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Committee A "Computational Aspects of Analysis and Design of Dams"

17th International Benchmark Workshop on Numerical Analysis of Dams

Theme B

First Impoundment of Plovdivtsi Asphalt-Concrete Core Rockfill Dam



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1 Introduction

1.1 Overview

For every dam, large or small, the initial impoundment process is of crucial importance to the commissioning of the dam and its appurtenant facilities. After cleaning the dam basin and taking the first measurements (the so-called “zero measurements”) of the instrumentation system for monitoring the dam, impoundment begins in accordance with the design specifications laid down in an initial impoundment plan. During initial impoundment, which is to be carried out in a controlled and phased manner, the structural and functional performance of the dam and of its appurtenant structures is closely observed and monitored using a higher frequency of instrumentation readings to measure displacements/deformations of the dam body and in particular of its impermeable element, stresses and strains at important points in the structures, seepage field parameters in the dam and its foundation, etc. In order to carry out these monitoring activities, to analyse the results thereof simultaneously and compare them with the design specifications, and to be able to take immediate action, if necessary, the first impoundment is generally carried out very slowly. In the case of an embankment dam, particular attention is paid to the impermeable element of the dam in terms of its sealing capacity, displacements / deformations, stress and strain conditions.

Where appropriate materials are locally available, rockfill dams are preferably implemented due to their relative structural simplicity, applicability to widely varying site conditions, economical construction and safe performance under broad spectrum of natural and operational impacts (Fell et al 2015).

Rockfill dams are constructed from suitable fill materials compacted in layers. Their impermeable element can be of different types - either a facing on the upstream slope or an inner core. A special solution of the inner core type is the asphalt-concrete diaphragm constructed by placing and compacting in layers a carefully designed mixture of mineral aggregates and bitumen. The Plovdivtsi Dam considered in the formulation of Theme B is of the latter type.

1.2 Main objectives

The objective of Theme B is to simulate the structural response of an existing asphalt-concrete core rockfill dam, namely the Plovdivtsi Dam in Bulgaria, to the first impoundment, as well as to the variation of the reservoir water level for several years of operation.

Due to the heavy rainfall in the first few days of December 2017 and the small volume of the reservoir, the initial impoundment process proceeded very quickly and not in accordance with the specifications of the corresponding initial impoundment plan. The numerical simulation of the impoundment aims at modelling the stress/strain behaviour of the ACD rockfill dam and its foundation under such unexpectedly unfavourable conditions.

In the formulation of the Theme, the geometry and basic material properties of the dam and its foundation, as well as the time-history of the initial impoundment of the dam reservoir are provided by the Formulators. Some aspects related to the numerical modelling are deliberately not specified so that Contributors can make their own assumptions and choose appropriate approaches for numerical analysis.

In particular, Contributors are expected to choose their own constitutive model and, based on the data provided, evaluate the corresponding material parameters in order to describe the non-linear behaviour of the materials in the body of the dam. In addition, they can choose to carry out an analysis in 2D or 3D. For both cases, appropriate geometry data are provided, and a finite-element mesh is also proposed. Thus, by comparing the different solutions, it should be possible to draw conclusions about how the different assumptions and approaches influence the results obtained.

2 Deliverables

2.1 Analysis results

Results of the analysis carried out are to be presented using the corresponding spreadsheet supplied by the formulators. Results must be presented in units of the International System of Units (SI units), as shown in the attached model file, 17_ICOLD_BMWS_ThemeB_Template_Results.xlsx. The file containing the results shall be named 17_ICOLD_BMWS_ThemeB_Names_Results.xlsx, where Names stands for the surname(s) of Contributor(s), joined by underscore(s).

The Formulators will compile, evaluate, and format the results for a general presentation at the workshop. The results will be presented in a logical order during the workshop identifying general findings and/or correlations between data sets. The summary of the results prepared by the Formulators will be made available to Contributors at least two weeks before the workshop date for review and preparation for constructive discussion at the workshop.

