMENT OR FOUNDATION
- TRANSVERSE CRACKS
- LONGITUDINAL CRACKS
- LOSS OF FREEBOARD

  DUE TO COMPACTION OF

  EMBANKMENT OR FOUNDATION
- RUPTURE OF UNDERGROUND CONDUITS
- OVERTOPPING DUE TO

  SEICHES IN RESERVOIR



LESSONS FROM DAM BEHAVIOR DURING EARTHQUAKES

- OVERTOPPING DUE TO SLIDES OR ROCKFALLS INTO RESERVOIR
- DISRUPTION OF DAM BY MAJOR FAULT MOVEMENT IN FOUNDATION
- DIFFERENTIAL TECTONIC GROUND MOVEMENTS
- FAILURE OF SPILLWAY OR OUTLET WORKS
- PIPING FAILURE THROUGH CRACKS INDUCED BY GROUND MOTIONS
- LIQUEFACTION OF EMBANKMENT OR FOUNDATION

SANTA BARBARA EARTHQUAKE, JUNE 29, 1925

Lesson 13: Embankment dams with low degree of compaction are vulnerable to earthquakes.

The dam was constructed in the winter of 1917 with 219.50 m long and 76 m high. The body of the dam was composed of silty sand and sandy silt containing some cobbles and boulders, but the upstream slope was faced with a 1.20m thick clay blanket. No records of the degree of compaction are available but it was probably about 75 to 80 percent based on the standard AASHO compaction test (ICOLD, 1975).

SAN FERNANDO EARTHQUAKE, FEBRUARY 9, 1971

Lesson 14: Hydraulic fills due to the development of pore pressure are susceptible to liquefaction.

Figure 13. San Fernando dam-dam view

OROVILLE EARTHQUAKE AUGUST, 1, 1975

Lesson 15: Rockfill dams with compacted material exhibit a good behaviour during the occurrence of earthquakes. To correct simulate the dynamic response of dams in steep triangular canyons a three-dimensional analysis is needed.

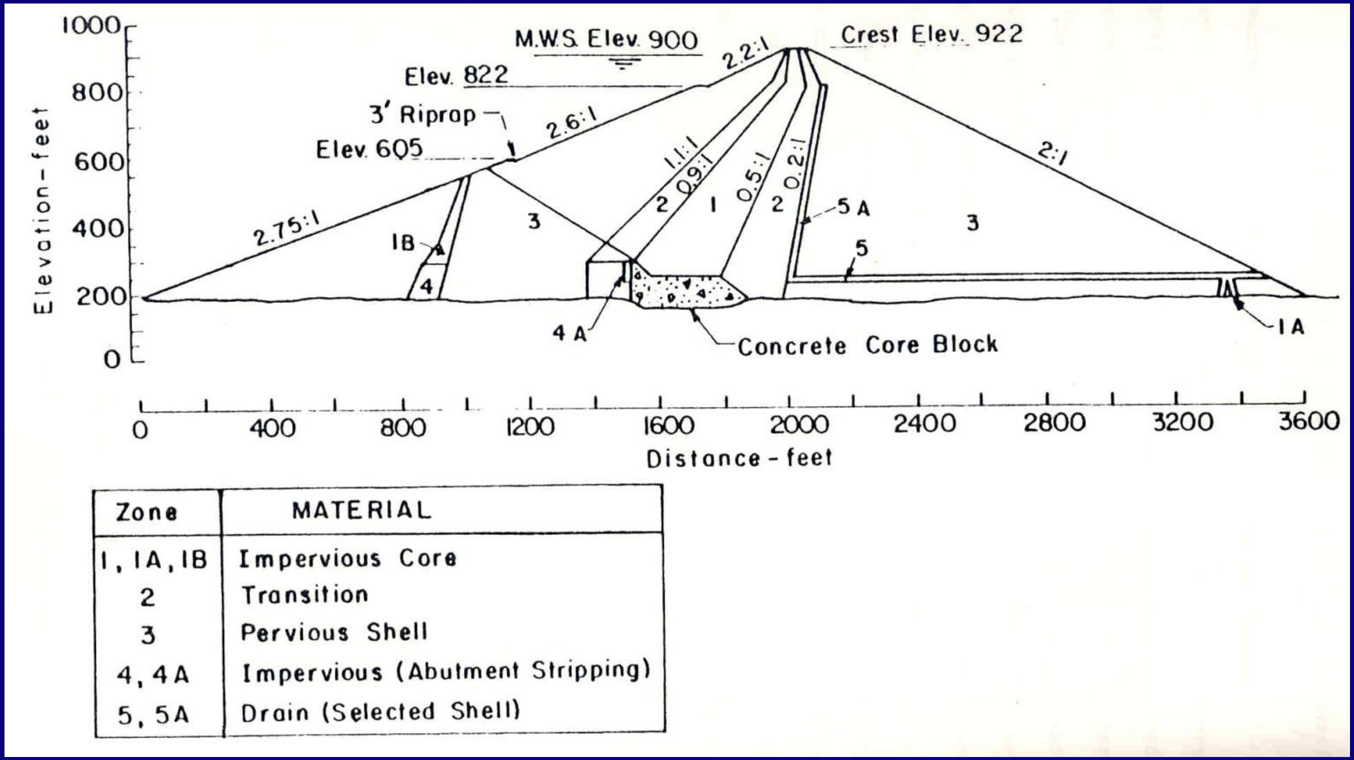


Figure 15. Oroville dam cross section

ASWAN EARTHQUAKE NOVEMBER, 14, 1981

Lesson 16: The identification of tectonic mechanisms, location and description of faults and estimation of fault activity play an important role to assess the involved dam risk.

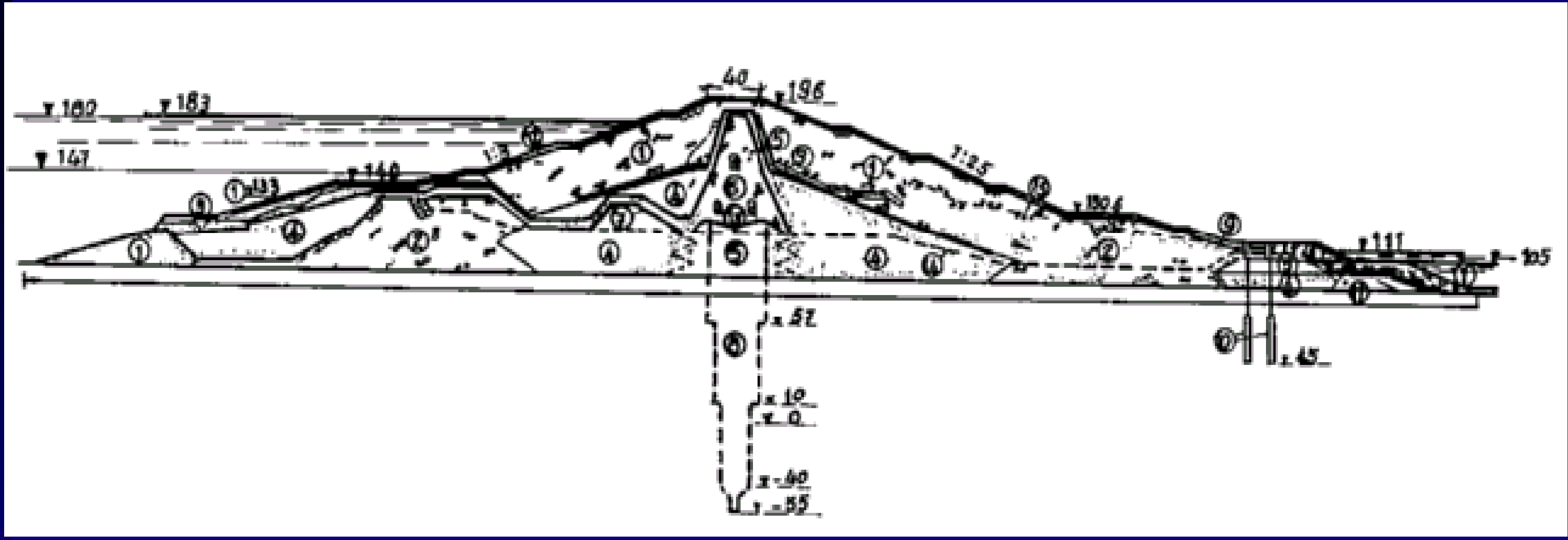
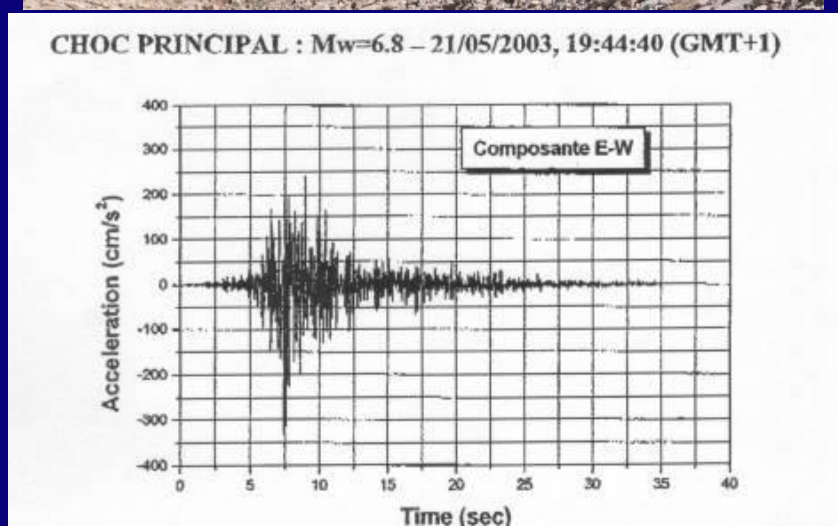


