

PROPOSAL FOR THE DAM SAFETY REGULATION OF MOZAMBIQUE

António Pinheiro*, **José Mora Ramos[†]**, **Laura Caldeira[‡]**, **António Batista[‡]**,
Eduardo Jossefa[§] and **Ângelo Boavida[§]**

*Instituto Superior Técnico, Universidade de Lisboa, EGC team
e-mail: antonio.pinheiro@tecnico.ulisboa.pt

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Abstract. *The paper presents the mains aspects of the proposal for the Dam Safety Regulation of Mozambique (DSRM), emphasizing aspects that may be considered innovative or specific to the Mozambican dam panorama. The scope of the DSRM and the criteria for dam vulnerability and potential damage in the downstream valley classification are presented. The Mozambican institutions that will be involved are listed and their roles briefly presented. Concerning the dam safety control, the Mozambican data base purposes are described and the several procedures and documents that will be used for that control are briefly listed and discussed. The main safety requirements to be considered in the design stage that were included in the proposal are also included. Finally, the guidelines adopted for the defaults penalties and for the owners financial support obligations are briefly described.*

1 INTRODUCTION

There are a significant number of medium and large dams in operation in Mozambique. However, the demand of water for urban supply and irrigation, as well as for power generation or the necessity to increase the flood control, will hopefully lead to the construction of more dams in the near future. This development is expected to be financially supported by private or public funds, from national or international sources. In the absence of national legislation, this funding diversity will also bring different design philosophies and dam safety criteria to Mozambique. In this context, the Mozambican authority (Direcção Nacional de Águas, DNA) acknowledged that would be urgent to establish a framework and criteria for the design, construction and operation rules of the existing and new dams.

In 2013 they launched a tender for consultancy services to prepare the Dam Safety Regulation of Mozambique (DSRM) and to evaluate the requirements and the economic impacts of applying that regulation to the existing dams. The consultancy services also include the basic training of Mozambican technicians necessary to implement the DSRM and to check its compliance by the dam owners. The consultancy was awarded to a Mozambican consulting company, EGC, Engenharia, Gestão e Consultoria, Lda, which organized a consulting team with the required skills.

The consultancy has been developed in close cooperation with DNA and with an Advisory

[†] Consultant, EGC team

[‡] Laboratório Nacional de Engenharia Civil (LNEC), EGC team

[§] Direcção Nacional de Águas

Committee specifically created for this purpose. The DSRM proposal has already been checked by the Advisory Committee, and adapted accordingly. More recently, an extension of the DSRM to tailing dams was also awarded to the EGC, being that part of the work still at a development phase.

The DNA also considered that the DSRM must be complemented with design, construction and operation Codes of Practice, being part of the contract with EGC the development of the Reference Terms to launch such work.

This paper presents the framework of the DSRM and the main criteria considered for the dam safety control. Special emphasis is given to some innovative aspects, such as the dam classification and the safety plan, or the decentralized of safety control procedure, which results from the Mozambican water resources management legislation, which determines that the Regional Water Authorities (ARA) should play an important role in these matters, although in conjunction with the DNA. The creation of a Mozambican dam data base was also included in the contract, being already operational, although in loading phase, will also be addressed.

The DSRM proposal took into account not only the applicable Mozambican legislation, but also very diverse dam safety regulations, such as those from South Africa¹, Portugal² and Brazil.

2 MOZAMBICAN DAM SAFETY REGULATION

2.1 Structure and safety criteria

It was DNA and EGC intention that the DSRM should integrate the tendencies of the most recent dam safety legislation and, at the same time, be easy to apply and take into account the general panorama of Mozambican dams.

The DSRM proposal comprises 46 articles organized in the following chapters and sections:

- Chapter 1 – General provisions
 - Section 1 – Scope, definitions and dam classification;
 - Section 2 - Safety control organization.
- Chapter II - Safety control instruments.
- Chapter III - Safety control along the different life stages of the dam.
- Chapter IV – Non-compliances and penalties.
- Chapter V - Transitional provisions.
- Chapter VI - Owners financial support obligations.