2.2 Paper

Contributors are to prepare a paper describing the approach and methods used in the analysis. The paper will present the results and, where appropriate, describe how they vary according to the parameters and methods used. In addition, the paper may include a discussion of the lessons learned from the analysis and general observations about which model parameters have the greatest impact on the results. The paper is limited to 12 pages and must follow the format provided in the attached template file 17_ICOLD_BMWS_ThemeB_Template_Paper.docx. The file containing Contributors' paper shall be named 17_ICOLD_BMWS_ThemeB_Names_Paper.docx, where Names stands for the surname(s) of the Contributor(s), joined by underscore(s).

2.3 Workshop presentations

During the Workshop session, the Formulators will present the case study and a summary of the analysis results submitted by Contributors.

The Workshop Committee will invite Contributors to present their general conclusions, aspects studied, unexpected analysis results and/or questions to be addressed in the future. The presentation of the results of the case study analysis should not form part of Contributors' presentations. The length of Contributors' presentations will be determined by the Workshop Committee according to the number of contributions.

The presentations will be followed by a discussion in which all workshop participants could participate.

3 Case study of Plovdivtsi Dam

Plovdivtsi Dam (Figure 1) is an asphalt-concrete core rockfill dam, located in southern Bulgaria (latitude 41°24'18 "N, longitude 24°48'3 "E), close to the border with Greece, at an altitude of around 900 m asl. It bars the valley of the Iskrets River, just upstream of the village of Plovdivtsi and fourteen kilometres south of the town of Rudozem. The Plovdivtsi Project comprises an upstream cofferdam (which is integrated into the dam body), the aforementioned asphalt-concrete core rockfill dam, its bottom outlet and morning-glory spillway, combined with an intake tower, and a potable water treatment plant (PWTP). The dam is approximately 50 m high at its deepest point, and creates a reservoir of total volume of 2.3 million m³. The project was designed in the 1980s; its construction started in the 1990s and was completed in 2017 after a long break.

The dam embankment is made of compacted rockfill which is obtained from a rock quarry located in the reservoir and close to the dam. The impervious element is an asphalt-concrete diaphragm (ACD) founded on a reinforced-concrete slab. The ACD thickness is 60 cm from the bottom to El. 904.00 and 50 cm above this elevation. The ACD is conjugated with the upstream and downstream rockfill shells by filters and transition zones.



Figure 1: The completed Plovdivtsi asphalt-concrete core rockfill dam

3.1 Geometry

The crest of Plovdivtsi dam is at El. 927.30 m asl, the maximum operating water level of the reservoir is El. 924.77 m asl, and the minimum operating water level is El. 908.60 m asl. The foundation of the embankment follows the natural morphology of the rock in the valley of the Iskrets River.

The maximum dam height is 47.35 m from the natural ground surface and 52.25 m from the foundation slab of the asphalt-concrete diaphragm. The crest length is 225 m. The layout of the dam is shown in Figure 2 (Technical design 2013).

Figure 3 shows the highest cross-section of the dam (Technical design 2013). The slope of the upstream shell is 1:1.8. The slope of the downstream shell varies from 1:1.8 at the toe to 1:1.6 at the crest. The downstream face features two 3 m-wide berms at 896.00 m asl and 912.00 m asl respectively.

The embankment dam body consists of an asphalt-concrete diaphragm, filter and transition zones, compacted rockfill shells and a rip-rap. A two-row grout curtain with a depth of 35.0 m below the ACD foundation slab is built.

The width of the filter zones on both sides of the ACD is as follows:

- 1.45 m for ACD width of 0.60 m (i.e., the lower part, up to elevation 904.00 m asl); and
- 1.50 m for the ACD width of 0.50 m (i.e., the upper part, above elevation 904.00 m asl).

The dam foundation consists predominantly of rhyolites. Macroscopically they are grey to dark grey, fine to medium grained, porphyric. In the surface zone they are modified to grey-whitish and rusty brown, fine to medium blocky jointed. Petrographic analysis has determined that the rocks at the dam and quarry site are hydrothermally altered rhyodacites.

Figure 2 presents the layout of Plovdivtsi Dam and PWTP Project. Figure 3 and Figure 4 give the highest cross-section and a longitudinal section along the dam axis respectively. It is noted that the hatched area below El. 864 indicates the part of the embankment built during the initial stage of construction that took place in the 1990s.