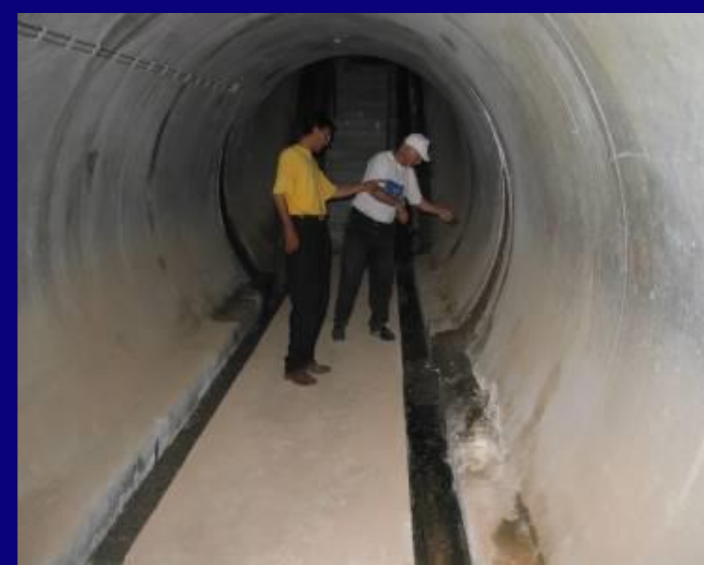
Figure 16. Cross section of Assuan dam

EARTHQUAKE 21 MAY 2003-ALGERIE

Lesson 17: Well designed and constructed embankment dams exhibit a good behaviour for strong ground motions.

Figure 18. Keddara dam-cracks observed at the crest





EDGECUMBE EARTHQUAKE 1987

Lesson 18: Due to the re-evaluation of design seismic action there is a need to strength the dams in order to accommodate the settlements and leakage.

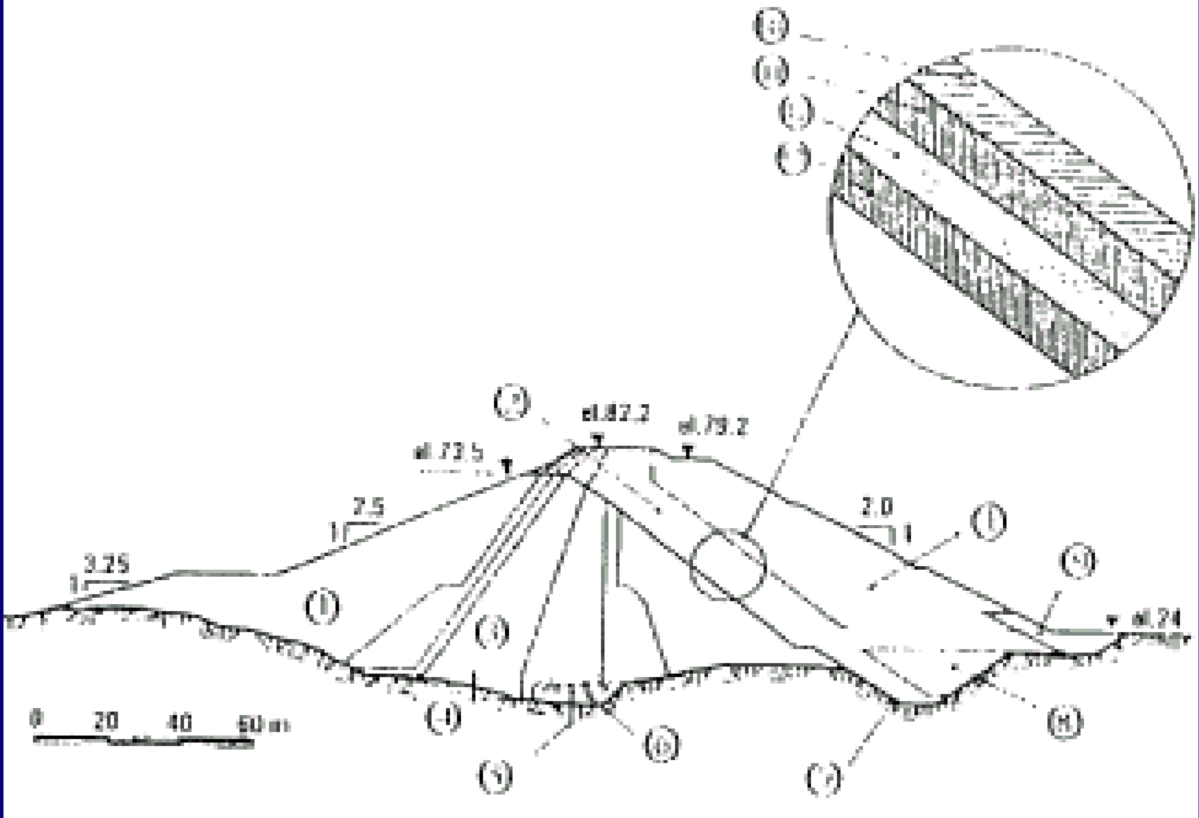


Figure 19. Matahina Dam (New Zealand)

NIIGATA EARTHQUAKE 2004

Lesson 19: In spite of some high settlements that occurred during earthquakes the embankment dams still accomplish their function.

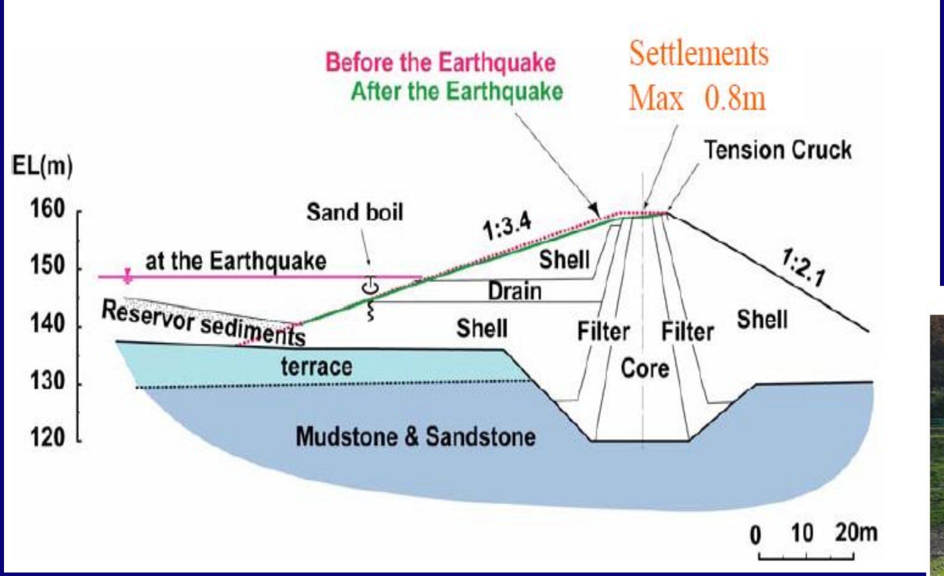


Figure 20. Yamamoto dam profile

CHILE EARTHQUAKE
March, 3, 1985

Lesson 20: Occurrence of liquefaction in a ground with heterogeneous conditions requires a deeper analysis and a better understanding of the interactive phenomena.

