DEVELOPING HIGH ARCH DAMS – A COMPREHENSIVE EXPERIENCE

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A decade (and more...) of high arch dam projects *)

*) In engineers' teams, joint ventures, etc.

- LARGE DAMS PROJECTS ARE COMPLEX . . .
  . . . AND REQUIRE THE RIGHT BALANCE

- A BRIEF TECHNICAL REFLEXION

- EXAMPLES

Bakhtyari	Iran	315 m	Preliminary studies
Luzzone	Switzerland	225 m	Heightening
Deriner	Turkey	253 m	Design-Implementation
Karun IV	Iran	230 m	Construction
Inguri	Georgia	272 m	Rehabilitation

- CONCLUSIVE REMARK

LARGE DAMS PROJECTS ARE COMPLEX . . .

. . . AND REQUIRE THE RIGHT BALANCE

They require or imply :

- Technique / SAFETY requirements
- Material availability
- Environmental impact
- Social acceptance
- Economic / financial soundness
- Legal compatibility
- Contractual aspects
- Political support
- Diplomatic stategy
- Operational quality
- Etc., etc.

A few selected fields :

APPROACH
Participative / Extraneous

PROFESSIONALS
Specialists / All-rounders

METHODS
Traditional / High tech

WORK PROGRESS
Straighforward / Feedback

IMPLEMENTATION
Steady quality / Peak performance

PROFITABILITY
Short term / Long range

Etc., etc.

è è è But no balance with the safety ! ! !

A BRIEF TECHNICAL REFLEXION

- Key elements for high arch dams: dependability of foundations, quality of rock / seismicity

- Three information sources :
  - direct, limited — reconnaissance (core drillings, tests, etc.)
  - direct, effective — *in situ* observations (excavations)
  - indirect — dam monitoring (operation)

- Straighforward approach (design → construction, without feedback) not optimal for high arch dams

- Importance of relying on :
  - a dependable archiving system for reconnaissance findings, tests, measurements, dam monitoring data
  - a longitudinal continuity → core team who masters the whole project chain, from feasibility studies to construction

PRELIMINARY STUDIES – Bakhtyari (Iran) 315 m

Studies, design

Storage = 4’900 mio m^3

To be commissioned in ~2018

Will be the highest arch dam in the world

Dam, geotechnics, roc mechanics, hydraulic structures, hydrology, water resources

† Importance of early & correct setting of switches

- Rapidly recognize the criticallity of key issues
- Make the right choice through hundreds of possibilities

† Certitude vs. flexibility

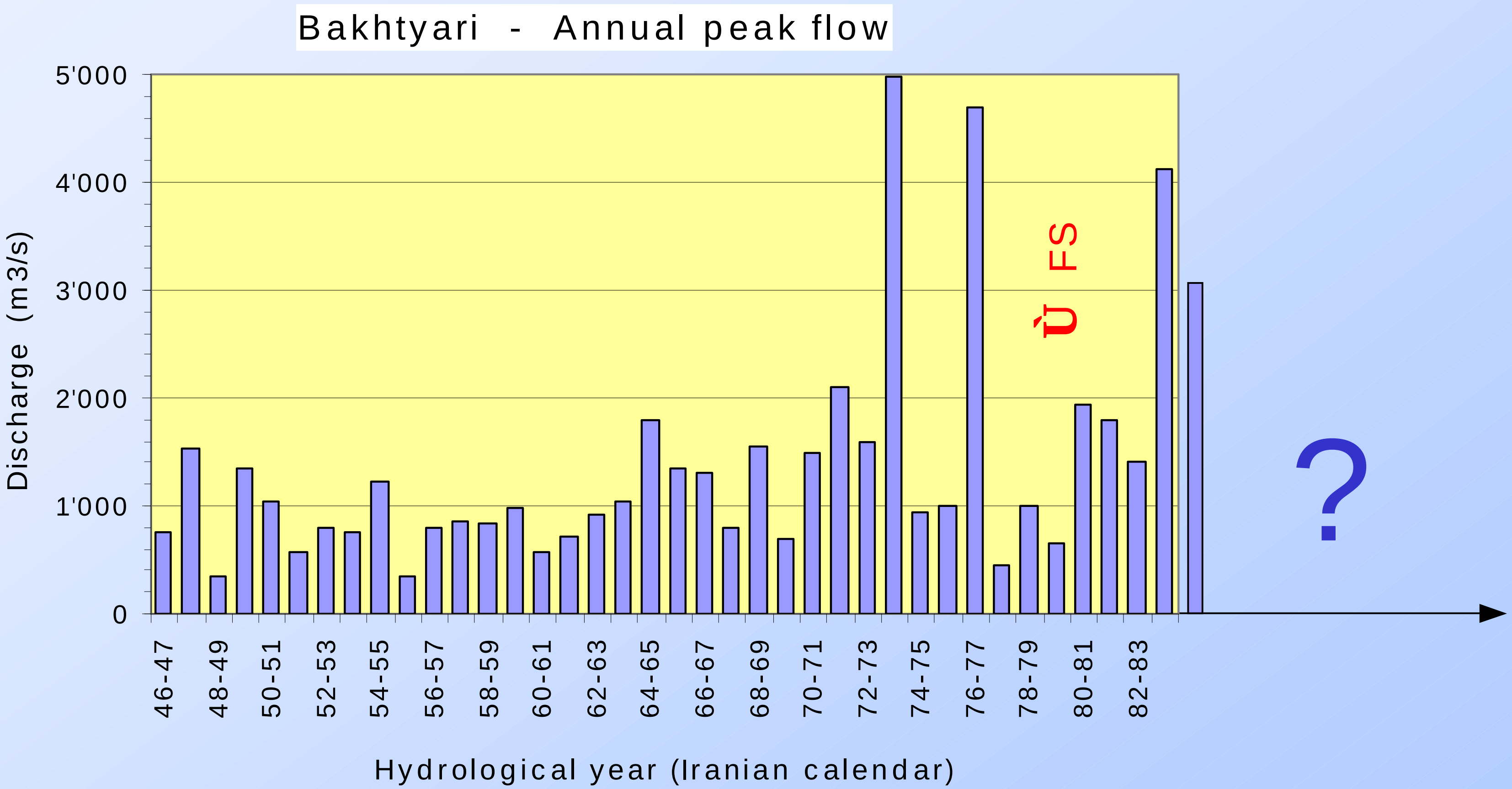
- Make relevant decisions out of sometimes fuzzy information
- Put everyhing together, but be ready to change rapidly