It establishes:

- Criteria for dam safety control.
- The functions assigned to the entities that participate in the safety control activities.
- The requirements to be met during the different life stages of the dam: design, construction, reservoir first filling, normal operation and decommissioning.

2.2 Scope

The DSRM will be applied to:

- a) Large dams, which are dams with:
 - i. Height larger than 15 m, measured from the lowest elevation of the general surface of the dam foundation;
 - ii. Height larger than 10 m and reservoir gross capacity larger than 1 hm³;
 - iii. Spillway design discharge larger than 2000 m³/s.

- b) All the other dams with medium or high potential damage (hazard), according to the criteria defined in the DSRM proposal.

2.3 Dams classification

The proposed dam classification criteria are according to the most recent trends, but adapted to the Mozambican existing dams. These criteria address the most sensitive aspects related with dam safety and intend to establish procedures and rules that will encourage the improvement of dam owners safety concerns.

According to the DSRM proposal, dams are classified in risk classes (Table 1), considering the classifications of the dam vulnerability and of the potential damage caused in the downstream valley by the dam failure.

Vulnerability	Potential damage		
	High	Medium	Low
High	Class I	Class I	Class III
Medium	Class I	Class II	Class III
Low	Class I	Class III	Class III

Table 1 – Dam risk classification according to the potential damage and vulnerability

To quantify the vulnerability, partial indexes which weight the dam characteristics, its state and the implementation of safety control procedures are proposed.

Partial indexes concerning the characteristics of the dam, varying between 1 and 9, and are related to: (i) height; (ii) crest length; (iii) type of dam/construction materials; (iv) type of dam foundation, distinguishing embankment dams and concrete dams; (v) dam age; (vi) spillway design flood.

Partial indexes concerning the state of the dam, vary between 1 and 6, are proposed for different status of the following parameters: (i) reliability of the spillway; including energy dissipators; (ii) reliability of the hydraulic circuits; (iii) seepage conditions; (iv) deformations, settlements, structural cracking, joint movements; (v) chemical reactions on the dam body; (vi) deterioration of the dam crest and of the upstream and downstream surfaces; (vii) reliability of appurtenant structures that are important for dam safety, such as powerhouses and navigation locks.

Partial indexes concerning the implementation status of safety control measures, varying between 1 and 6, are proposed to appraise the existence of: (i) dam operation director and technical staff; (ii) technical archive and technical book; (iii) dam operation procedures; (iv) dam monitoring plan; (v) safety inspections procedures; (vi) reports on dam behaviour safety inspections and monitoring.

The vulnerability index is determined by an aggregation of the partial indexes, being the dams classified according to the following vulnerability classes: (i) low; (ii) medium; (iii) high (Table 2).

The dam classification relatively to the potential damage is achieved by the product of partial indexes, varying between 1 and 6, accounting for: (i) reservoir gross capacity; (ii) potential human lives loss; (iii) potential damages to the natural and built environment; (iv) potential social and economic impacts; (v) existence of an internal emergency plan for the dam; (vi) existence of an environmental safety plan. Accordingly, the dams are classified in one of the following potential damage classes: (i) low; (ii) medium; (iii) high (Table 3).

Vulnerability	Vulnerability Index
Low	$I_V \leq 5$
Medium	$5 < I_V \leq 20$
High	$I_V > 20$

Table 2 – Vulnerability classification as a function of the Vulnerability Index

Potential damage	Potential Damage Index
Low	$I_{PD} \leq 20$
Medium	$20 < I_{PD} \leq 250$
High	$I_{PD} > 250$

Table 3 – Potential damage classification as a function of the Potential Damage Index, I_{PD}

The potential loss of human lives will be estimated considering the number of homes in the area affected by the dam break wave. The values to be considered were adapted to the Mozambican reality in rural areas. The value 1 is reserved for areas, flooded by the dam break wave, where no homes or roads exist, and the value 6, for areas where 10 or more homes or national or district roads exist.