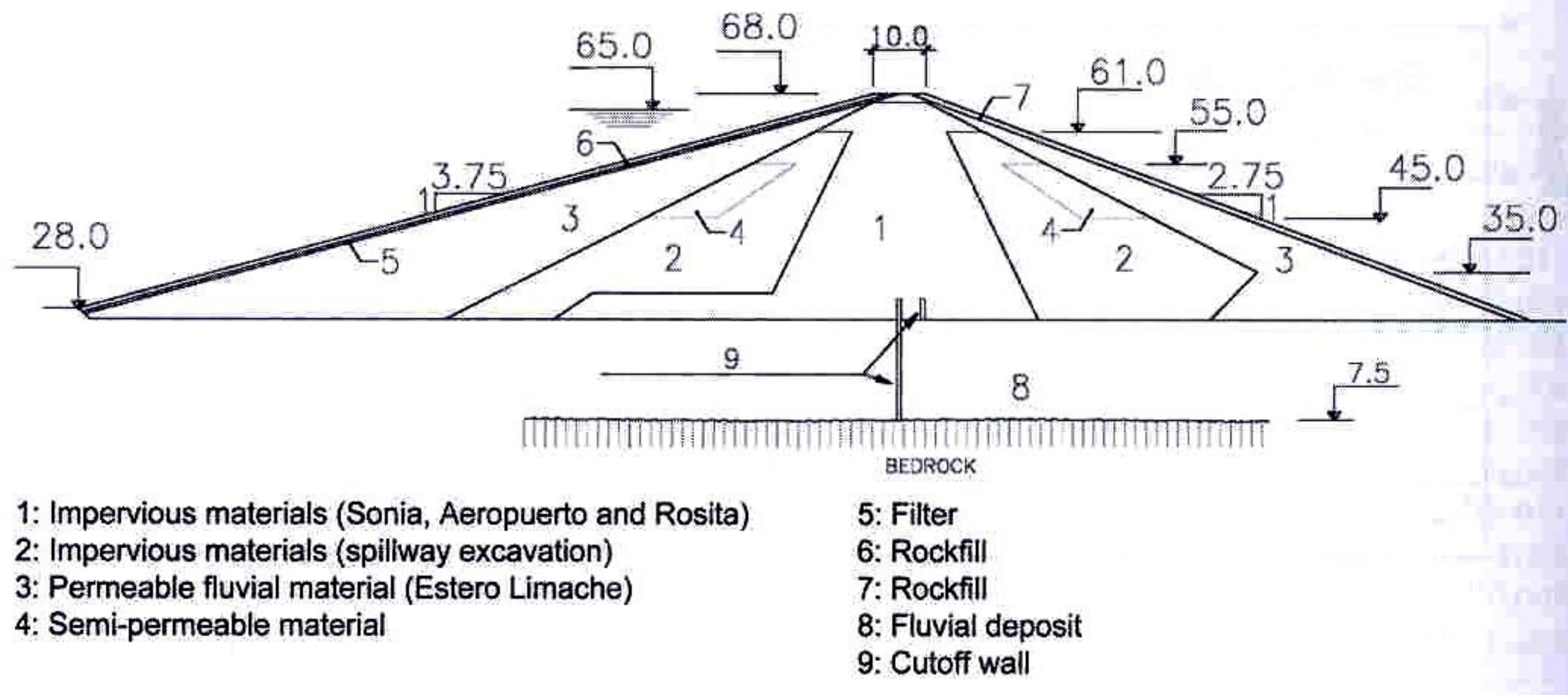


Figure 22. Cross section of Aramos dam

PAKISTAN EARTHQUAKE
October, 8, 2005

Lesson 21 : Dams behaviour during earthquakes contribute to update and implement national codes.

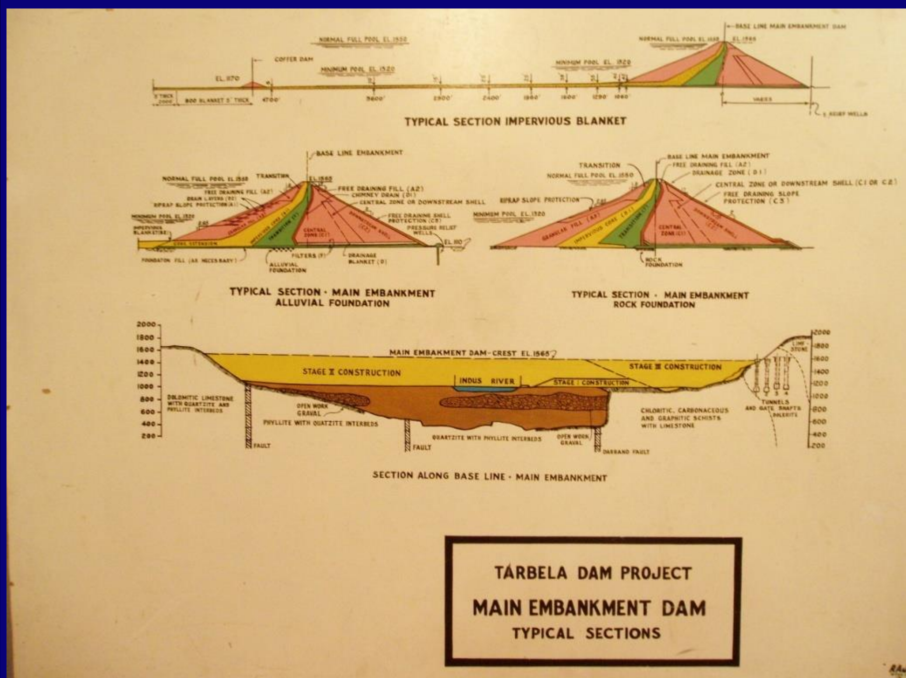
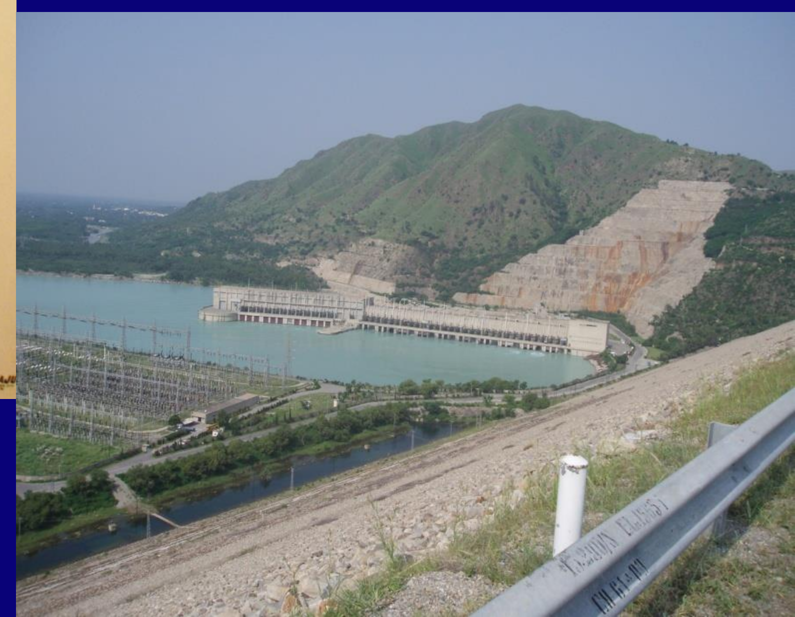


Figure 24. Tarbela dam –general view



WENCHIAN EARTHQUAKE
May, 12, 2008

Lesson 22: In spite the apparent good behavior of CFRD dams during earthquakes there is still a lack of case histories of CFRD operating with full reservoir.

