Acta Technica Napocensis: Civil Engineering & Architecture Vol. 55 No. 2 (2012)

Journal homepage: http://constructii.utcluj.ro/ActaCivilEng

Safety and Risk in Exploatation of Hydro Technical Structures

Florin Trofin[1]

[1]*Military Technical Academy, George Coșbuc 81-83 Boulevard,050141, Bucharest- Romania*

Received 12 March 2012; Accepted 10 September 2012

Abstract

Hydrotechnical structures are large - scale works which engage large volumes of investment and labor. Risk and safe operation of these structures are the defining elements to be working continually. Dams, hydrotechnical structures in general, are now subject to strict control in terms of security conditions. Execution techniques evolution, using better building materials, supervising the structure during working time, all these are leading to a higher security level of these structures. This manuscript presents the hydrotechnical structures settlement's of new safety - risk correlation during the working time, including measures should be taken to increase their safety.

Rezumat

Construcţiile hidrotehnice sunt lucrări de mare anvergură, care angrenează mari investiţii financiare şi volume de forţă de muncă. Riscul şi siguranţa în exploatare al acestor structuri sunt elemente definitorii care trebuie să preocupe în permanenţă activitatea specialiştilor din domeniu. Barajele, construcţiile hidrotehnice în general, fac astăzi obiectul unui control riguros din punct de vedere a respectării condiţiilor de securitate. Evoluţia tehnicilor de execuţie, folosirea de materiale de construcţie mai performante, supravegherea construcţiei în exploatare, conduc la ridicarea gradului de siguranţă a construcţiilor. Manuscrisul prezintă soluţionări noi ale relaţiei siguranţă-risc în exploatarea construcţiilor hidrotehnice respectiv măsuri care trebuie adoptate în vederea creşterii siguranţei acestora.

Keywords: probability of dam failure, seismic risk, water reservoir , probabilistic approach, minimal investment cost.

1. Introduction

According to The American Heritage Dictionary of the English Language, 1978 "Engineering is the application of scientific principles for practical purposes such as design, construction and operation of structures, equipment and systems for efficient and economical" [6].

Using scientific and practical knowledge, any professional engineer in the field, can design and achieve both high quality products with relatively high costs and products less secure, less reliable and / or less efficient, the immediate advantage of low costs [1]. In case hydro technical constructions, whose operational risks in all aspects, may have important social consequences (e.g., damage caused by disasters, poor quality water services, etc.), it is imperative to take decisions on the basis of criteria reflect the national interest or, at least regional.

2. Aspects regarding the safety of hydrotechnical structures in operation

According to a statistical study, following the failure of large dams in the period 1950 - 1990, there were over 5,000 worldwide deaths and property damage of about one billion dollars. Only in the U.S., between 1890 -1965, the destruction of 20 dams caused a number of 2802 victims.

However, casualties, according to data from Table 1, are lower compared to that resulting from other disasters; psychological impact on people is high level because of these kinds of events.
Table 1 showed a population loss of life resulting from the breaking of dams.

Table 1

Dam denomination	Location	Year of breaking the dam	Height of the dam (m)	Loss of life (Number of victims)
Puentes Viejas	Spain	1802	50.0	680
Kuala Lumpur	Malaysia	1861	45.4	600
Iruka	Japan	1868	28.0	1200
South Fork	U.S.A.	1889	21.9	2142
Bouzey	France	1895	23.0	156
Austin	U.S.A.	1911	15.0	100
Gleno	Italy	1923	52.0	600
Saint Francis	U.S.A.	1928	63.4	400
Mohne	Germany	1943	40.3	1200
Quebrada la Chapa	Columbia	1953	47.8	250
Malpasset	France	1959	66.5	421
Vega de Terra	Spain	1959	34.0	144
Oros	Brasil	1960	54.0	50
Babii Iar	U.S.S.R.	1961	44.5	145
Hioriki	South Korea	1961	50.6	250
Vajont	Italy	1963	265.5	1994
Breadfield	England	1964	30.0	238
Sempor	Indonesia	1967	53.6	200

Hydrotechnical construction works whose design must take into consideration the concept of safety and low budget dualism. Thus, If is an attempt to increasing the investment budget, accepting a risk of dam failure, then the safety of construction decreases, and vice versa. Raising the level of safety construction, with intent to reduce operational risk, can generate oversize of the building, an increase the volume of material and labor consumption, with effect increase investment budget.

