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Brasília, juin 2009

RISK ANALYSIS OF ODELOUCA COFFERDAM
RESULTS OF AN EVENT TREE ANALYSIS*

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1 INTRODUCTION

The Odelouca dam is located in the South of Portugal. It will be part the Odelouca-Funcho water supply system for the Algarve windward. At the present time in construction phase, Odelouca dam will be the second higher embankment dam in Portugal, with a maximum height of 76 m and net reservoir volume of 157 hm^3. The dam implantation cross section is located near elevation 35 of Odelouca River and dominates a 393 km^2 hydrological basin with an average annual affluent volume of 122.2 hm^3.

The first dam construction contract was signed in October 2001 and suspended at the end of 2003, with several work components partially built. The river diversion system works were, naturally, the first ones to be initiated and constituted, at the suspension date of the contract job, the ones that were at an

* Analyse des risques du batardeau d'Odelouca. Résultats d'une analyse d'arbre d'events

advanced phase of construction or were already concluded. The diversion tunnel and the entrance structure were concluded. The stilling basin was partially executed, as well as the cofferdam, 29 m high, 7.5 m below the crest elevation. The cofferdam embankments would be concluded in 2004, after a contract specifically launched for the purpose. The dam construction was retaken with a new contract in 2007.

Between 2004 and 2007, the Odelouca cofferdam functioned as an isolated work, being a large dam, with a maximum high of 36 m and 19 hm^3 storage capacity referred to the crest elevation. The built hydraulic structures allowed the routing of a flood with 50 years return period and a 0.8 m freeboard. It was a particular case of a temporary structure to be incorporated in the definitive work that, due to the interruption of first contract of dam construction, saw prolonged his life period, including a set of new no anticipated risks.

This paper presents, initially, a general characterization of Odelouca cofferdam and some constructive aspects relevant. The synopsis of dam break results is included, identifying it main consequences. In the following, a risk analysis, using event tree method, is described and the principal obtained results are presented.

2. ASPECTS OF COFFERDAM DESIGN AND CONSTRUCTION

2.1 COFFERDAM LAYOUT AND MAIN CHARACTERISTICS

The Odelouca dam is an embankment zoned dam, with 76 m of maximum height and 2 000 000 m^3 of embankments volume. The exterior slopes have upstream and downstream inclinations of 1:2 (V:H) e 1:2.25 (V:H), respectively above and below 66.5 elevation (cofferdam crest elevation), and, at downstream, of 1:2,25 (V:H) e 1:1,5 (V:H), above and below 46 elevation (downstream rockfill toe elevation). The cross section type integrates a symmetrical central core, of residual schist soils and colluviums materials, and shoulders, essential constituted of schist materials of extensive grain size. Between the core and the downstream shoulder, a chimney filter is inserted. This filter is prolonged in foundation contact, under the shoulder, and has, in the central valley zone, a mix cross section filter-drain-filter. The upstream shoulder incorporates, in second phase, the Odelouca cofferdam embankments, whose total volume ascends to 270 000 m^3.

The cofferdam cross section type is zoned, similar to the dam, but without internal filter/drainage system, as it was not previewed its operation as an isolated work. The cofferdam crest has 8 m of wide and the slopes are inclined at 1:2.25 (V:H), upstream, and 1:1.9 (V:H), downstream. The core crest, with 4 m wide, is located at 65.5 elevation and its slopes have inclinations of 1:0.3 (V:H).

The core construction materials (of the dam and cofferdam) characterized in the design phase, exhibited fines percentages between 40 and 80%, clay percentages between 6 and 15% and plasticity indexes (IP) between 6 and 18%. The normal Proctor tests furnished values of the optimum water content between 14 and 19.5% and maximum dry unit weight between 17.5 and 19 kN/m^3. For the shoulder materials, the obtained results in the design phase corresponded to fines percentages between 15 and 25%, coarse percentages between 40 and 70% and IP between 10 and 15%.

Besides the cofferdam, the provisory diversion works integrate a tunnel with 5 m diameter and 430 m length (for placing, in second phase, the intake and bottom outlet conduits), and a stilling basin by hydraulic jump, downstream. The river diversion works were designed for a flood with a maximum affluent flow of 715 m^3/s (T= 50 years). The correspondent maximum affluent flow is 280 m^3/s and the freeboard (in relation to cofferdam crest elevation) is 0.8 m.

In Figure 1 the general works layout is presented and, in Figure 2, the cross section types of the dam and of the cofferdam.

2.2 SOME CONSTRUCTION ASPECTS

The tender design [1] was adjudicated by INAG to the Necso/Construtora do Tâmega Consortium, in October 2001, start date of the contract job. This would be suspended at the 2003 end, with several work components partially built. The cofferdam embankments would be afterwards concluded, in 2004. The execution phase of the trial embankments and the evaluation of excavation, placement and control procedures were a very long-lasting ones (namely, some of the trial embankments were repeated) and some difficulties were evidenced by the contractor in these questions field.

Observation carried out during the cofferdam embankment execution, some time before the contract Job suspension, at 2003 end, raised some doubts about the quality of the core embankments. During the sheet foot cylinder passages, a distinct “cushion” effect was verified, together with an apparent excess of water and a significant irregularity of layer surface after compaction (Photos 1 and 2). After these observations, the core embankments were object of the investigation works carried out by the Centro de Estudos de Geologia e Geotecnia de Santo André (CEGSA). The prospecting campaign carried out by CEGSA in the core embankment materials allowed to characterize locally a 10 m thickness of embankment. *SPT* test results, namely, between 8 and 11 blows, were obtained. From the consulted control data analysis, one can verified that the used cofferdam core materials are situated, in a general way, in the finer zone of the specified grain size distribution and the used shoulder materials in the coarse zone of respective grain size distribution, accenting the contrast between the core (more deformable and less resistant) and the shoulder (less deformable and more resistant) mechanical behaviour.