A final calibration of all the parameters considered in the classification is expected to be made after the analysis of the DSRM application to the existing dams.

3.3 Involved institutions and their roles

The institutions involved in the dam safety control are: (i) the DNA, as the national authority for dam safety; (ii) the 5 ARA, as the regional authorities for dam safety within the catchment areas under their administration; (iii) the National Institute for Disasters Management (INGC), to which are committed the responsibilities of coordination in case of natural and man caused disasters; (iv) the Mozambican Laboratory for Engineering (LEM), which will be the technical consulting institution of the DNA; (v) the dam owner, which may be a private or a public company or institution, and is the prime responsible for the dam safety; (vi) the Consulting Committee for Dam Safety (CCSB), yet to be created, which will advise the DNA and will promote the debate and dissemination of dam safety issues.

The role of LEM is fundamental in the proposed DSRM. This role is already stated in its by-laws, but is expected that a transitional period will be necessary so that the Laboratory may acquire the necessary technical skills to fully address all the technical issues raised by the application of the DSRM.

3 DAM SAFETY CONTROL

3.1 Safety control instruments

The DSRM establishes that dam safety control will be based in the following documents, data or procedures:

- a) Mozambican dams data base;
- b) Central digital archive of monitoring data;
- c) Dam design documents and Safety Plan;
- d) Construction data documents;

- e) Dam risk classification;
- f) Emergency external plan;
- g) Reservoir first filling plan;
- h) Dam safety inspections;
- i) Reports and analysis of dam behaviour and of inspections;
- j) Curriculum vitae of the Construction Director and of the Dam Operation Director;
- k) Dam decommissioning plan (if required).

The most significant features concerning the data base of Mozambican dams, the Safety Plan, the safety inspections and the roles of the Construction Director and of Dam Operation Director are described below.

3.2 Dams data base

The dam data base will be set at the DNA headquarters. It intends to include the main data of all the Mozambican dams, of all classes of risk, in the different life stages: design, construction, operation and decommission. The data base will include the dams and appurtenant structures characteristics, the design documents, the design drawings, photos, and inspection and behavior analysis reports, as well as other documents considered as relevant for future safety analysis.

The basic specifications of this data base were: (i) decentralization of the data production and uploading; (ii) data uploading and access via Web; (iii) central control in the DNA; (iv) public access to general dam characteristics and information about each dam; (v) privileged access to specific data and confidential information to authorized technicians of DNA, ARA, LEM and the specific dam owner, whose access is controlled by passwords.

The main benefits expected with the data base implementation are:

- a) Obtaining updated information of each dam characteristics and of the respective safety evaluation;
- b) Building an archive of relevant information obtained during the different life stages;
- c) Making available the information necessary to promote and update the risk classification of each dam;
- d) Helping to define the conservation measures that are required to guarantee the dam safety.

The loading of the data base fields has being made by gathering the information existing in different institutions, searching in the Mozambican and Portuguese archives, with relevance to the information available at the DNA and at the LNEC, in Lisbon.

3.3 Safety Plan

The Safety Plan is a part of the design documents, and consists of four independent subdocuments:

- a) Monitoring Plan of the dam body, its foundation and appurtenant structures;
- b) Operation Procedures Code of Practice, relative to hydraulic and hydromechanical equipment safety;
- c) Internal Emergency Plan, concerning the dam and the downstream area more close to the dam where the INGC warning cannot be given in time for the affected populations to reach safe places;
- d) Environmental Safety Plan.

It is expected that these four subdocuments, required to be part of the design documents, will allow that dams to be built in Mozambique will comply with more strict safety requirements.

The Monitoring Plan will define the monitoring systems to be installed, the safety inspections to be carried out (type and frequency), the methods to analyze the dams behavior shall be analyzed, the assessment of the dam safety conditions and the reports to be produced.