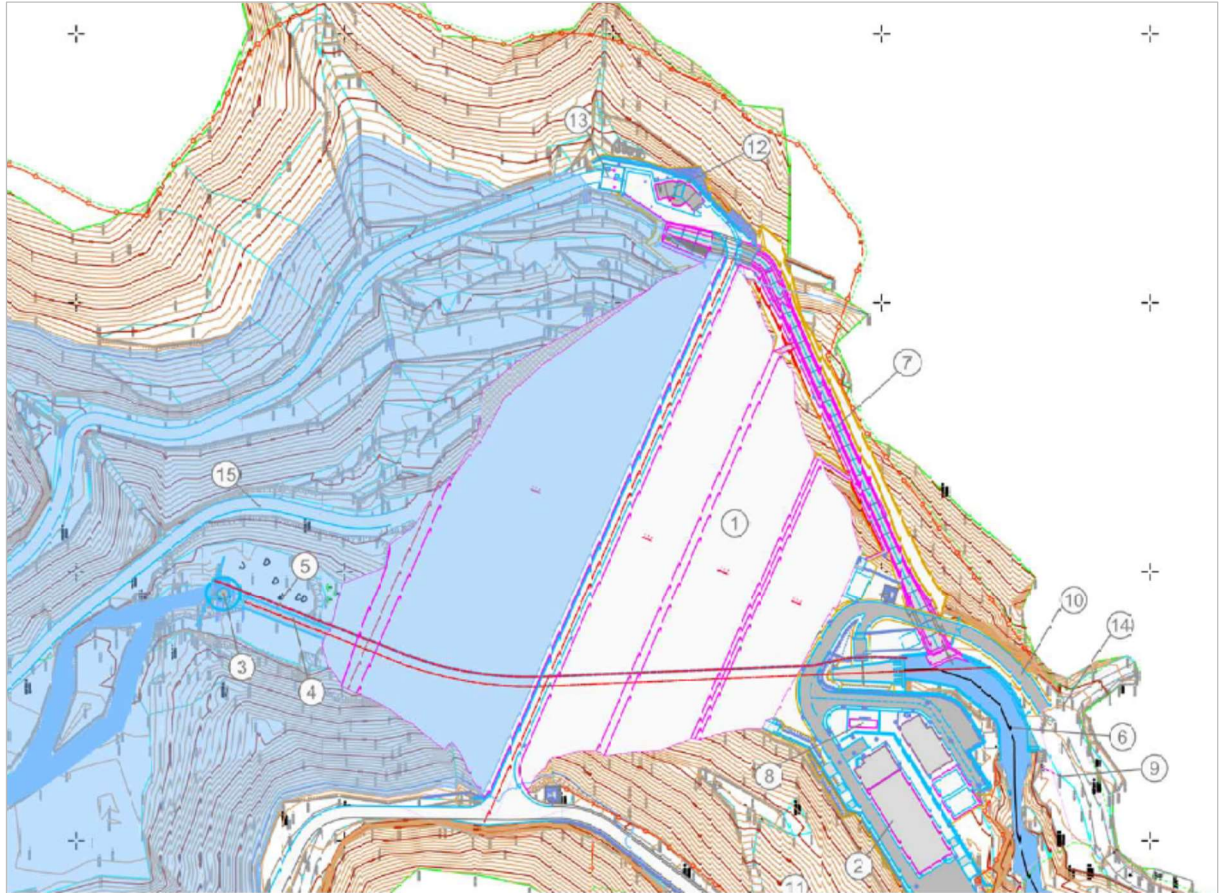


Figure 2: General layout of Plovdivtsi Dam and PWTP Project

1 – Dam; 2 – PWTP; 3 – Intake tower and morning-glory spillway; 4 – Diversion gallery; 5 – Bottom outlet; 6 – Correction of the Iskrets river; 7 – Ogee spillway; 8 – Transformer station; 9 – Water supply collector; 10, 11 – Service roads; 12 – Service building; 13 – Weather station; 14 – Check point; 15 – Temporary access roads