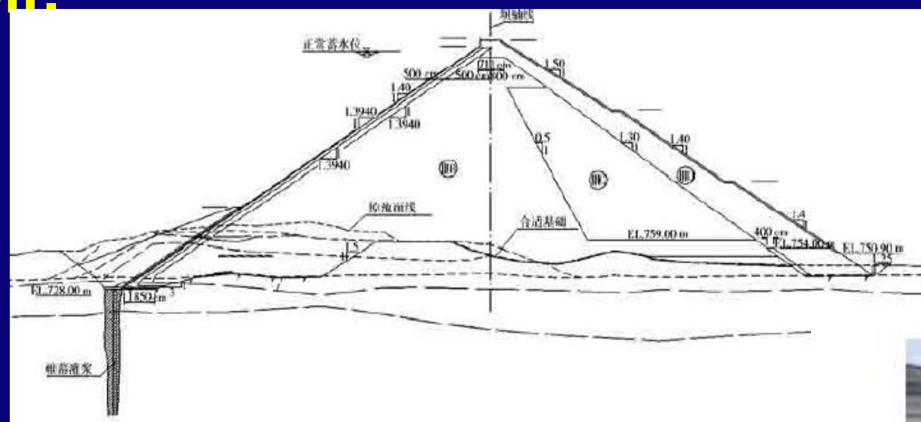
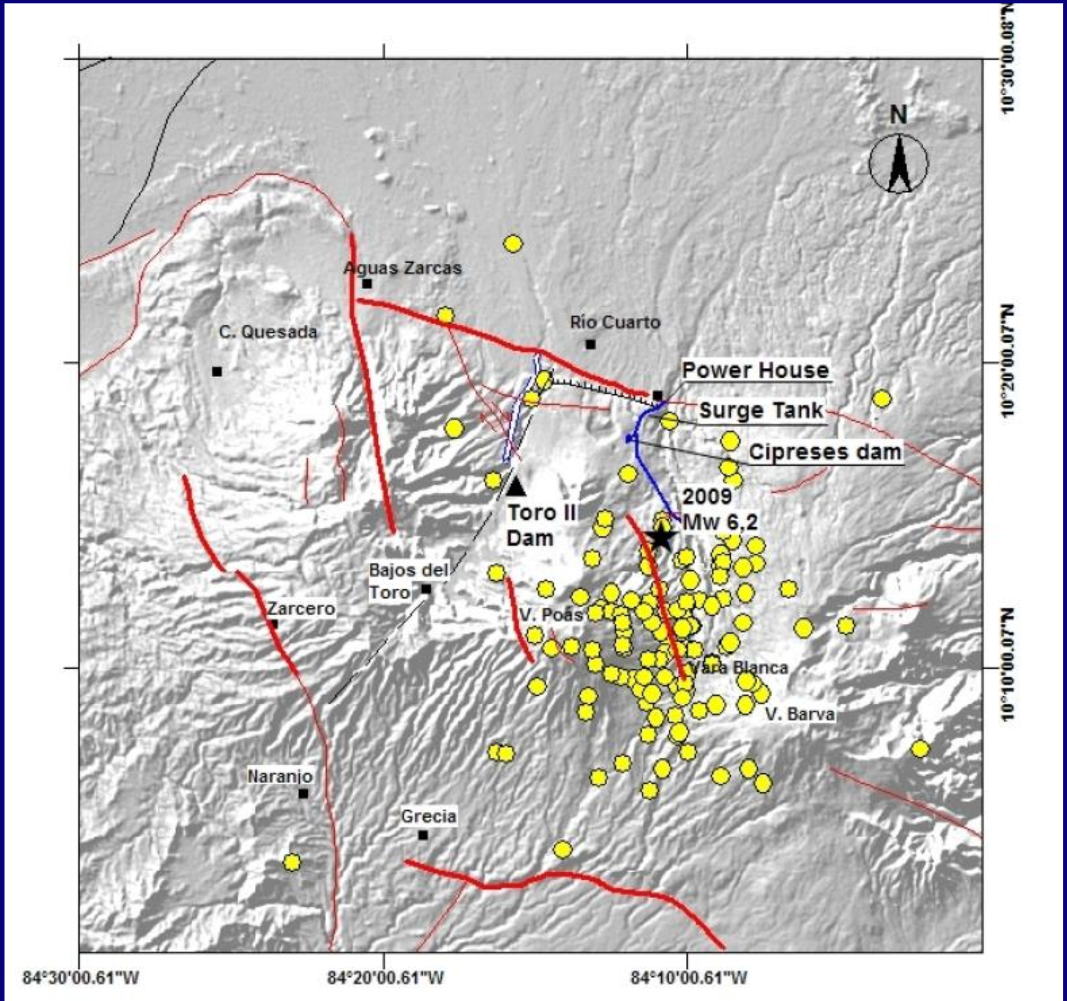


Figure 25. Zipingpu dam profile

COSTA RICA EARTHQUAKE January, 8, 2009

Lesson 23: Dams located near faults can exhibit a good behaviour for strong motions with only minor cracks.



PROMETHEUS

Conclusion: The current state of the art and state of practice allow to the design and construction of embankment dams a good performance record in regards of earthquake shakes, with less than 1% dam failures.

Prometheus offers the fire to the Humanity that represents the knowledge .
Descartes in his book Methodology inspired in Prometeus and has considered that the lessons are important to benefit human life and knowledge

HISTORICAL BACKGROUND EARTHQUAKES

- According to Aristotle (384-322 B.C.) in his book Meteorologica earthquakes were produced by the dried exhalations (spirits or winds) in caves inside the earth which trying to escape make the earth shake
- Martin Lister in England and Nicolas Lemery in France in 17th century were the first to propose that earthquakes were produced by large explosions of inflammable material formed by a combination of sulfur, coal, niter and other products accumulated in the interior of earth. The explosive theory was also proposed by Newton`s Optics (1718).
- In France the world was considered a good place in which everything that happened was viewed to be “for the best” and earthquake was considered with optimism. Voltaire in his novel Candide presented a hard attack to this optimistic view point. Also Kant and Rosseau defended the optimist position

Pre-Historic Period

Pre-Historic (before 1940)–This period was characterized by the development of historical earthquakes and Paleoseismicity, the use of empirical methods, the knowledge was primary and parcelled. The measurement of the destructiveness of the earthquake was based in human reaction and observed damage and use of Mercalli scale. Investigation of the earthquake induced damage due to Great San Francisco earthquake (1906) was performed by Sano (1916). For the assessment of seismic behavior of embankments dams Mononobe & Matsuo (1929) and Okabe (1924) methods were proposed.

Classic Period (1940-1983)

Attempt to organize as scientific discipline, records of typical earthquakes e.g. El-Centro earthquake (1940), the use of magnitude for the physical measure of size of the earthquake and several scales based on the amplitude of seismograph records. After Niigata and Alaska earthquakes in 1964 the first studies of liquefaction evaluation of sands and silty sands came out. Use of geophysical tests namely refraction tests, up-hole and downhole tests. Use of laboratory cyclic tests namely reasonant column tests, simple shear tests and triaxial tests for soil behavior and definition of shear modulus and damping ratio. Developments of pseudo-static methods for embankments (Ambraseys, 1960) and simplified methods for assessment of displacements (Newmark, 1965, Sarma, 1975, Makdisi and Seed, 1977). Implementation of codes in total stress SHAKE in 1971 and QUAD 4 in 1974.

Modern Period (1983-1995)

Definition of seismic action using strong ground motions parameters PGA, PGV and PGD, response spectra and use of deterministic and probabilistic methods. Development of laboratory and field tests with more automation in operation, use of seismic arrays and SASW. Use of physical models e.g. shaking table, reaction walls, centrifuge tests, calibration chambers and prototype tests. Proposals for liquefaction assessment of dam materials were presented. Developments of mathematical models for dynamic analysis and codes in effective stress using plasticity models e.g. DIANA, DYNAFLOW, TARA among others. First stage of development of codes and standards. Lessons from Mexico earthquake (1985), Loma Prieta earthquake (1989) and Northridge earthquake (1994) were taken into account.

Actual Period (after 1995)

Implementation of cyclic triaxial tests and torsional shear tests. Combination of laboratory and field tests to assess design parameters. Development of more realistic coupled models, using boundary elements and discrete elements, incorporating non linear behavior, ageing, thermal effects and 3D analyses.
Verification, calibration and validation of computer codes (ICOLD, 1993). Prediction of residual strength and allowable deformation of soils exploring aerial photographs. Implementation of instrumentation and monitoring to assess seismic behavior of structures. Great emphasis on diffusion of knowledge by journal, conferences, codes of practice and development of networks. Use of case histories for a better understanding of seismic behavior of embankment dams and calibration of predictions. Developments of techniques for remediation and rehabilitation of embankment dams.