The DSRM specifies the parameters to be monitored according with the type and height of the dam, and takes into account the guidelines provided by the ICOLD.

The operation of the reservoir, including the definition of an environmental flow regime, the rules established for the operation of the spillway and for the hydraulic circuits, under normal and emergency situations, the definition of operational tests and the existence of adequate inspections and maintenance plans for the equipment must be considered to define the Operation Procedures Code of Practice.

The Internal Emergency Plan must be prepared taking into account the External Emergency Plan, which will be elaborated by the INGC, the characterization of the valley downstream of the dam, and the determination of the flood maps and of the potential damage associated with the worst accident scenarios expectable for the dam failure.

The Environmental Safety Plan will establish methodologies for checking operation procedures related the environment, the water quality, the sedimentation of the reservoir, the evolution of the river bed downstream of the dam, the ecological monitoring necessary to assess the efficacy of the ecological flow regime, the control of groundwater levels and the effects of the reservoir in public health, if applicable.

3.4 Safety inspections and dams behavior reports

The DSRM establishes three types of inspections: (i) routine inspections; (ii) main inspections; (iii) special inspections, and the following reports:

- a) End of construction.
- b) Reservoir first filling.
- c) Behavior analysis, to be prepared under the responsibility of the Dam Operation Director.
- d) Reference reports, to be prepared by the dam owner.
- e) Environment safety.

The proposed periodicities of safety inspections and of reports elaboration are presented in Table 4.

3.5 Construction Director and Dam Operation Director

The proposal for the DSRM underlies the importance of the Construction Director and of the Dam Operation Director to the safety of a dam. Their knowledge and experience acquired in related previous jobs can be determinant to solve the problems that are posed during the construction and the operation of the dam, respectively. In these conditions, it is required that:

- The Construction Director and the Dam Operation Director have more than 5 years of professional experience for class I dams, and more than 2 years for class II dams.
- The Dam Operation Director must be recognized by the Ministry of Public Works and Housing as adequate to perform that job; this is a procedure that is established in some dam safety regulations, such as the South African one, that intends to increase the responsibility of that important job.

	Routine inspections	Main inspections	Behaviour reports	Reference reports	Environment safety reports
Class I	Bimonthly	Annual	Annual	Five-year	Biannual
Class II	Semi-annual	Biannual	Biannual	Five-year	Five-year
Class III	Annual	Five-year	Five-year	-	-

Table 4 – Safety inspections and reports periodicity.

4 SAFETY REQUIREMENTS IN THE DESIGN STAGE

The DSRM proposal establishes the requirements that must be complied with during the different life stages of the dam. These aspects must be considered in the design phase and checked for the existing dams. It is expected that, for the dams not complying with the proposed criteria, the respective dam owners will take the necessary actions to achieve the required safety standards, within a reasonable period also defined in the proposal. The proposal defines partial seismic risk indexes (Table 5), the minimum recurrence period of the maximum design earthquake to be considered in the dam design (Table 6), the minimum recurrence period of the design flood to be considered in the spillway design (Table 7) and the minimum freeboard relatively to the Maximum Flood Level (Table 8).

The proposed specifications aim that, although the new dams to be built in Mozambique, possibly by designers of different nationalities, using different design standards and used to different dam safety regulations, all the dams will have to comply with safety design criteria adequate to the Mozambican reality. In the future, with the expected elaboration of design and construction codes of practice, it may turn out as adequate to remove such specifications from the DSRM.