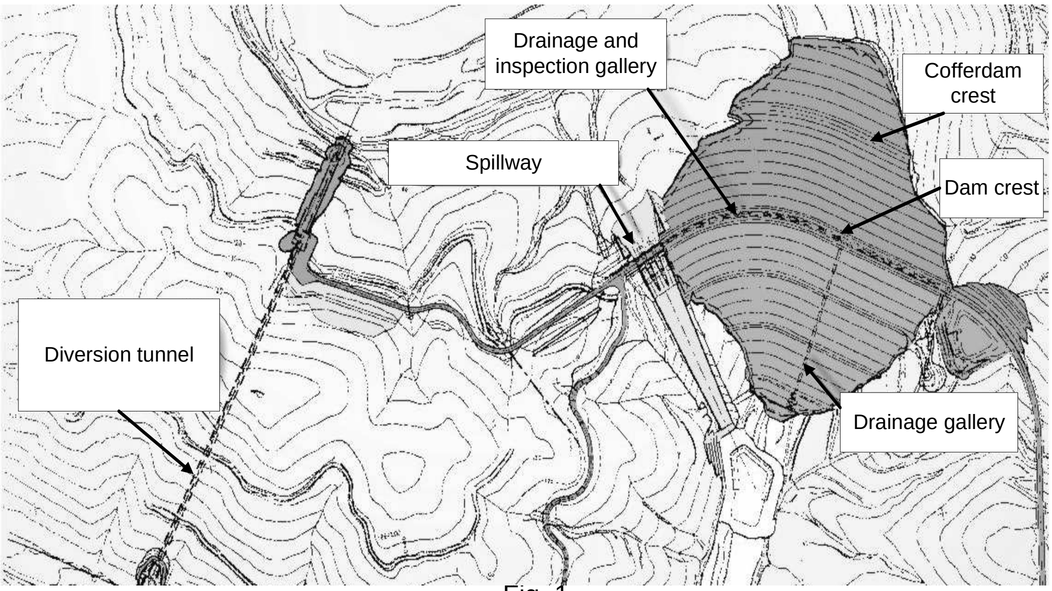


Fig. 1
Odelouca dam layout
Layout du barrage d'ODelouca

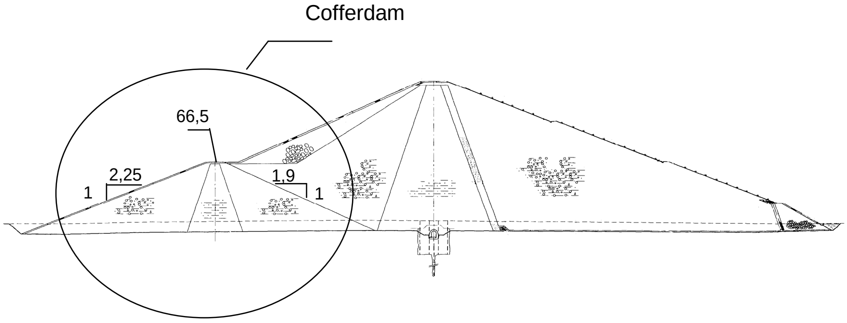


Fig. 2
Odelouca Dam and Cofferdam cross sections
Sections transversaux du barrage e du batardeau d'Odelouca

Photo 1
General view of the cofferdam body [2]
Vue général du corps du batardeau

Photo 2
View of a core layer surface after compaction [2]
Vue de la surface da la couche après compactage

2.3 COFFERDAM EXPECTED QUALITATIVE STRUCTURAL BEHAVIOUR

The available elements of the design and construction phases, complemented with the modelling studies, based some qualitative reflexions about the expect performance of the cofferdam embankments, in comparison with the design estimations, which are discriminated as follows [3]: (i) finer and more plastic core materials; (ii) more compressible and less resistant core embankments; (iii) heterogeneity of the core fills behaviour, induced by a deficient compaction of some layers; (iv) coarser shoulder materials; (v) less deformable and more resistant shoulder embankments; (vi) higher core susceptibility to hydraulic fracturing; (vii) higher core susceptibility to internal erosion; (viii) in reference to the global stability, the higher shear strength of the shoulder materials should compensate the inferior expected strength of the core materials, unless the occurrence of deficient compaction of the shoulder embankments and/or deficient connection to the foundation.

The materialization of hydraulic fracturing and internal erosion of core embankments will depend, naturally, of the water inflows and of the floods periods sustained by the cofferdam. In the other side, due to reduced outflow capacity of the built hydraulic structures, whose objectives were the river deviation and the yard flood routing, the overtopping probability of cofferdam body seemed as potentially important, increasing with the service life period increase (as an isolated work).

3. ASPECTS OF DOWNSTREAM VALLEY AND DAMBREAK CONSEQUENCES

The downstream valley of Odelouca cofferdam has, in the first 5 km, a much reduced occupation. The zone is characterized by disperse habitations, the most of them non residential, and by subsistence agriculture. The valley occupation increases towards downstream. A higher permanent occupation, some artisanal industry and significant important road infrastructures were recognized. About 23.5 km downstream of the dam implantation local there are the confluence of Odelouca River with Arade River, which upstream valley, up to Silves city, exhibits an important and growing occupation. The Arade River segment downstream the confluence that ends in Portimão enlarges substantially, contributing to the routing of flood wave resulting from the dam rupture. Photos 3 and 4 present two views of Odelouca River valley.

Following the works suspension, dam break studies of the Odelouca cofferdam were performed [4]. An external erosion failure mode was adopted in the sequence of overtopping. The trapezoidal breach shape was considered, having the average wide (103 m) and the formation time (0.8 h) being established by Froëhlick [5] equations. The flood wave propagation was calculated by the *BOSSDAMBRK* numerical model along about 33.7 km, distance between the cofferdam implantation local and the mouth (Portimão).

Photo 3
View of downstream near valley (< 5 km) (09/09/2005)
Vue de la vallée en aval prochain (< 5 km) (09/09/2005)

Photo 4
View of downstream valley between 5 and 10 km (09/09/2005).
Vue de la vallée en aval entre 5 and 10 km (09/09/2005)

According the performed studies, the maximum discharged flow near the dam is 10 303 m^3/s and the wave propagates downstream at an average velocity of 1.8 m/s, reaching the 33.7 km after 5.3 h, with a maximum flow of 1065 m^3/s. Table 1 presents a summary of the results. Based on the flood propagation results, the downstream valley consequences were estimates, which are summarized in Table 2.

4. RISK ANALYSIS

4.1 EVENT TREE ANALYSIS

4.1.1 General Considerations

The event tree analysis is a logic method, of the inductive type, which uses the graphic representation of the event sequences.

In the dam's domain, the more current event trees are of the *physical system models* type. The event tree construction is, in this case, sequential, sketched from the left to the right, parting from an initialising event and describing, successively, the event sequences that can occur to the final results, according with cause-effects relations.

First of all, the initialising events to be analysed shell be identified. For each initialising event, different failure modes can be materialized, each one having several success or unsuccessful paths. In some cases, it can be advantageous to perform more than one event tree.