Selection of Design Earthquakes

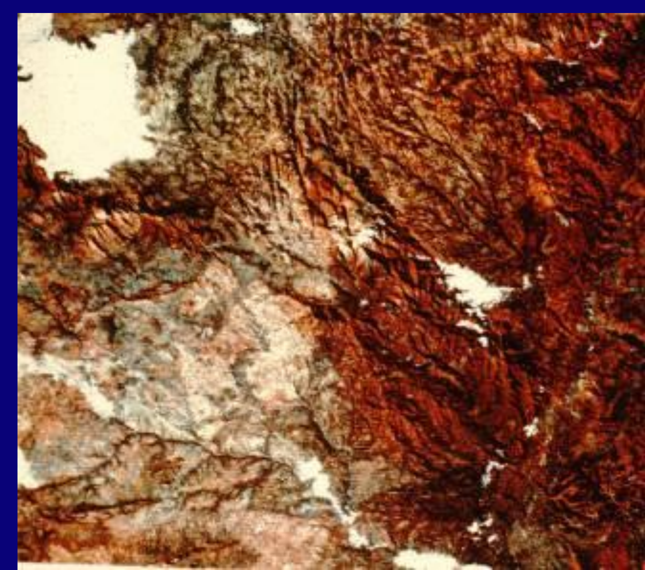
The regional geologic study area should cover, as a minimum, a 100 km radius around the site, but should be extended to 300 km to include any major fault or specific attenuation laws.

2 levels for seismic activity, namely MCE (Maximum Credible Earthquake) considering a return period of 500-1000 years and DBE (Design Basis Earthquake) for a return period of 145 years, with a probability of exceeding in 100 years less than 50%, were proposed by ICOLD(1989).

We can not control the natural hazards
but we can minimize the consequences
We should refuse the fate
Nicolau Maquiavel
(1469-1527)
Great political thinker

TECTONIC CONDITIONS

- Following (ICOLD, 1998) an active fault is a fault, reasonably identified and located, known to have produced historical fault movements or showing geologic evidence of Holocene (11 000 years) displacements
- Surface fault breaking i.e. surface slip along an identified fault zone under the dam is considered as the most dangerous tectonic scenario for dam safety.
- Following Sherard et al. (1974) a concrete dam on active faults or near major active faults is not advisable and if a site with fault movements can not be avoided it is recommended to build an embankment dam



Potentially Liquefiable Soils

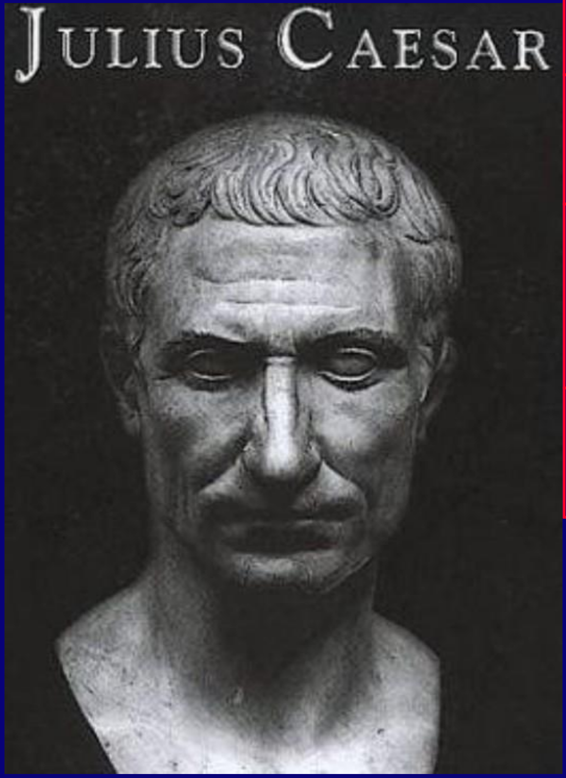
- The new proposals integrate: (i) data of recent earthquakes; (ii) corrections due to the existence of fines; (iii) experience related with a better interpretation of SPT test; (iv) local effects; (v) cases histories related to more than 200 earthquakes; and (vi) Bayesian theory.

- The remedial measures against liquefaction can be classified in two categories (TC4 ISSMGE, 2001; INA, 2001): (i) the prevention of liquefaction; and (ii) the reduction of damage to facilities due to liquefaction.

Performance Basis Design

Table 1. Acceptable level of damage in performance based design

Acceptable level of damage	Structural	Operational
Degree I: Serviceable	Minor or no damage	Little or no loss of serviceability
Degree II. Repairable	Controlled damage	Short term loss of serviceability
Degree III: Near Collapse	Extensive damage in near collapse	Long term or complete loss of serviceability
Degree IV: Collapse	Complete loss of structure	Complete loss of serviceability

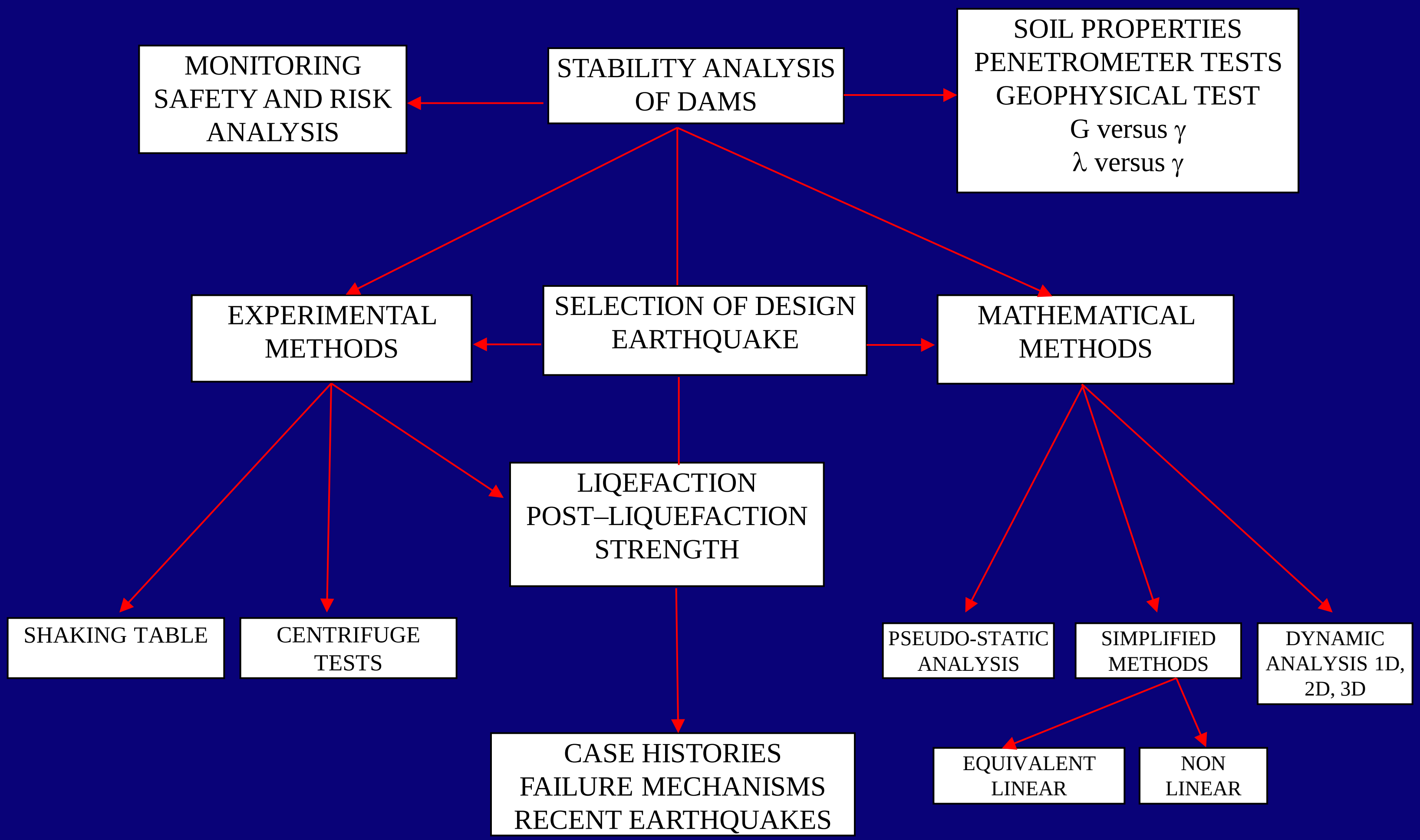


Julius Caesar made a crucial decision crossing the Rubican with the army

ANALYSIS OF DAMS STABILITY DURING EARTHQUAKES

- EXPERIMENTAL MODELS
  - SHAKING TABLE
  - CENTRIFUGE TESTS
- MATHEMATICAL MODELS
  - PSEUDO –STATIC ANALYSES
  - SIMPLIFIED PROCEDURES TO ASSESS DEFORMATIONS
  - DYNAMIC ANALYSIS