Studies on construction of buildings, are largely confined to a considerable economic and timely information they provide is often limited, requiring extrapolation more or less correct. Increased investments beyond certain limits lead to a nonlinear raising of the construction safety. Investment budget increases asymptotically in relation to the safety coefficient.

The projects developed to the present are the result of the specialists work, the solutions adopted resulting from comparing costs, socio-economic advantages and potential damages accepted in accordance with international standards and domestic legislation, aimed to achieving the optimum efficiency in a certain degree of safety and risk accepted. In some cases, working standards require the introduction of conventions or their interpretations, due to difficulties in determining the characteristics of certain parts of the structure, especially foundations. In other cases, due to technical developments, builders may interfere with the settlement's new safety - risk relationship.

Examples of settlement outside the framework decision are the concrete arched dams Tolla - France, with 90 meters height and 1.85 meters thick canopy based on the master section, Gage - France, with 41 meters height and 2.57 meters thick canopy master section and Idbar - Bosnia - Herzegovina, with 38 meters height and 4.20 meters thick canopy master section [7].
For the design, specialists have accepted a higher risk, with purpose of testing this type of dam, pushing the resistance of concrete to the limits. Lately, were used probabilistic approaches of hydrotechnical construction safety, with a more accurate representation of reality, covering all cases could lead to its failure.

The water level changes from storage lake, fluctuation of temperature on site, the drainage system to reduce underpressure, poor execution of sealing veil, changes in mechanical properties of foundation soil, deterioration in time of technical proprieties of materials or aging phenomena, are parameters that influence the stability of the construction [3].

Combining these parameters, result efforts of stability and instability, defined by Br (x) and Fs (x) parameters, fr (x) density parameters and fs (x) probability parameter, in which "x" is a variable representing the intensity of efforts (R) and instabilitity (S), during the construction failure. These parameters are characterized by average values R_0 and S_0. The distribution parameters are represented graphically as in Fig. 1. The shaded area represent the zone of instability, with risk of construction failure, and calculated with the following convolution integral:

$$P_c = P(S > R) = \int_0^{\infty} F_S(x) \cdot f_R(x)dx - \int_0^{\infty} f_S(x) \cdot F_R(x)dx$$

The major issue comes from the definition of the parameters F (x) and f (x). If we have determined the parameters of distribution, density and probability, then we can calculate the probability of the construction failure [4].

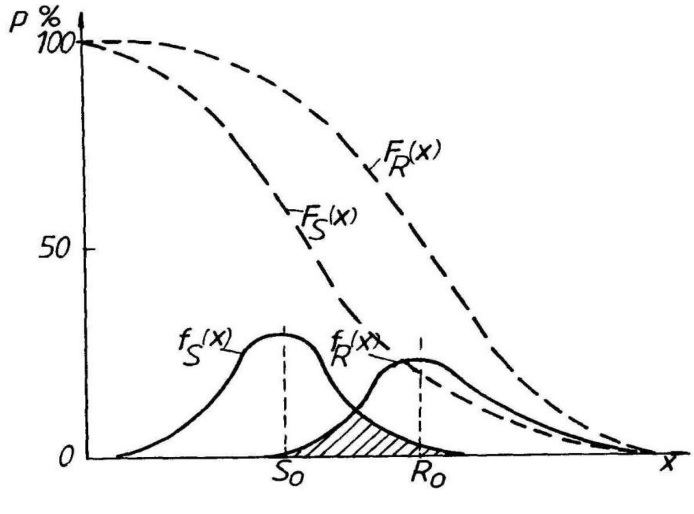

Fig. 1. Graphical representation of the probability of failure construction.