Table 1
Results of dam break studies [4]

Km	River level (m)	Maximum water level (m)	Wave			
			Maximum water height (m)	Maximum flow (m^3/s)	Arrival time (h)	Maximum velocity (m/s)
0.27	34.0	53.08	19.08	10303	0.76	6.83
2.00	30.5	47.70	17.20	9480	0.80	3.70
4.50	27.0	39.18	12.18	7937	0.92	5.52
5.90	25.0	34.31	9.31	7596	1.04	4.17
9.50	17.0	25.54	8.54	6256	1.36	3.59
12.50	13.0	21.97	8.97	4553	1.56	2.70
16.10	10.0	15.34	5.34	3920	1.88	2.19
20.20	7.0	11.34	4.34	2447	2.88	0.99
24.70	3.0	6.01	3.01	1235	3.72	0.97
30.20	-1.0	1.55	2.55	1072	5.17	0.46
33.70	-2.0	1.00	3.00	1065	5.30	0.35

Table 2
Identification of the consequences of Odelouca Cofferdam break

Valley	**Human Loss**		**Economical and financial losses**	**Environmental losses**
	PAR	**PLL**		
Near (< 5 km)	14	7	• 3 habited one family houses • 12 ruin one family houses • macadamized roads • subsistence agriculture	• Protected habitats
Faraway (5 a 33.7 km)	130	31	• 30 inhabited one family houses (Odelouca River) • 20 ruined one family houses (Odelouca River) • 20 inhabited one family houses (Arade River) • NR, MR, macadamized roads • viaducts and disperse infrastructures • subsistence agriculture	• Protected habitats

PAR – People at Risk; PLL – Potential Loss of Life

For quantitative analysis, the probability of occurrence of the initialising event and the probability of occurrence of each event shell be evaluated. The probability of each branch is calculated by the product of the probabilities of the constituent events. The success probability corresponds to the sum of the branch probabilities that culminates in success and the unsuccessful probability to the sum of the branch probabilities that culminates in unsuccessful.

4.1.2 Studied Situations

Viewing the situation identification to be analysed, an influence system diagram was sketched. The influence diagram is a graphic representation that helps to visualize, for a particular system, the relations between the initialising events, the nature states, system conditions and effects with interest for the analysis. The explicitness of event relations (without the ramification that characterizes the event trees) is, perhaps, the principal advantage of this type of representation. An influence diagram shell allows representing the system logical, the influences over the system and the uncertainties that affect its performance. Figure 3 represents the influence diagram of Odelouca cofferdam.

The Odelouca cofferdam is only charged during the flood occurrence. For these reason, the initialising events were considered the flood occurrence with different return periods. The here present example corresponds to a 10 years return period flood. Supposing a 1 year functioning period (in reality, its period would be higher) for the isolated work, the event probability will be 0.1.

The affluent flood will produce a rising of the reservoir water level, which will depend of the flow out the diversion tunnel and of reservoir storage volumes curve. In what concerns the tunnel performance, the possibility of obstruction of its section was admitted, due to dragging of deforestation products that were deposited upstream along the water line, at the contract job interruption.

The tunnel obstruction percentage will influence the pair of values (discharged flow, reservoir water level) and will determine the occurrence, or not, of the cofferdam overtopping. This overtopping will provoke external erosion, with or without breach formation, as a function, namely, of the water high above of crest, the overtopping duration and the external erosion resistance of the embankment materials.

For the total tunnel obstruction it will be almost certain, although some uncertainties may subsist related to the flood hydro gram and to the reservoir storage volumes curve. In the other side, if there are no tunnel obstruction, it will practically certain that there will not be overtopping, due to the fact that the system was designed for a 50 years flood. The uncertainties report to the flood hydro gram estimates, to the reservoir storage volumes curve, to the tunnel outflow curve and to the performed flood routing studies. To this set of possibilities, conditioned essentially by the hydraulic performance of the discharge structures, was named as Situation 1.

The absence of chimney filter and the grain size distribution differences between the core (residual schist and colluviums soils with a high fines percentage) and the shoulder materials (altered schist of extensive granulometria with a reduce fines percentage) led to the consideration of possibility of internal erosion materialization (by establishing erosion path with reservoir connection) or, alternatively, to a set of effects conducting to the freeboard loss and overtopping, followed by external erosion, with or without breach formation.