Flowchart for embankment dams



RESERVOIR INDUCED SEISMICITY

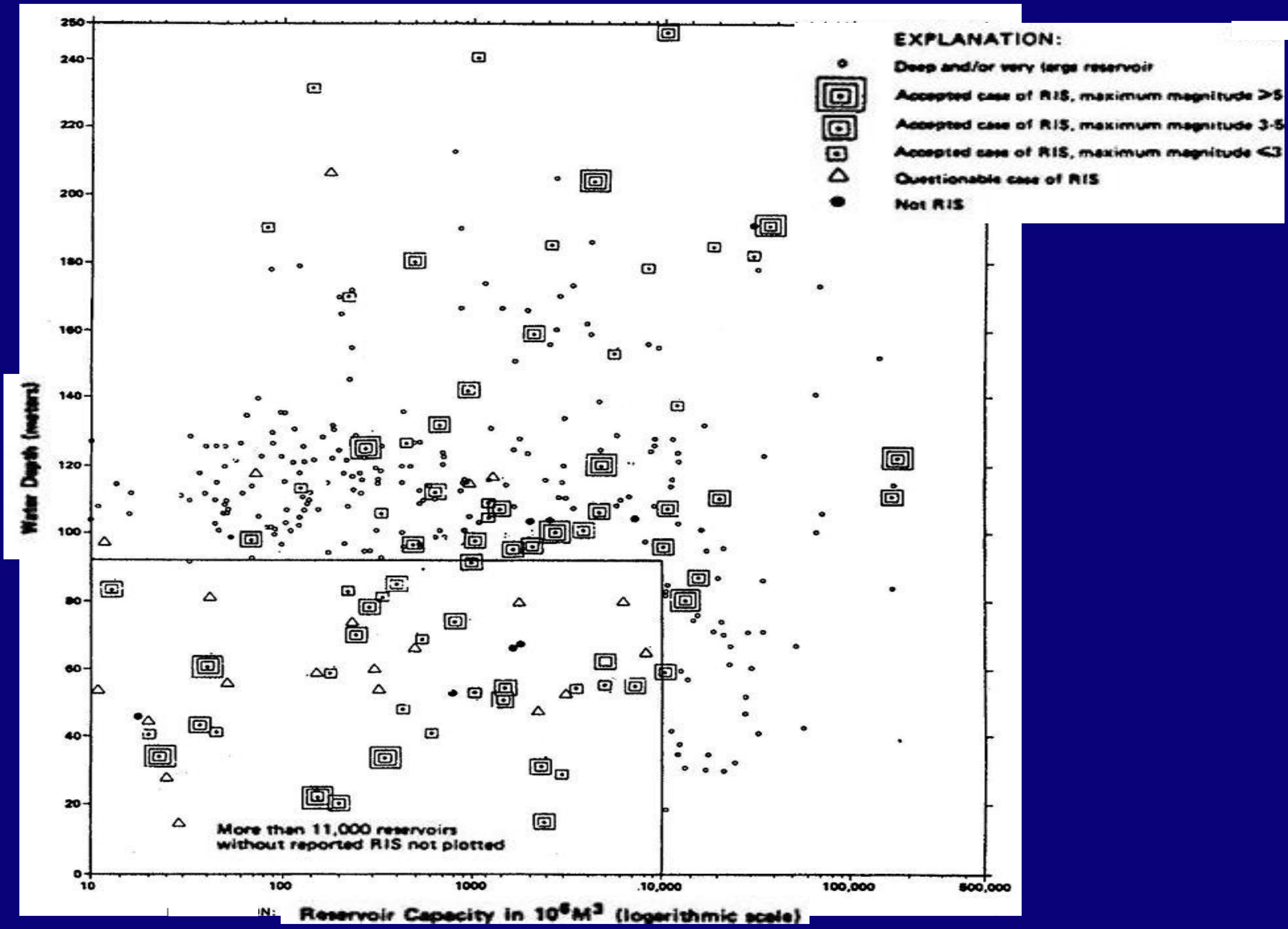
- DAMS HIGHER 100 m
- LARGE RESERVOIRS GREATER THAN 500×10^6 m^3
- HISTORICAL SEISMICITY AND SURVEYS OF GEOLOGICAL STRUCTURES
- INSTALATION OF A PERMANENT NETWORK

The good fortune which the valiant Don Quixote had in the terrible and undreamt adventure

Table 3 Examples of dams with induced seismicity

DAM	Country	Type	Height (m)	Reservoir volume (x 10^6 m^3)	Year of impounding	Induced seismicity		Prior seismicity
						M	year	
Marathon	Greece	gravity	63	41	1930	5	1938	moderate
Hoover	U.S.A.	arch-gravity	221	36703	1936	5	1939	---
Kariba	Zimbabwe/ Zambia	arch	128	160368	1959	5,8	1963	low
Haifengkiang	China	buttress	105	10500	1959	6,1	1962	aseismic
Koyna	Índia	gravity	103	2708	1964	6,5	1967	low
Kremasta	Greece	embankment	165	4750	1965	6,3	1966	moderate
Roi Constantine	Greece	embankment	96	1000	1969	6,3		moderate
Oroville	U.S.A.	embankment	236	4298	1967	5,7	1975	moderate
Nurek	Tajikistan	embankment	330	11000	1972	5	1977	moderate
Tarbella	Pakistan	embankment	143	14300	1974	5,8	1996	low
Aswan	Egypt	embankment	111	163000	1974	5.3	1981	aseismic

Scattergraph of RTS cases (after USSD, 1997)



MONITORING AND INSPECTIONS

- POTENTIAL RISK DEPENDS ON STORAGE CAPACITY, HEIGHT OF THE DAM, DOWNSTREAM DAMAGE AND EVACUATION REQUIREMENTS

- SEISMIC DOWNHOLE ARRAY DATA PROVIDE SOURCE OF INFORMATION

MONITORING AND INSPECTIONS

- REGULAR MEASUREMENTS USING INSTRUMENTATION

- DATA VALIDATION
- DATA STORAGE
- VISUAL INSPECTIONS
- SAFETY EVALUATION
- CORRECTIVE ACTIONS

Sisyphus punished by the Gods cursed to roll a huge boulder up a hill.
We should avoid that our master piece could be destroyed by a failure

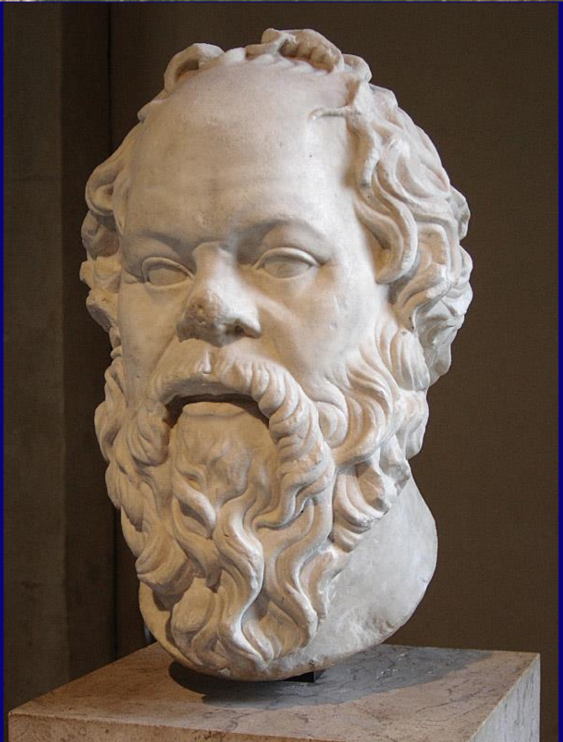
VISUAL INSPECTIONS

- INSPECTIONS BEFORE THE FIRST FILLING
- INSPECTIONS AFTER THE FIRST FILLING
- INSPECTIONS AFTER EXCEPTIONAL OCCURRENCES
- DURING INSPECTIONS THE FOLLOWING ASPECTS DESERVE ATTENTION: DAM BODY, SPILLWAY, OUTLET WORKS, RESERVOIR AND ACCESS ROAD