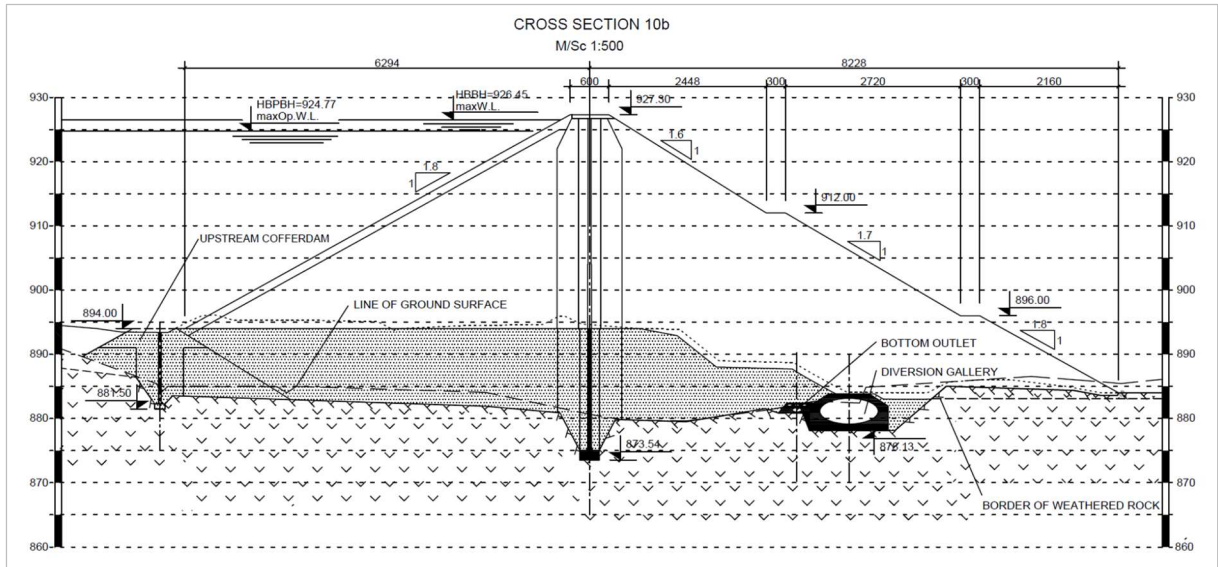


Figure 3: Highest cross-section of Plovdivtsi Dam

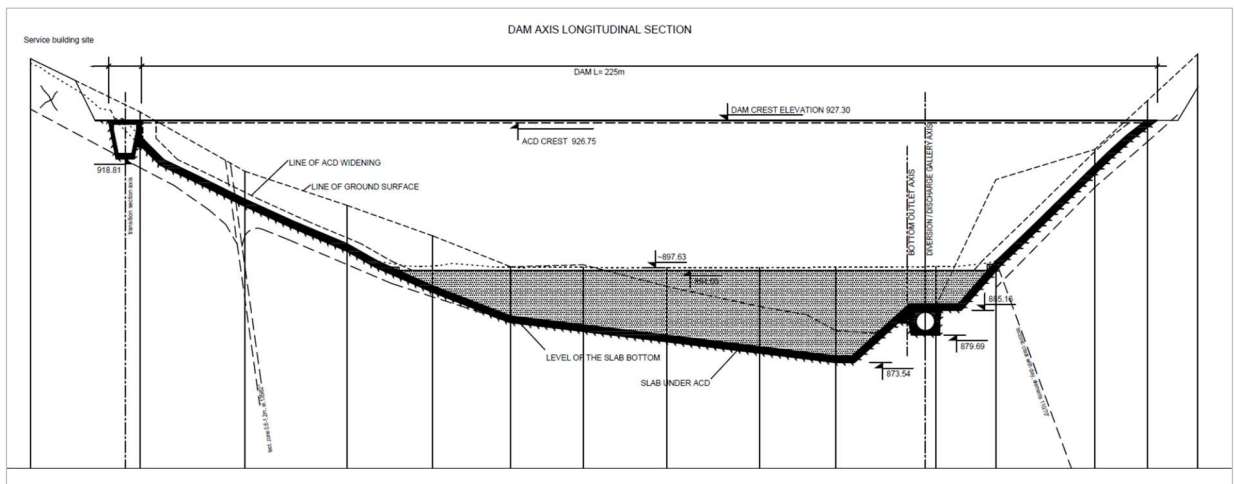


Figure 4: Longitudinal section of Plovdivtsi Dam

3.2 Materials

It is well known that the stress-strain behaviour of rockfill materials depends on numerous parameters such as mineralogy, particle size distribution, void ratio, stress level and water content. In general, the mechanical behaviour of rockfill materials is non-linear, with strength and stiffness dependent on applied load and stress level (Marsal, 1972).