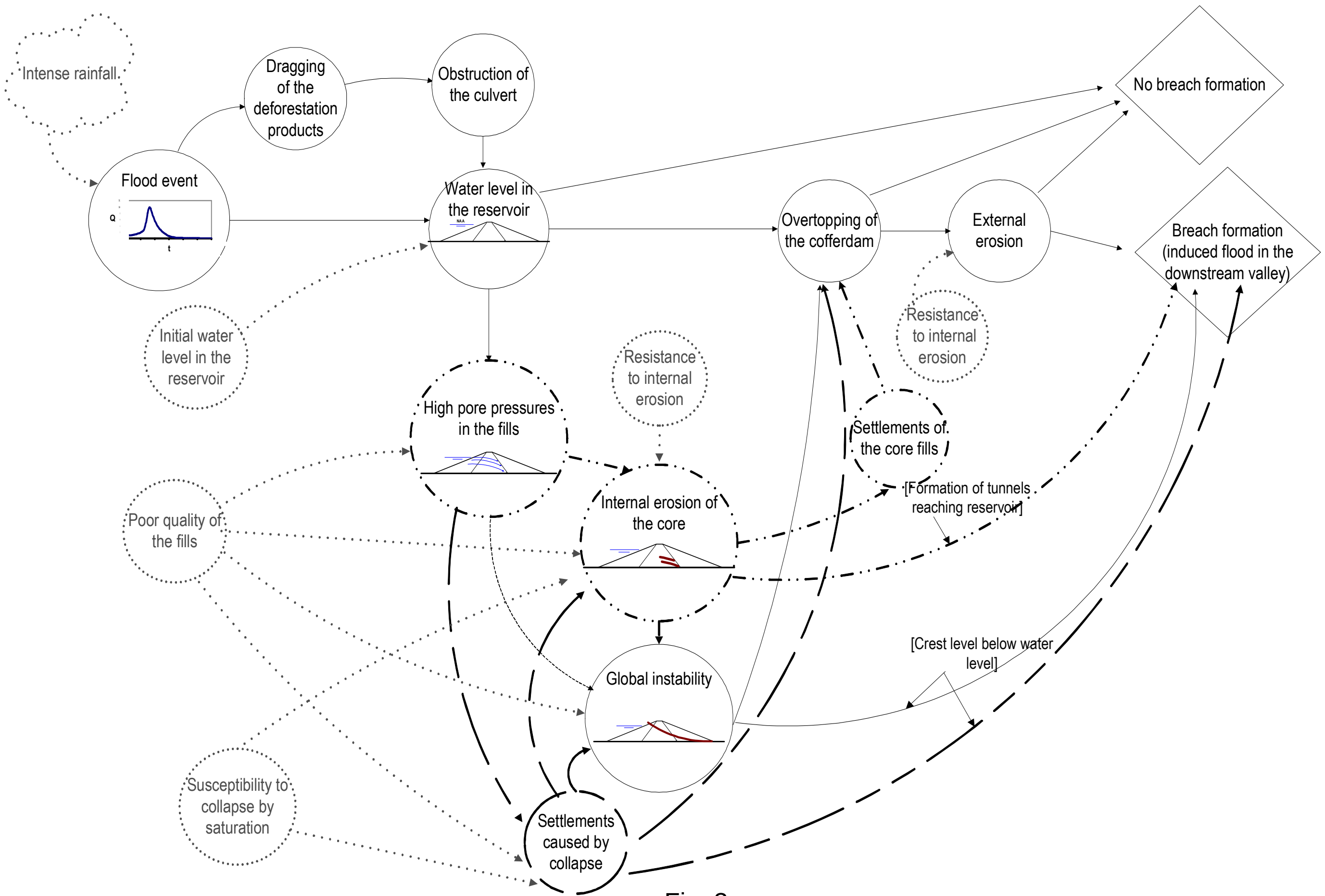


Fig. 3

Influence Diagram for Odelouca cofferdam

Diagramme d'influence du batardeau d'Odelouca

The initiation of the internal erosion phenomenon by mechanical dragging (and diffuse transport, through the downstream shoulder, or the concentrated transported, for instance, in the embankment-abutment contacts) will depend of the achieved reservoir water level, of the stay time of this level and of the internal erosion resistance of the core materials. The occurrence of wetting collapse of the embankments will potentiate the internal erosion occurrence.

To this possibilities set, essentially conditioned by internal erosion of the fills (with or without wetting collapse), which may lead to internal erosion failure of the fills or to a failure produced by the effects set of internal erosion followed by overtopping and external erosion, herein was named Situation 2.

Associated to this situation, Situation 3 was considered, that includes the possibility of occurrence of fill wetting collapse, freeboard loss and overtopping followed by external erosion, with or without failure.

A last hypothesis was still considered, the Situation 4, related to the fill global stability loss of the downstream shoulder and of the core, inducing directly the embankment failure by freeboard loss or to the freeboard reduction and subsequent overtopping due to the reservoir water level raise, followed by external erosion.

4.1.3 Construction of the Event Trees

The event tree construction is always subjective and depends, not only of the skills and knowledge of who makes it (in the related technical-scientific fields to the system and to the risk analysis), but also of the initialising event and of the select study situation.

Figures 4, 5 and 6 present the event trees for the analysed situations. In the example, here presented, the probabilities were estimated based on statistical analysis of historical record (floods), engineering judgment (the generality of events) and reliability analysis by Monte Carlo method (loss of global stability of the downstream shoulder and core).

In following, the quantification of the failure probability, by loss of global stability involving the downstream shoulder and core, of Odelouca cofferdam is presented. This is the ultimate limit state includes in situation 4 for reservoir water levels between elevation 60 and elevation 66.5 m (event tree of Figure 6).

In what refers to the failure probability quantification by loss of global stability of the downstream shoulder, the parameters uncertainty was considered by the Monte Carlo method (Figure 7).