AGEING EFFECTS

- AGEING IS A CLASS OF DETERIORATION ASSOCIATED WITH TIME
- THE METHODS USED ARE INSPECTION, TESTING AND MONITORING
- THE PROGRESS IN SAFETY OF DAMS IS DUE TO THE IMPROVEMENTS OF DESIGN AND CONSTRUCTION

Socrates has evoked the swan song and stressed that considering our work a creation of our last action is very important



REHABILITATION OF DAMS

• DAM DETERIORATION RELATED WITH SETTLEMENT OF FILL OR FOUNDATION , POOR CONCRETE AND SHRINKAGE CRACKS

• DANGERS TO GEOMEMBRANES ARE DUE FALLING ROCK, BLOWS FROM HEAVY FLOATING OBJECTS, ULTRAVIOLET RADIATIONS AND WILLFUL DAMAGE

Montaigne stressed that we have the duty to preserve our heritage and our knowledge

RISK ANALYSES

- TO IDENTIFY REAL RISKS ASSOCIATED WITH TYPE AND HEIGHT OF DAM
- THREE QUESTIONS: WHAT CAN GO WRONG? HOW LIKELY IS IT? WHAT DAMAGE WILL IT DO?
- RISK ANALYSIS TO GUIDE FUTURE INVESTIGATIONS TO MAKE DECISIONS ON DAM SAFETY
- DISCUSSIONS RELATED FAILURE MODES AND EFFECTS ANALYSIS(FMEA) , FAILURE MODE, EFFECTS AND CRITICALLY ANALYSIS (FMECA), EVENT TRESS ANALYSIS (ETA), FAULT TREE ANALYSIS (FTA)

Fig. 31 – Framework for risk management (after Ho et al, 2000)

RISK ANALYSES

Icarus wax Wings conceived by Daedalus

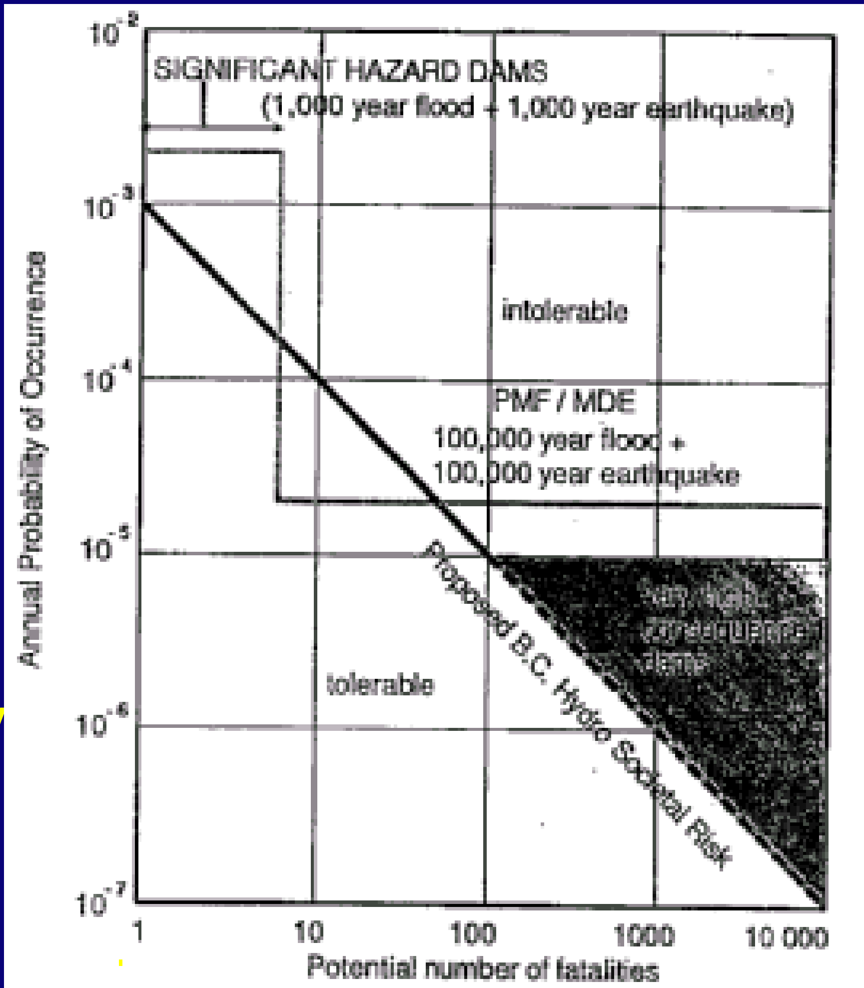


Fig. 32-Incremental hazard criteria (after Salmon and Hartford, 1995b)