In 1982 year, Seraphim J.L. and Valadares T.L. presented a formula for calculating the probability of failure for "K" cascade dams, as follows:

$$P(k) = \exp\{-\alpha[\sum_{j=0}^{k-1} p^j \cdot l(k-j)]\}$$

$\alpha -$ constant

Where p^j represents the probability of dam failure j and l (k) is a loss coefficient generated by dam failure. Fig. 3 presents the probabilities of dam failure, as percentage, calculated with same formula.

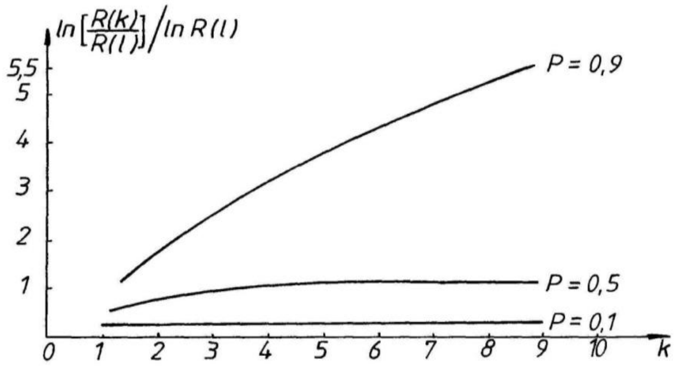

Fig. 3 Probabilities of cascade dam failure (%)

Another formula expresses the number of dam failures during the decade "i" according with the number of dams built in the decade "i" and the probability of failure P (i, j), of the dam aged "j", also expressed in decades:

$$F_{i_j} = N_{i_1} \cdot P_{i_1}(0) \qquad \text{For } i_1=1$$

$$F_{i_j} = N_{i_1} \cdot P_{i1}(0) + \{\sum_{i=1}^{i1-1} N_i \cdot P_i(i_1 - i) \cdot [\prod_{k=0}^{i_1-i-1}(1-P_i(k))]\} \qquad \text{For } i_1>1$$

N (i) = number of dams built in the decade "i" and F (i) = number of dam failures from the decade "i". These formulas are used to calculate the probability of dam failure, expressed as a percentage. The values of these percentages are shown in Table 2

Table 2

$P_i(j)$ cu i=1,… ,7; j=0,…6(%)

i \ j	0	1	2	3	4	5	6
1	2.43	0.38	0.58	0.39	0.39	0.20	0.20
2	1.50	0.24	0.36	0.24	0.24	0.12	0.12
3	0.51	0.08	0.12	0.08	0.08	0.04	-
4	0.22	0.04	0.05	0.03	0.03	-	-
5	0.30	0.04	0.07	0.05	-	-	-
6	0.28	0.04	0.06	-	-	-	-
7	0.17	0.03	-	-	-	-	-

Fig. 4 shows the failure probability, in percentage, from 1910 to1920, using i = 1.

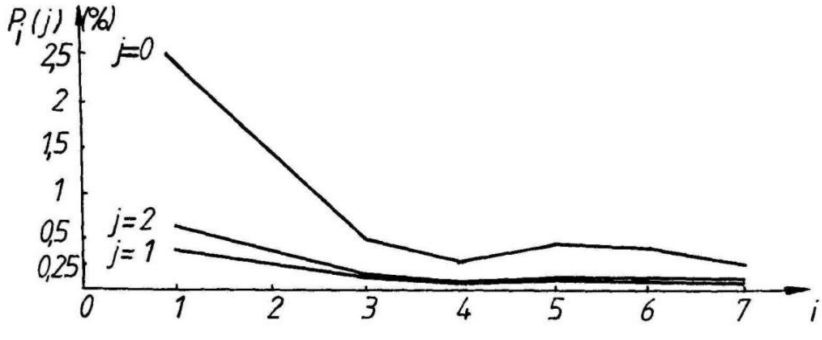

Fig. 4 The probability of failure per decade, (%)

Table 3 shows the results of the study concerning the dam's failure during 1851 to 1971, according to dam's height and the building materials used for dam construction.