Reservoir gross capacity		Dam height		Potential damage	
V (hm ³)	Partial index (i ₁)	h (m)	Partial index (i ₂)	Number of homes at risk (N)	Partial index (i ₃)
120 ≤ V	6	h ≥ 50	6	400 ≤ N	32
1 ≤ V < 120	4	50 > h ≥ 30	4	10 ≤ N < 400	28
0.1 ≤ V < 1	2	30 > h ≥ 15	2	1 ≤ N < 10	16
V < 0,1	0	h < 15	0	N = 0	12
				N = 0	4

 Table 5 – Partial seismic risk indexes (Seismic risk index - IR = i₁+ i₂+ i₃)

5 NON-COMPLIANCES, PENALTIES AND OWNERS' FINANCIAL SUPPORT OBLIGATIONS

The proposal for the DSRM considers three level of non-compliances: (i) level 1, for disrespecting the monitoring periodicities, the monitoring equipment maintenance plan, the main inspections schedule and the elaboration of the behavior analysis reports and reference reports; (ii) level 2, for not giving to the Authorities information concerned with dam safety, for not complying with the hydromechanical equipment maintenance plans; for neglecting evidence of possible safety incidents and for not carrying out rehabilitation works determined by the Authorities; (iii) level 3, for disregarding the operation rules of the spillway and other hydraulic circuits, causing damage in the valley downstream; for neglecting evidence of possible dam accident; and for significant non-compliance with the operation code of

practice.

Seismic risk index (IR)	Recurrence period (years)
4 a 10	1 000
12 a 20	2 500
22 a 30	5 000
32 a 44	10 000/SME

Table 6 – Minimum return period of the dam maximum design earthquake (SME – maximum expectable seism).

Concrete	Embankment	High or medium potential damage	Low potential damage
$h > 100$	$h \geq 50$	5 000	2000
$100 > h \geq 50$	$50 > h \geq 15$	2 000	1000
$50 > h \geq 15$	$15 > h$	1 000	500
$15 > h$	–	500	200

Table 7 – Minimum recurrence period of the design flood to be considered in the spillway design

Dam type	Height (m)	Freeboard (m)
Embankment	≥ 100	2.00
	$30 \geq$ and < 100	1.50
	< 30	1.00
Concrete	-	1.00

Table 8 – Minimum freeboard (m) relatively to the Maximum Flood Level

The penalties applicable to the dam owner, corresponding to the different levels of DSRM non-compliances, will depend on the risk class of the dam. The penalty units are established in the DSRM. The Metical (MZN) value of one penalty unit will be defined by the DNA and periodically revised.

The DSRM proposal also establishes that the dam owner will have to support the cost of the activities concerned with the dam's safety control carried out by the Authorities and by the LEM. As with the penalties, the DSRM defines the cost units for the different activities associated with dam safety control. The Metical (MZN) value of one unit will also be defined by the DNA and periodically revised.

6 FINAL COMMENTS

The proposal for the Dams Safety Regulation of Mozambique prepared by the EGC consulting team, who worked in close cooperation with the DNA technicians and with the Mozambican Advisory Committee, is reaching its final stage. The structure and the criteria considered in that proposal allowed obtaining a coherent document that will be applicable to the existing dams and also those that are in the design stage or under construction.

The innovative approach that was considered for the risk classification of the dams must

be pointed out. It incorporates the international trends in this area and was adapted to the Mozambican dam's reality.

A decentralized of safety control procedure, resulting from the Mozambican water resources management legislation, was proposed.

The proposal of creating a Safety Plan, including the Monitoring Plan of the dam and appurtenant structures, the Operation Procedures Code of Practice, the Internal Emergency Plan and the Environmental Safety Plan is also innovative and is expected to allow the Mozambican authorities to better control the different aspects of dam safety along the different life stages of each dam.

The non-compliances with the DSRM and the corresponding penalties as well as the owners' financial support obligations were also specified. These provisions are expected to be a powerful instrument for the DNA to enforce the all the DSRM provisions.

REFERENCES

- [1] National Water Act (36/1998): Regulations: Safety of dams. South African Government Gazette, 24 February 2012.
- [2] Portuguese Dam Safety Regulation. Decreto-Lei n.º 344/2007, Diário da República, 1.^a série, N.º 198, 15 de Outubro de 2007 (in Portuguese).