RISK ANALYSIS

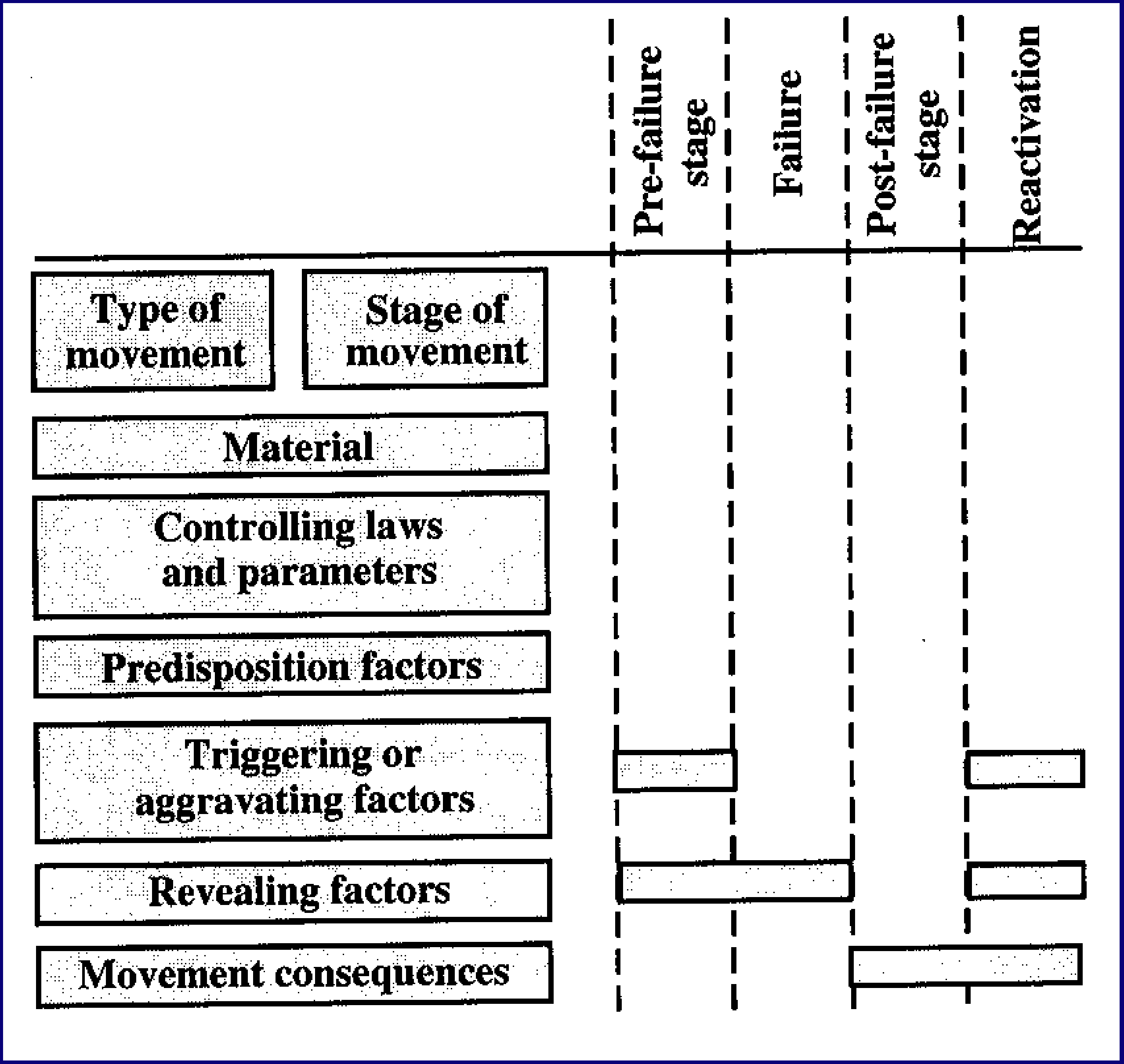


Fig. 34 Possible avenues for warning systems

RISK ANALYSIS

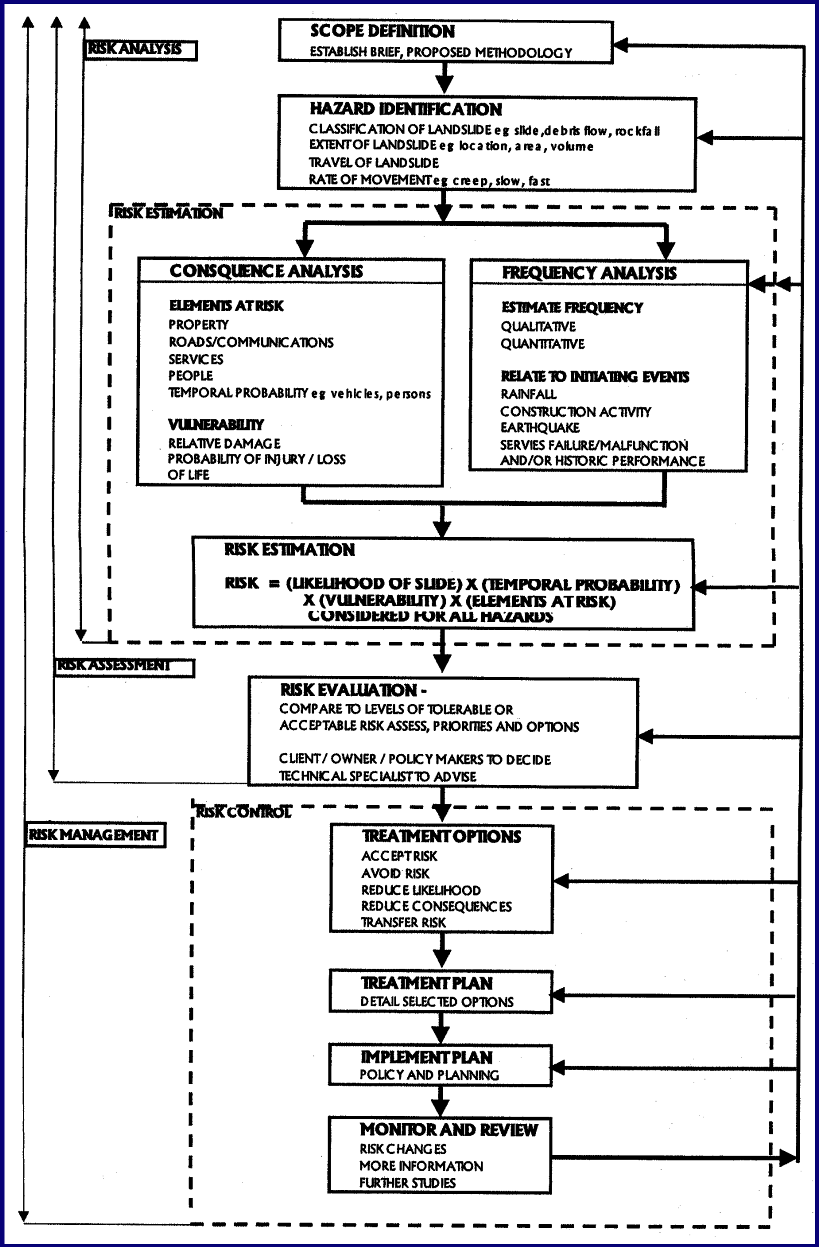


Fig. 35. Risk analysis proposed by AGS (2000)

BENEFITS AND CONCERNS OF DAMS

- PREDOMINANT CONCERN ABOUT RESERVOIRS IS RESETTLEMENT
- BENEFITS OF DAMS WITH THE MULTIPURPOSE USES
- SOCIAL, POLITICAL AND ENVIRONMENTAL CONSEQUENCES ARE IMPORTANT

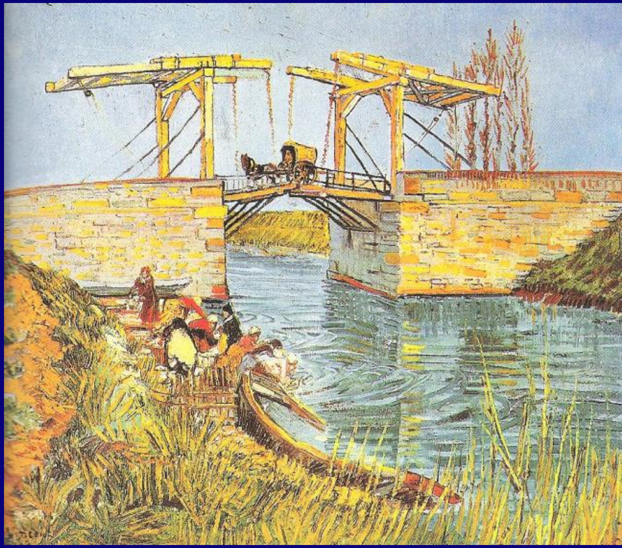
- Ulisses hero of Homero poem has appointed the responsability of Man in chosen his own Destiny

NEW CHALLENGES

- Coupled models with non linear analyses and pore water pressure generation and dissipation models
- Hydrodynamic effects of reservoir associated with dynamic foundation-structure interaction
- Failure of tailing dams that currently reach more than 200m high and reservoirs with more than one billion tons of slimes due to the occurrence of liquefaction and the increase of the resistance due to ageing effects of the deposits.

FINAL REMARKS

- **All the essential steps of good analyses, shall be performed with a sufficient degree of accuracy that the overall results can be extremely useful in guiding the engineer in the final assessment of the static and seismic stability of embankment dams. This final assessment is not made by numerical results, but shall be made by experienced engineers who are familiar with the difficulties in defining the design earthquake and the material characteristics, who are familiar with the strengths and limitations of analytical procedures, and who have the necessary experience gained from studies of past performance**



Langlois bridge – Van Gogh 1888

FINAL REMARKS

- To progress and to reach our goals we need leadership, development of news strategies, capacity and perseverance to fight against conservative practices, implementation of innovative solutions and courage to put in practice new policies

Searching for the Fourth Dimension – Salvador Dali 1979

LESSONS FOR TOMORROW

1. Further discussion in recent codes related performance based design and allowable displacements for the 2 levels of seismic action.

2. Vulnerability is associated with the degree of loss or the potential loss and integrates the range of opportunities that people face in recovery. Resilience is a measure of the system`s capacity to absorb recover from a hazardous event

LESSONS FOR TOMORROW

3. The recognition of a better planning, early warning, quality of evacuation for extreme events. Plato (428-348 BC) in the Timaeus stressed that destructive events that happened in the past can happen again, and for prevention and protection we should followed Egyptians example and preserve the knowledge through the writing.

4. The none recognition for the engineers work is lacking since the past, e.g. the Egyptian King Cheops has his name linked with the great pyramid, a master piece engineer work, but the history does not record the name of the engineer.

5. Interaction with the Owners, Decision Makers, Society and General Public and to explain that the concern for man and fate has been always the core interest of the engineer profession.

6. The engineers should have competence, devotion and honesty.

7. The Engineers should enjoy the activities during the day, but only by performing those that will allow to sleep at the night.

LESSONS FOR TOMORROW

8. Contribution of Voltaire and the book Candide published in 1759, after the Lisbon earthquake (1755), for the change from the intellectual optimism and potential fatalism that is a necessary condition for the construction of future scenarios in a reliability and risk analysis context.

9. It is important to narrow the gap between the university education and the professional practice, and remember that Theory without Practice is a Waste, but Practice without Theory is a Trap. Kant has stated that *Nothing better that a good theory,* but following Seneca *Long is the way through the courses, but short through the example.*

10. 7 Pillars of Engineering Wisdom: Precedents, Practice, Principles, Prudence, Perspicacity, Professionalism and Prediction.

HIPPOCRATES

"The art is long
and life is short
experience is fallacious
and decision is difficult"