† Necessity of relying on very experienced professionals

- Strong and independent minds, but . . .
- . . . ready to compromise for an overall better solution !

Ø *Example*

Design of diversion system **è** *need to have correct update, validation and interpretation of data of major hydrological events*


Bakhtyari - Annual peak flow
5'000
4'000
3'000
2'000
1'000
0
Discharge (m3/s)
46-47
48-49
50-51
52-53
54-55
56-57
58-59
60-61
62-63
64-65
66-67
68-69
70-71
72-73
74-75
76-77
78-79
80-81
82-83
Hydrological year (Iranian calendar)
?

HEIGHTENING – Luzzone (Switzerland) 225 m

Design, supervision

Storage = 108 mio m^3

Commissioned in 1963

Heightening by 17 m after 35 year of operation (1998)

Design & construction supervision

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† Importance of proper archiving

- Design documents, basic data and as-built drawings
- Dam monitoring and dam behaviour records

† Necessity of using proper conceptual tools

- Differential material properties and behaviour
- Dam monitoring data for calibration of calculation model

† Additional constraints with respect to initial construction

- Continuity of operation has highest priority
- Construction site no more fully available

Ø *Example*

Unfavourable geometry of left bank **è** *development of an artificial buttress to adequately channel additional forces*

DESIGN - IMPLEMENTATION – Deriner (Turkey) 253 m

Contractor Advisor

Storage = 1’970 mio m^3

Commissioning planned for ~2011

Final design & implementation

† Interactions between design and implementation

- Take construction findings into account to amend design
- Useful to have the same specialists in both project phases

† A blend of complementary qualities

- Rely on a strong theoretical background (design)
- Have a deep sensitivity to all practical aspects (construction)

† Highly important: ensuring team continuity

- Integrate young engineers at early stage of project
- Keep retired specialists as back office advisors / experts

Ø *Example*

During excavations, problem of slope stability **è** *rapid design of additional anchoring through use of self-developed software*

CONSTRUCTION – Karun IV (Iran) 230 m

Contractor Advisor

Storage = 2'190 mio m^3

Will be commissioned in ~2012

Implementation

† Practical reality prevails over theory

- Design confronted with the pitiless reality
- Translate design concepts into operational decisions

† Position of the Engineer

- Between Owner, Designer, Contractor, Manufacturer, others
- Bridge between cultures, relation network with suppliers

† Some required key qualities

- Good technical knowledge & excellent field experience
- Sharp sense of anticipation & flair for improvisation

Ø *Example*

In summer, T > 50 °C **è** *conception of an economic, efficient and reliable cooling system for materials (two-step cooling)*

REHABILITATION – Enguri (Georgia) 272 m

Design, supervision

Storage = 1’200 mio m^3

Commissioned in 1987

Currently the tallest arch dam in the world

Provides 50% of country energy

Dam monitoring / Gates / Drainage system / Grout curtain

- Guarantee a good archiving system, otherwise . . .
  - Unearth new information during study by "serendipity"
  - Quickly adapt rehabilitation philosophy to new conditions
- Main challenges set to intervention team
  - Ability to prioritize, capacity to revise project in real time
  - Rigorous coordination rehabilitation works / operation
- Main requirements set to the Engineer
  - Technical and organizational qualities required
  - Contractor selection, flexible procurement & financing

Example

Emptying the head race tunnel for months **→** *flawless coordination between operation & rehabilitation activities*

CONCLUSIVE REMARK

It appears that practitionners' *know-how*, not commodities, is the special ingredient that leads to well-designed, well-equipped, and well-constructed projects.

C. Vansant, HRW, September 2006