In addition, the loading rate can also play an important role when the structural behaviour is non-linear. However, in the case of the relatively rapid impoundment of the Plovdivtsi Dam reservoir, no dynamic character of the loading is necessary to be accounted for. The loading rate in this case is far from that of a seismic excitation, for example, and can be applied in stages as a static load. The main objective of Theme B is to model and analyse the complex behaviour of the dam under the unexpected conditions of the first impoundment.

The grain-size distribution of the materials in the different zones of the dam body is presented in Figure 5 (Technical design 2013). Additional parameters of these zones are given in particular, too.

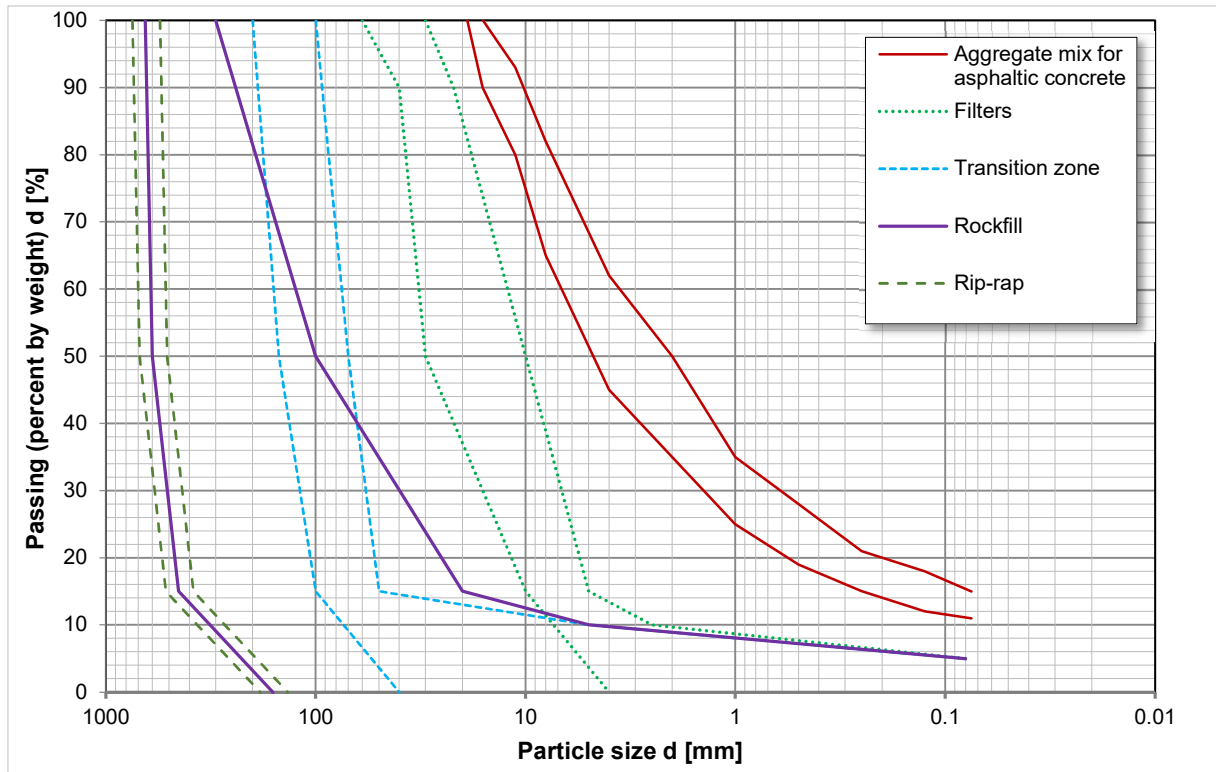


Figure 5: Granular distribution of the material zones of the dam body

Table 1 summarizes the physical and mechanical parameters used in the design calculations (Technical Design 2013). The values of the various material characteristics were defined based on the results of extensive field and laboratory investigations performed in 2012-2013 after the construction break in 2001.