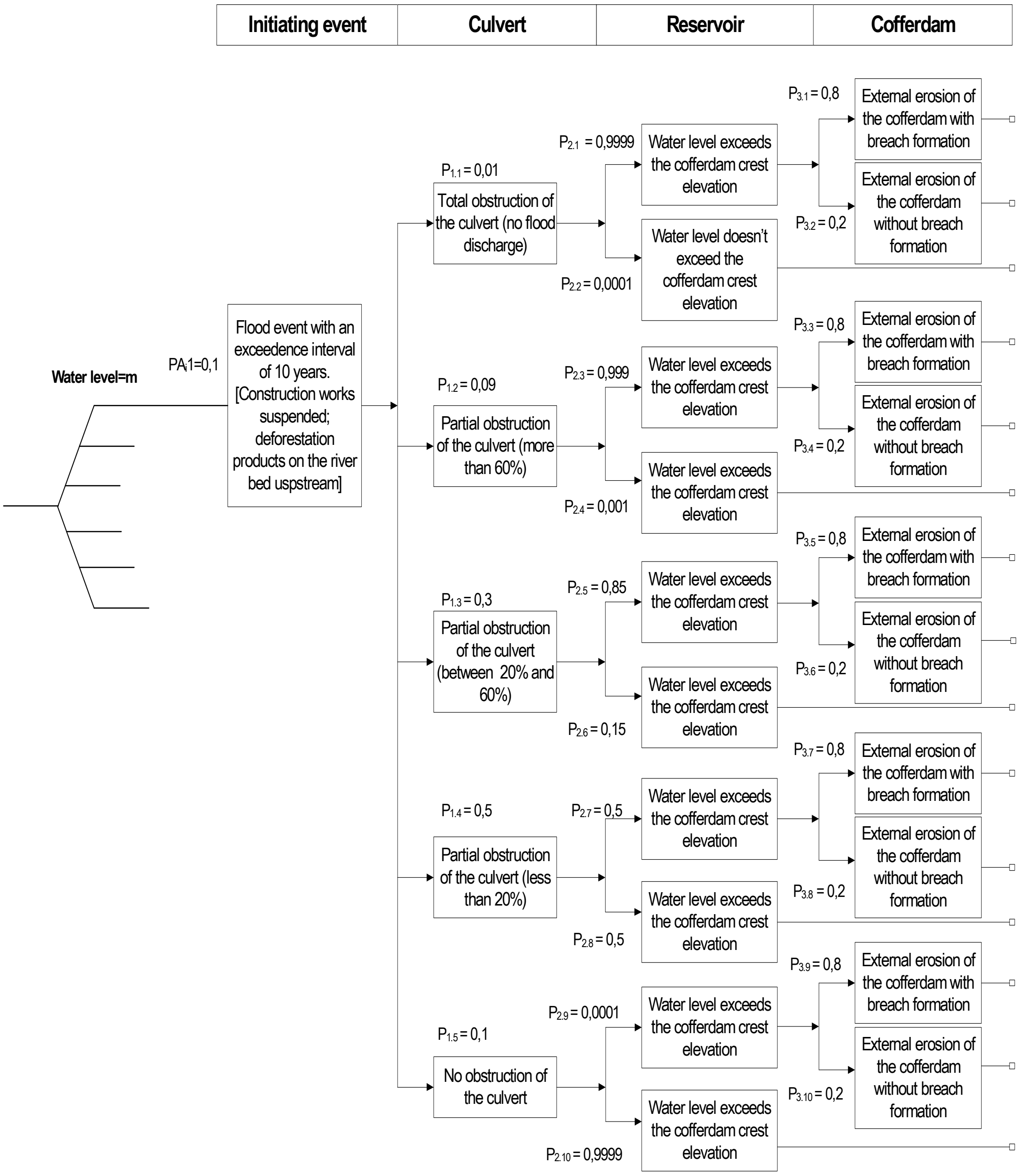


Fig. 4

Odelouca Cofferdam event tree for situation 1

Arbre d'évents du batardeau d'Odelouca pour la situation 1

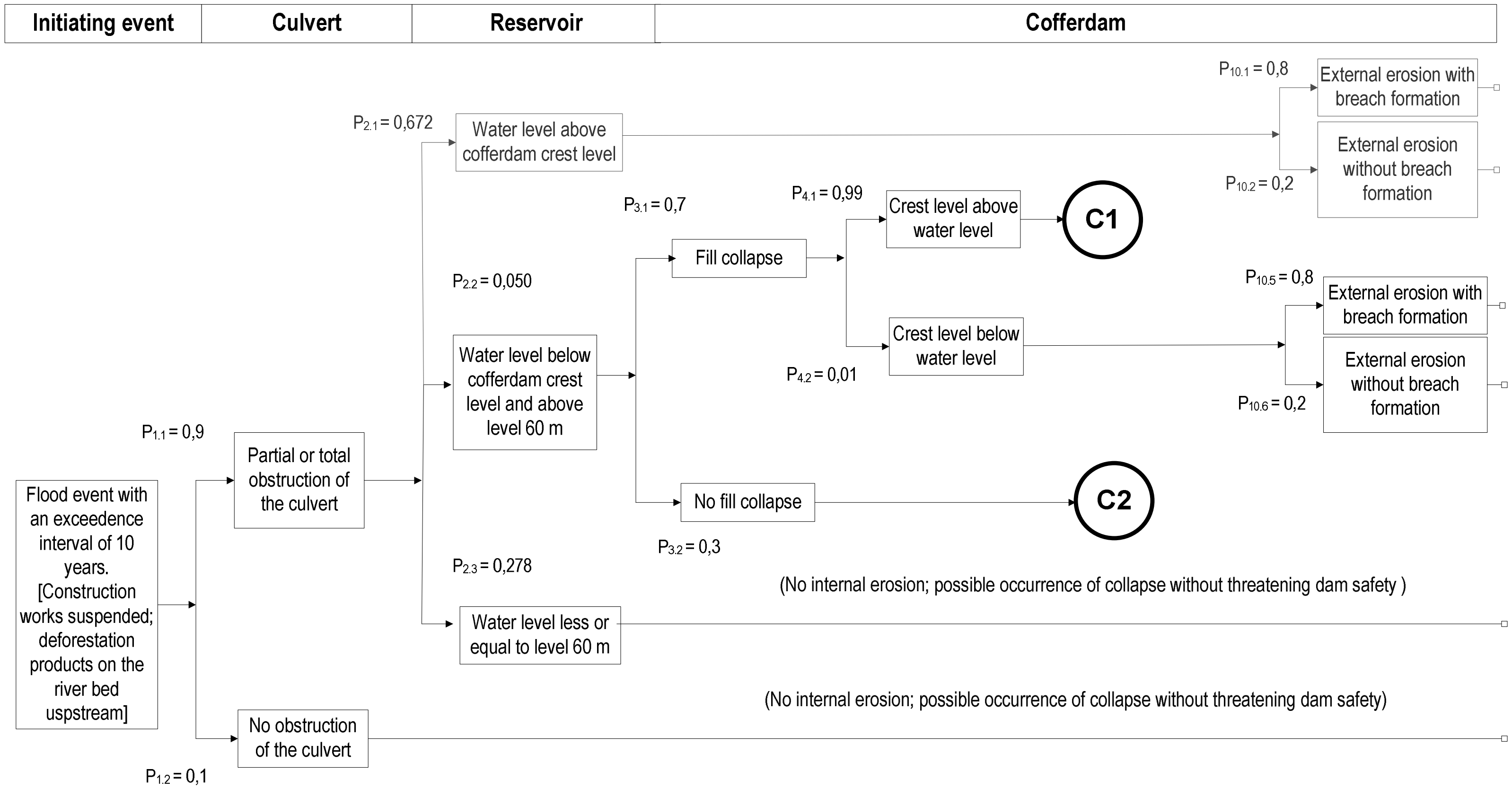


Fig. 5

Odelouca Cofferdam event tree for situations 2 and 3

Arbre d'évents du batardeau d'Odelouca pour les situations 2 et 3

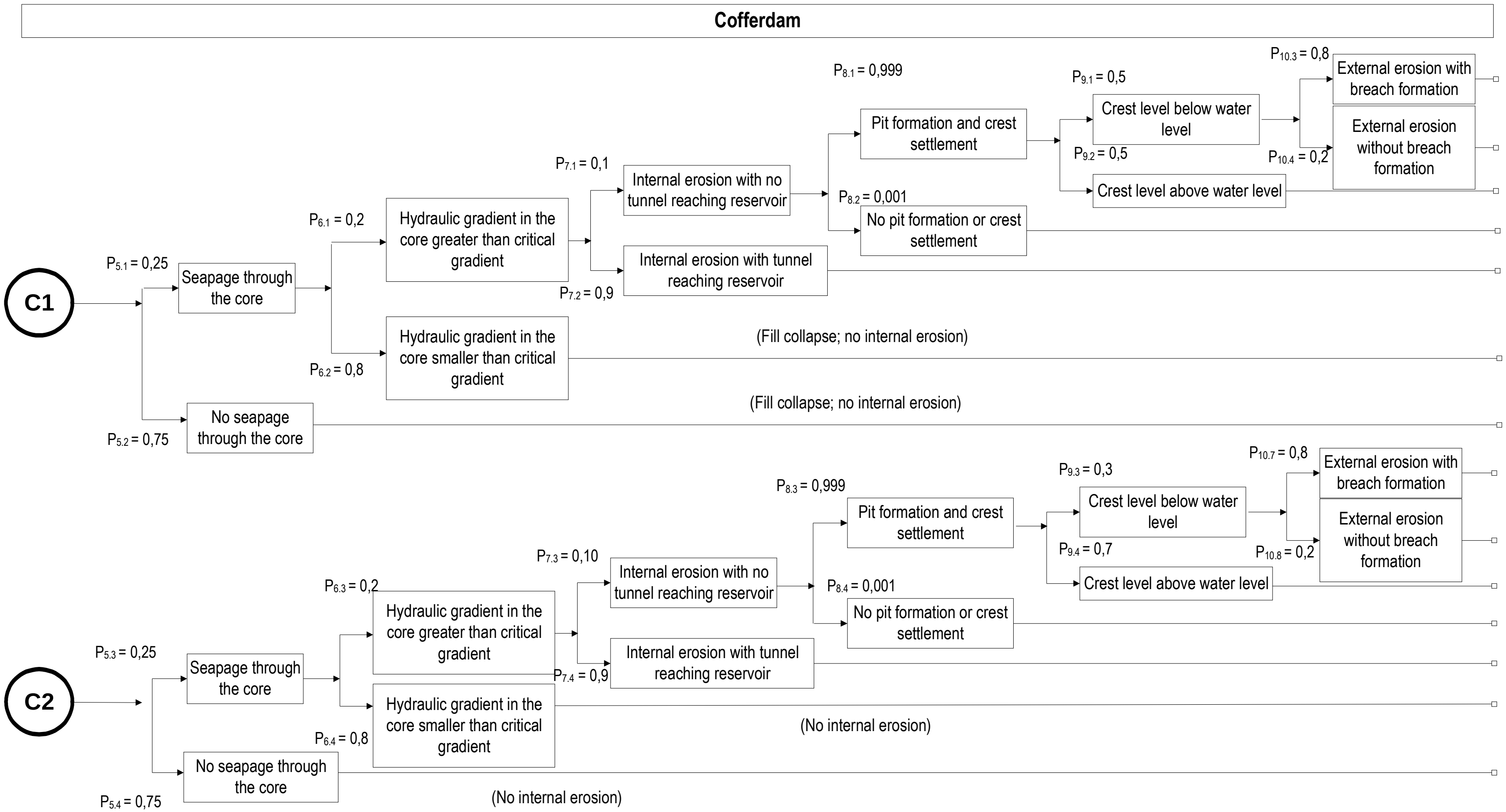


Fig. 5 (cont.)

Odelouca Cofferdam event tree for situations 2 and 3

Arbre d’événts du batardeau d’Odelouca pour les situations 2 et 3

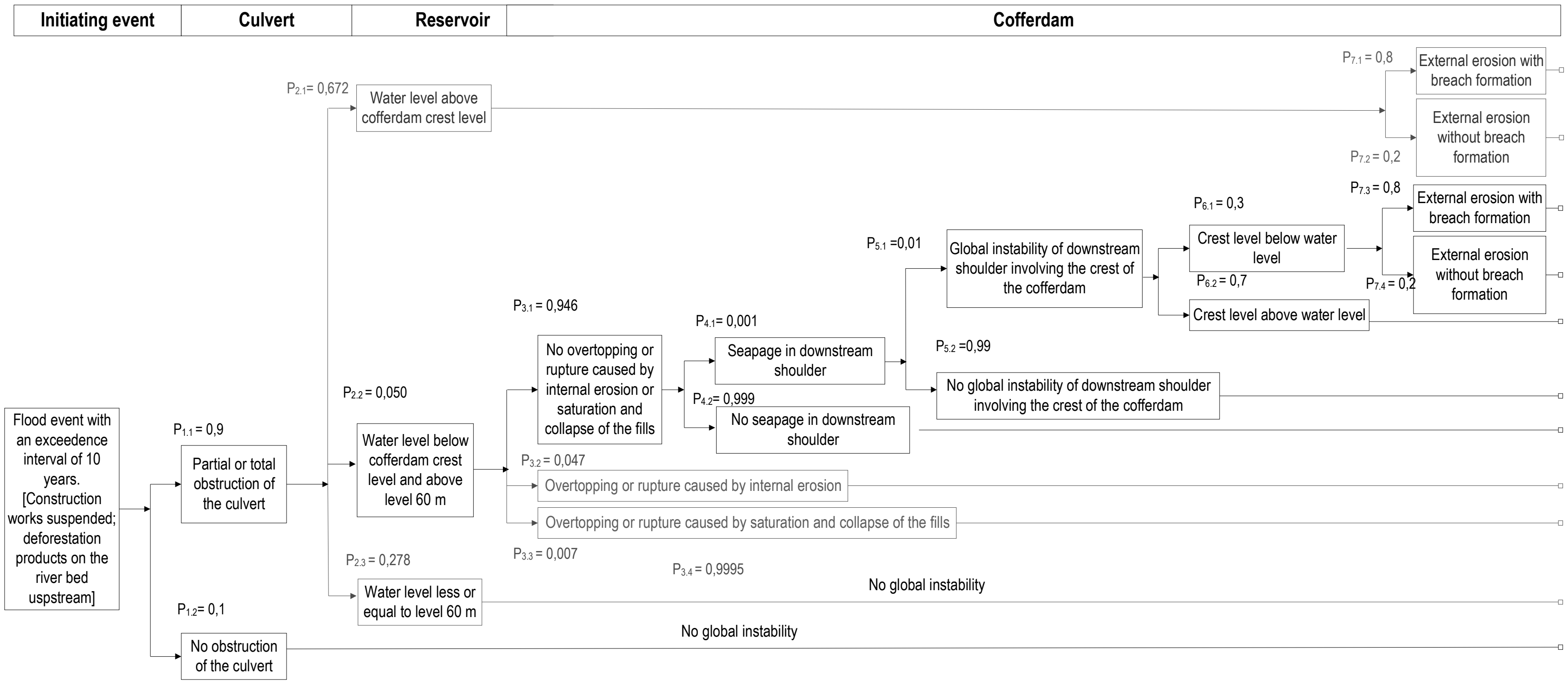


Fig. 6
Odelouca Cofferdam event tree for situation 4
Arbre d'events du batardeau d'Odelouca pour la situation 4

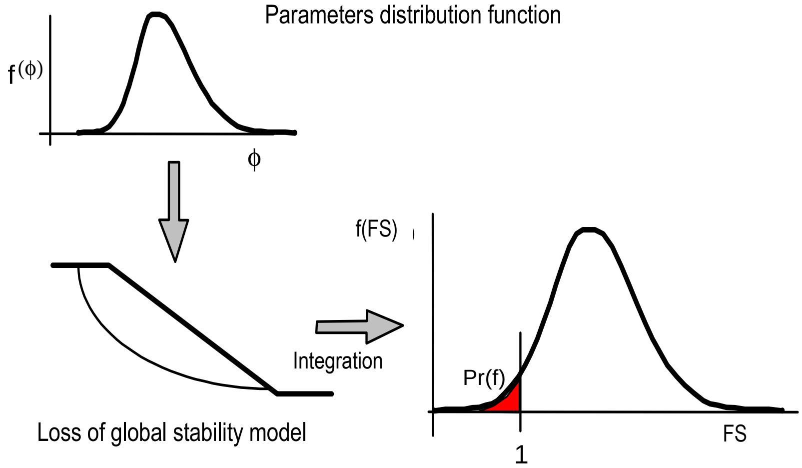


Fig. 7
Schematic representation of the Monte Carlo analysis
Représentation schématique de l'analyse de Monte Carlo

In the analysis presented the reservoir water level is above level 60 and below crest level and normal distributions for the parameters were admitted, which are characterized by its mean and standard deviation values.

For the obtained critical surface, from the considered calculus model and for the mean values of the adopted parameters, the Monte Carlo method was applied, using the automatic calculus program SLOPEW.

The variation of the material properties is done through a generation random function, being calculated, for each property set, the corresponding safety coefficient. The safety coefficients, obtained in this way, follow, presumably, a normal distribution, allowing the mean value and standard deviation determination.