Table 3

Results of the study concerning the dam's failure during the years 1851 - 1971

Dam's height (m)	Number of dam failures	Building materials	Number of dam failures
15-30	10	Concrete masonry	4
30-60	4	Local materials	11
>60	1	Others	0

3. Aspects regarding the risk failure of hydraulic construction in operation

The latest statistics of accidents to hydrotechnical structures had levels upward. Technical progress in the field was not led to their decrease. As an example, between 1946 and 1955 were 12 accidents from a total of 2000 dams executed worldwide. The decade 1956 - 1965 was registered only a total of 24 accidents to 2,500 dams worldwide. The percentage growth from 0.60% to 0.96% could be generated by: assuming a higher risk to structure failures, to achieve more economical construction, errors to dam designing or an inadequate management of the hydrotechnical works.

The risk failure of hydrotechnical structures, such as:

- Damage risk to earthquake according with the seismicity of hydrotechnical structure emplacement;
- Seismic risk generated by the earthquakes induced by big reservoirs (for dams with canopy height > 90 meters, and volume of water accumulated more than 100 million m^3);
- Risk of exceeding the capacity of flood discharge, properly sized to accepted certain importance classes (due to high waters under dimension of arresters);
-

A conclusive example would be the waste-way of Euclides da Cunha (Brazil), located on the River Pardo - Sao Paulo State, and sized to a flood flow of 200 m/s. Due to precipitation that exceeded the critical threshold of 230 mm in 24 hours, on 19 January 1977 the flood reached a flow of 3000 m3/s, resulting a dam breach discharge.

Risk assessment by mathematical calculation is required to achieve a rational balance at a certain time, between safety and economy. Traditional methods of calculation are considering the minimum investment cost criteria, as opposed to the probabilistic approaches, where the rule of decision is given by minimizing the overall cost, as follows:

$$C_g = I + \sum_i P_{ci} \cdot C_{pi}$$

Where I = investment, P_{ci} = probability of failure corresponding to mechanism failure and C_{pi} = cost damaging associated with the mechanism of transfer "*i*" [5].

In 1977 I.C.O.L.D. (The International Commission on Large Dams) published a "Report on risks to third parties arising from the realization of large dams". The report finds that over the past 175 years occurred an average of three breaks of dams/year. The risk to third parties ranged from one site to another, depending on population density, nature and extent of downstream industrial and agricultural development.

4. Conclusions

The hydrotechnical construction safety is an important concept which must capture the attention of designers and contractors of such works. For this reason the risk assessment must be made with maximum responsibility and reviewed according to new climate conditions.

Climate change, land seismicity, the sliding slopes, sudden floods, aggressive action of water and other causes related to structure size, are risk factors in the hydrotechnical construction exploitation. Also, the climate change modifies the ratio between these two elements, in the sense of increasing operational risk and decrease the level of safety of the construction.

Increasing the risk and decrease the level of safety of hydrotechnical structures in operation, requires an update of structural design and operating hypotheses and also changes to the regulation during emergency situation.

I conclude it is necessary to increase the monitoring of extreme loads induced by climate change to hydrotechnical structures, such as:

- Changing geological conditions of terrain;
- Changing behavior of hydrotechnical structures to the efforts resulted from operating;
- Increasing the infiltrations flows;
- Changing the conditions to takeover flows downstream of hydrotechnical structures (exceeding the carrying capacity of the riverbed, processes of riverbeds erosion, deterioration of ecosystem because lower water system;
- Dam degradation by structural cracking.
-

5. References

[1] Varduca, A. - *Monitoringul integrat al calităţii apelor, Ingineria resurselor de apă,* Editura H.G.A., Bucureşti 1999;

[2] Ionescu Şt., - *Impactul amenajărilor hidrotehnice asupra mediului,* Editura H.G.A., Bucureşti, 2001;

[3] Bica I., - *Protecţia mediului – politici şi instrumente*, Editura H.G.A., Bucureşti, 2002;

[4] Stănescu, V. - *Măsuri nestructurale de gestiune a inundaţiilor,* Ed. HGA Bucureşti, 2002;

[5] Giurma I., Crăciun I. - *Viituri şi măsuri de apărare,* Editura „Gh.Asachi”, Iaşi, 2003;

[6] ICOLD - *Dams and environmental – water quality and climate,* Bulletin 90, 1993;

[7] ICOLD - *Dams and environmental – geophisical impacts*, Bulletin, 1993;