3.2.1 Foundation

The length of Plovdivtsi reservoir at maximum water level 926.45 is about 1.1 km. The ground in the area of the reservoir is built of Oligocene vulcanites covered by quaternary rock deposits.

The site of the dam body is located in a valley of an asymmetric profile with a left abutment slope of 15-25° and a right abutment slope of 35-45°. The valley is 50-80 m wide within the area of the dam body.

The dam foundation is formed by volcanic rocks, namely rhyolite shroud of Oligocene age (μPg3), overlaid by Quaternary formations.

The rhyolites are macroscopically grey to dark grey, small to medium grained, porphyritic varieties. They change in the surface zone to grey-whitish and rusty brown, fine to medium-block fractured.

Talus accumulations are represented by sandy clays, light brown, with edgy rock fragments and as outwash of strongly sandy clays. Talus accumulations are outcropping on the surface at the section of formed plainness of the site and along the slope to the southeast thereof. The talus accumulations thickness is determined to be 1.2 m to 2.0 m thick along the slope up to 2.5 m to 4.5 m thick at the levelled site section.

A seepage coefficient $k_r = 1.46 \cdot 10^{-5} \text{ cm/s}$ (0.0126 m/day) was determined for the rock foundation during the investigations performed in 2012. However, mechanical cleaning of the foundation rock was carried out at the start of dam construction, and a two-row grout curtain was built. Consequently, the bedrock foundation can realistically be considered sound, homogeneous and impermeable, with the parameters shown in Table 1.

The friction coefficient in the contact “rockfill embankment – rock foundation” can be assumed $f = 0.6$.

Table 1: Physical and mechanical parameters of the embankment zones materials and the rock foundation used in the design calculations

	Parameters	Dry density	Porosity	Bulk density of saturated embankment	Deformation modulus	Poisson' s ratio	Angle of internal friction	Cohesion
№	Materials	ρ_d	n	ρ_r	E_0	ν	ϕ	c
		g/cm ³		g/cm ³	MPa	-	°	kPa
1	Rock foundation	2.50	-	-	6 000	0.29	-	-
2	Upstream rockfill shell	1.88	0.26	2.14	34	0.32	29	35
3	Downstream rockfill shell	1.88	0.26	-	39	0.32	31	37
4	Previously built rockfill	2.05	0.26	2.22	58	0.32	29	35
5	Upstream transition zone	1.90	0.29	2.19	41	0.30	28	74
6	Downstream transition zone	1.90	0.29	-	41	0.30	32	74
7	Previously built transition zones	1.92	0.29	2.21	41	0.30	28	74
8	Upstream filter	1.80	0.24	2.05	33	0.30	30	20
9	Downstream filter	1.80	0.24	-	33	0.30	34	26
10	Previously built filters	2.04	0.24	2.28	30	0.30	30	20
11	Asphalt concrete (ACD)	2.40	-	-	65	0.25	-	-
12	Concrete	2.30	-	-	25 000	0.18	-	-

3.2.2 Embankment shells

The rockfill shells of the dam were designed with a grain-size content and distribution according to the requirements of EM 1110-2-2300 2004. The material for construction of the shells was obtained from the rock quarry in the reservoir area.

The mechanical properties of the compacted rockfill of the dam shells were determined by means of field investigations carried out by means of plate load tests. The estimated values are listed in Table 1.

In addition, longitudinal (compressional) and transverse (shear) seismic wave velocities were defined for the previously built rockfill (below El. 894) as follows: $V_p=1800$ m/s; $V_s=848$ m/s.

3.2.3 Transition zones and filters

The transition zones of the dam were designed with a grain-size content and distribution according to the requirements of EM 1110-2-2300 2004 and considering the recommendations of ICOLD Bulletin 84 of 1992.

The average seepage coefficient of the transition zones was determined to be $k_{tz}=4.8 \times 10^{-3}$ cm/s (4.2 m/day).

The prevailing gravel-sand fraction content justified the use of an average value of the filter zones seepage coefficient $k_f = 2.58 \times 10^{-2}$ cm/s (22.3 m/day).