The number of calculations to be performed by Monte Carlo method, for the desirable confidence level, depends of the number of parameters considered as random variables and of the expected failure probability for the limit state in analysis. In the performed analysis, 10000 simulations were carried out, for each assessed situation.

In the probabilistic analysis, the slope stability is assessed by the reliability index and the failure probability (i.e., the probability of a safety coefficient less than 1). The reliability index describes the slope stability by the number of standard deviations that apart the mean value of the value 1, being considered, by some authors, as a way of normalizing the safety coefficient in relation to the uncertainty. Being known the probability distribution, the reliability index is related directly to the failure probability. In Table 3, the material properties and the respective coefficients of variation (COV) adopted in the calculus are presented. The taken mean values are the design values considered in the stability studies of the Odelouca cofferdam body [6].

Table 3
Material properties and coefficients of variation

Materials	Unit weight (γ)		Effective cohesion (c')		Effective friction angle (ϕ')	
	Mean value (kN/m^3)	COV (%)	Mean value (kN/m^2)	COV (%)	Mean value (º)	COV (%)
Upstream and downstream shoulders (above level 47)	21.0	5	-	-	36	6
Upstream and downstream shoulders (below level 47)	21.0	5	-	-	36	12
Core (above level 47)	20.5	5	10	30	29	10
Core (below level 47)	20.5	5	10	60	29	20
Foundation (superficial levels)	21.0	-	50	-	36	-

Figure 8 presents the slip surface with the minimum safety coefficient, between the studied surfaces, taking into account the centre meshes and the radius tangents considered. Figure 9 contains the results of the Monte Carlo method application. A failure probability of approximately equal to 0.01 and a reliability index of 2.33 were obtained.

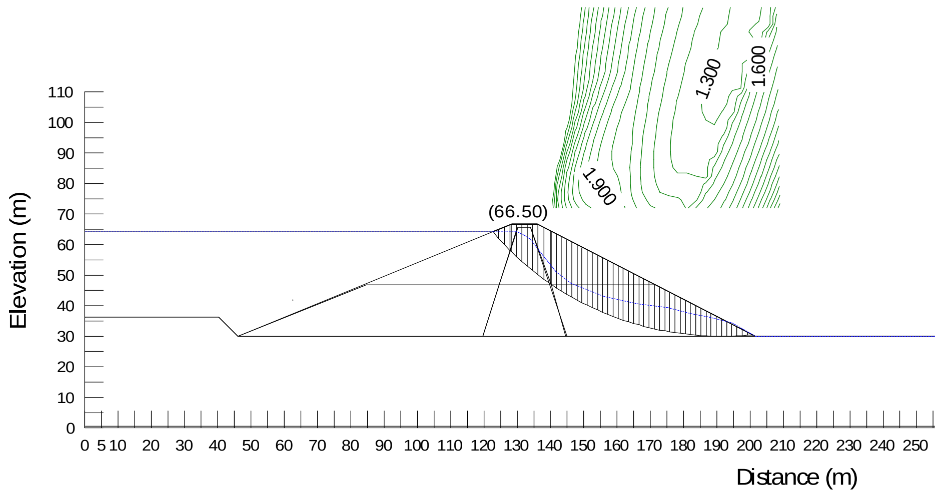
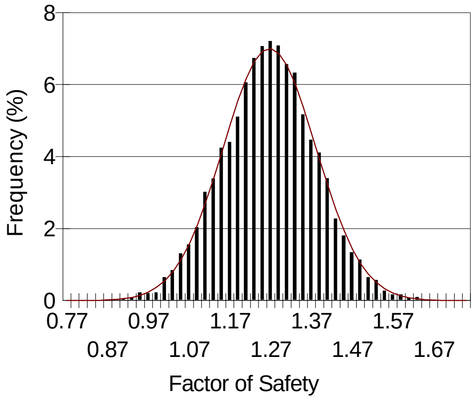
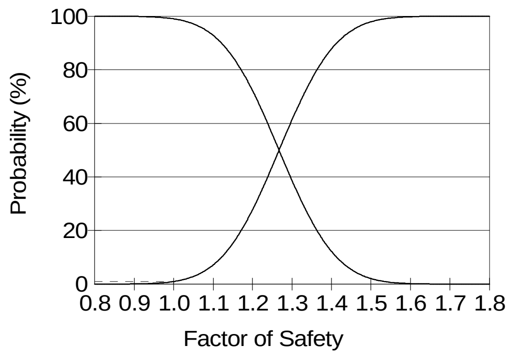


Fig. 8
Instability surface studied by Monte Carlo reliability analysis
Surface d'instabilité étudiée avec l'analyse de fiabilité de Monte Carlo

The obtain failure probability was adopted in the event tree represented in Figure 6 and corresponds to event 5.1 probability (there is a loss of global stability of the downstream shoulder materialized by a surface that intersects the crest and the upstream shoulder upper elevations).



a)



b)

Mean F of S	1.27	Standard Dev.	0.11
Reliability Index	2.34	Min F of S	0.86
P (Failure) (%)	0.99	Max F of S	1.73

Fig. 9
Results of Monte Carlo reliability analysis: (a) probability density function and (b) failure probability and reliability distribution functions for the safety coefficient
Résultats de l’analyse de fiabilité de Monte Carlo: (a) fonction densité de probabilité et (b) fonctions de distributions de probabilité de rupture et de fiabilité pour le coefficient de sécurité

Concerning the consequences estimate, the following losses were considered.

i. In the failure induced by the overtopping and fill external erosion sequence, for reasons essentially associated to the hydraulic structures functioning or to the fill collapse inducing immediately to freeboard loss (modes assumed of fast development), 38 fatalities. For the others failures, induced by internal erosion or by loss of global stability, or by combination of structural modes, 27 fatalities were considered.

   For the risk estimation, a five hundred thousand euros value per fatality was attributed.

ii. Concerning the financial losses, the cofferdam body collapse, the destruction of 33 one family edifications, of estimated low economic value, a segment of a national road, several viaducts and macadamized roads and a significant dimension leisure and sport infrastructure were considered.

   For the risk estimation, a five million euros value for the structures and infrastructures, above referred, reconstruction was considered.

iii. The possibility of affecting natural habitats and some protected piscicultural species was also assumed, at which a two and a half millions value was attributed.

iv. For the situations without reservoir storage volume water release, with the damages are restricted to the cofferdam body, the quantities for the embankment rehabilitation were estimated as a function of the predicted deterioration extension.

4.1.4 Interpretation of the events trees

The failure probability with a downstream flood wave release (considering all the relevant failure modes) is 4.86×10^{-2} and of the probability of non occurrence of a flood wave release (with or without cofferdam body damages) is 5.14×10^{-2}.

Table 4 presents a summary of the probabilities, consequence and risks of the studied failure modes with a downstream flood wave release.

Table 4
Calculated risk for different collapse modes with water release downstream

Failure modes with downstream water release	**Probability of failure**	**Consequences (€)**	**Risk (€)**
Reservoir water level rise, overtopping, external erosion and breach formation.	4.84×10^{-2}	26 500 000 €	924 681 €
Internal erosion and breach formation.	2.01×10^{-4}	21 000 000 €	4 305 €
Reservoir water level rise, internal erosion, crest settlement, overtopping, external erosion and breach formation.	7.86×10^{-06}	21 000 000 €	222 €
Reservoir water level rise, wetting collapse, overtopping, external erosion and breach formation.	2.52×10^{-5}	26 500 000 €	736 €
Reservoir water level rise, loss of global stability, overtopping, external erosion, breach formation.	1.02×10^{-8}	24 000 000 €	0 €

The conditioning failure mode of the total probability of failure (with the storage volume release) elapses from the deficient functioning of the hydraulic organs, due to obstruction of the diversion tunnel cross section with deforestation products, without anomalous structural performance contribution.

The consequences monetary value is conditioned by the estimated number of fatalities, even having been used a low monetary value per fatality (500 000 €), less than some values mentioned in several bibliography (1 000 000 to 1 800 000 €).

The risk quantity is not an intuitive one and it will very difficult to define acceptability and tolerability limits that do not have in consideration de pair of values (probability, consequences).

Figure 10 presents the obtain results superimposed to the FN plot with the proposed acceptability and tolerability limits for the Portuguese embankment dams [7].

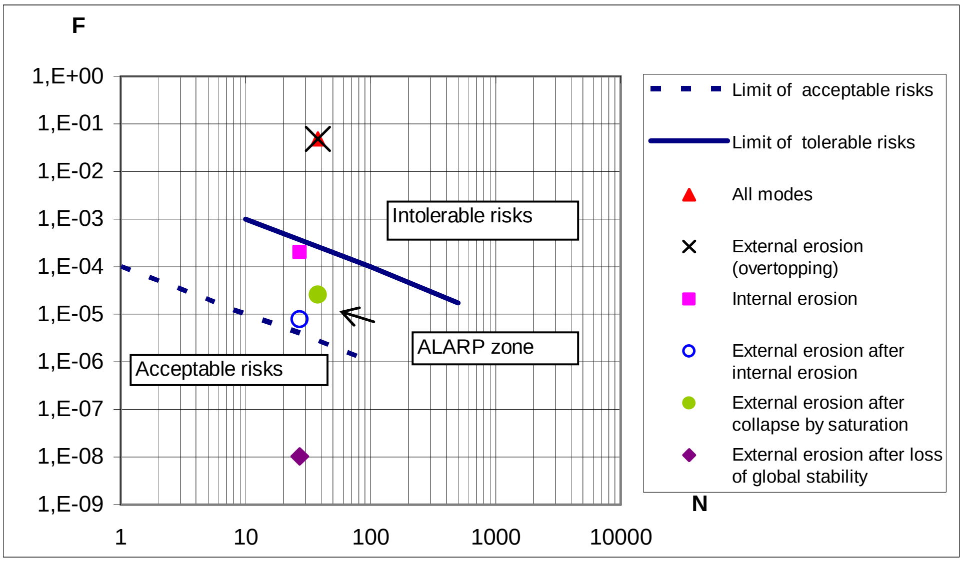


Fig. 10
FN plot representation of the Odelouca Cofferdam risks
Représentation graphique FN des risques du batardeau d'Odelouca

These failure probabilities are very high. In particular, those corresponding to external erosion in sequence of overtopping (originates by hydraulic causes) and to the sum of all the failure modes. The calculated failure probabilities will increase for cofferdam service life time (as an isolated work) greater than considered (one year). The flood occurrence with higher return periods will also lead to superior failure probabilities. In reality, the presented case study corresponds to an exceptional exploration situation, since it is an embankment work with an appreciable dimension and significant storage volume, which was not conceived, from the structural point of view, to work an independent work. It should be add that the contract job interruption generated other risks, namely those associated to the reservoir deforestation products, which were not removed.

5. FINAL CONSIDERATIONS

The risk analysis success, namely by event tree analysis, depends on the system knowledge and on the skills and experience of those performing the analysis. The tree construction detail assumes particular importance in this type of analysis optimization. It should be defined as a function of system in question and of the purposes that ones intend to achieve.

In event tree analyses, the initialising event identification of greater potential impact on the system/subsystem will allow to reduce significantly respective analysis time and costs, aspects that constitute the main obstacles to its application, at least, in the quantitative form. If the event tree implementation and interpretation slowness can be contoured by the application of automatic calculus programmes, which helps its construction and interpretation. The probabilities estimation will always face great practical difficulties.

In embankment dam's field, the probabilities estimation of many events only can be done by *engineering judgement*. The occurrence probabilities of some events can be evaluated through *reliability analyses* theory based on historical data.

ACKNOWLEDGEMENT

Thanks are due to the Portuguese Water Institute (INAG) for permission to publish the information regarding Odelouca dam.

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SUMMARY

In this paper we present the risk analysis of Odelouca Cofferdam, using an event tree analysis.

The initializing events, failure modes and analysed limit states are discussed based on an influence diagram. The constructed event trees and their interpretation are presented. The obtained risk values are represented in an *FN* plot superimposed to the acceptability and tolerability risk limits proposed for Portuguese dams.

Initially, particular emphasis is placed on the main characteristics of the cofferdam and deviation hydraulic structures, as well as on some important construction aspects conditioning the expected structural behaviour and the analysed limit states. Downstream valley characteristics and the results of dam break studies, which based the consequences identification and evaluation, are also present.

RESUMÉ

On fait la présentation de l'analyse de risques du batardeau d'Odelouca par la méthode des arbres d'évents.

À travers d'un diagramme d'influence on fait la discussion des événements primaires et des modes de défaillance considérés dans l'analyse de risques. On présente les arbres d'évents élaborés et leur interprétation. Les risques calculés sont présentés dans un graphique du type FN sur posés aux limites acceptable et tolérable proposés pour les barrages portugais.

Initialement, on souligne les principales caractéristiques du batardeau et des ouvrages hydrauliques de dérivation de l'oued, aussi bien que les aspects constructives plus significatives, tenant compte de leur importance sur le comportement structurel envisagé et les états limite étudiés. En outre, on présente les caractéristiques de la vallée en aval et les résultats des études de rupture du batardeau qui ont basé l'identification et évaluation des conséquences.

1 RISK ANALYSIS OF ODELOUCA COFFERDAM. RESULTS OF AN EVENT TREE ANALYSIS

2 2009

3 Q91

4 R

5 English

6 Zoned dam, Risk analysis**,** safety of dams, Odelouca cofferdam

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