The as-built filter zones parameters were as follows:

- bulk density of the skeleton: $\rho_d=1.87$ g/cm³;
- volume content of water-soluble particles in the filters less than 5%;
- the content the filter material particles passing through sieve $d=0.074$ mm did not exceed 5%.

3.2.4 Asphalt-concrete diaphragm (ACD)

The asphaltic concrete is a mixture of gravel, sand, filler and bitumen.

The granular design of aggregates content for the ACD was performed according to the Fuller's curve ($P_i = (d_i/d_{max})^{0.41}$), i.e., in the range between 0÷19 mm, improved by a filler with grain size up to 0.063 mm. For better watertightness and workability, a natural round sand was added with gradation conforming to the aforementioned Fuller's curve.

The grain-size distribution of the ACD aggregates is given in Table 2.

Table 2: Grain-size distribution of the ACD aggregates

Sieve size mm	Passed quantity % by mass
19	100
16	90 - 100
11.2	80 - 93
8	65 - 82
4	45 - 62
2	35 - 50
1	25 - 35
0.5	19 - 28
0.25	15 - 21
0.125	12 - 18
0.063	11 - 15

The type of bitumen used was B70/100. The required content of bitumen was determined based on tests on samples taken from the asphalt-concrete built during the initial stage of dam construction, i.e., before the construction break in 2001. The objective was achieving void content less than 3% by volume.

The as-built bitumen content of the diaphragm varied from 6.5% to 7.5 % from the total weight, which allowed obtaining good workability and meeting the technical requirements.

Bitumen mastic is placed on the top of the reinforced-concrete base of the ACD to ensure good interface between the two elements.

The mastic consists of crushed stone with size of grains 0-4 mm, filler and bitumen in the following proportions by weight:

- bitumen 20%;
- filler 15%; and
- aggregates 65%.

The mechanical properties of the asphalt-concrete have been determined by means of laboratory tests. They are as follows (Høeg 2012):

- Residual porosity: maximum 3%;
- Compaction coefficient: minimum 0.98%;
- Swelling in percent of volume: 0.3%;
- Water saturation in % of the mass: 1.0%;
- Permeability $5.0 \cdot 10^{-7}$ cm/s;
- Volume density: 2.35 g/cm^3 .

In Figure 6 and Figure 7 below, stress and strain curves are shown as an example for two samples of the ACD (Høeg 2012).

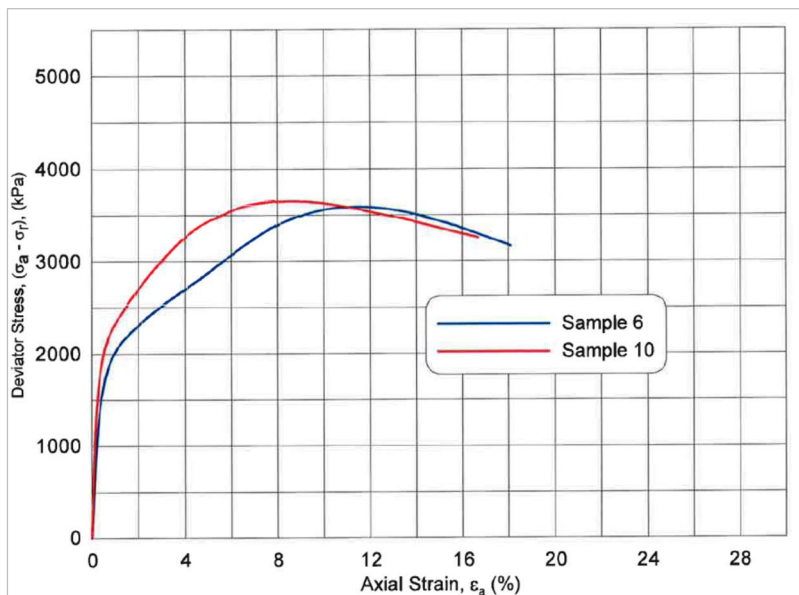


Figure 6: Deviatoric stress – axial strain curves for two samples of the ACD tested at the NGI (Høeg 2012)

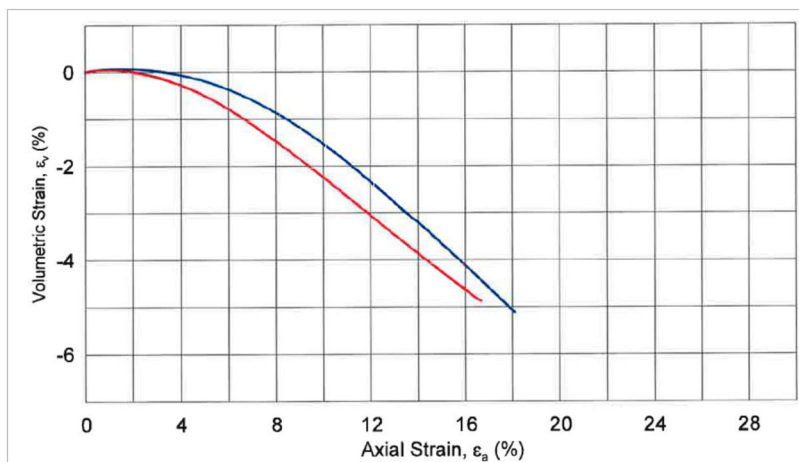


Figure 7: Volumetric strain – axial strain for two samples of the ACD tested at the NGI (Høeg 2012)

3.3 Construction stages

The part of the dam shown in Figure 3 and Figure 4 with grey hatch, as well as the intake tower and the gallery of the bottom outlet were already built in 2001, before the break until the restart of the works in February 2015. In Table 1, these material zones are referred to as “Previously built”. However, there is no need to consider in detail the two periods of construction (1999-2001 and 2015-2017). Thorough field and laboratory investigations were carried out in 2012, before the restart of the construction for completion of the dam and its facilities. The materials used for building the dam were obtained from the same sources and the placement and compaction of the fills were performed with the same methods. Also, the interface between the existing and new parts of the structures were carefully prepared. The executed physical connection between the existing and the new material zones allows considering the embankment zones as homogeneous ones. Nevertheless, if participants choose to consider that the existing and the new part of the embankment are different, they may use the material properties shown in Table 1.

3.4 Loads and load combinations

Theme B deals with the static analysis of the dam-foundation-reservoir system. The static loads are the self-weight of the asphalt-concrete core rockfill dam and the water loads of the reservoir.

During the design stage, the initial impounding was analysed for different variants with respect to the time (month) of the start of impounding process and the hydrological conditions (i.e., inflow to the reservoir) of the characteristic year (wet, average and dry).

It was foreseen to keep the water level in the reservoir at the following elevations (according to the requirements of the current national building code):

- Keeping the water level at El. 891.20, i.e., at 1/4 of the maximum reservoir depth, and maintaining this level during minimum 15 days for carrying out of the necessary observations and measurements;
- Keeping the water level at El. 902.30, i.e., at 1/2 of the maximum reservoir depth, and, from this water level, regulating the outflow through the dam bottom outlet for carrying out of the second series of measurements with maintenance of this level for at least 15 days, too.

Since it was not possible to determine precisely the starting moment of Plovdivtsi reservoir staged impounding, the following scenarios were developed (Technical design 2013):

- Initial reservoir impounding in an average hydrological year taking into account the residual water discharge and with start of impounding:
 - first variant: on 1-st February; and
 - second variant: on 1-st June.

According to the analyses carried out for such year, it was foreseen that the impounding could be completed as follows:

- first variant: for a total of approximately 2.5 months; and
 - second variant: for a total of approximately 7.5 months.
- Initial reservoir impounding in a dry year with annual probability of exceedance (APE) of 95%, taking into account the residual water discharge and with start of impounding:
 - first variant: on 1-st February; and
 - second variant: on 1-st June.

In this case, the impounding could be completed as follows:

- first variant: for a total of approximately 3.5 months; and
 - second variant: for a total of approximately 8.5 months.
- Initial reservoir impounding in a wet year with APE of 25%, taking into account the residual water discharge and with start of impounding:

- first variant: on 1-st February; and
- second variant: on 1-st June.

In a wet year with APE of 25%, the impounding could be completed as follows:

- first variant: for a total of approximately 2 months; and
- second variant: for a total of approximately 6 months.

In fact, the initial reservoir impoundment was completed in 18 days. Most of the flow entering the reservoir (about 1.5 million cubic meters) occurred on 2-nd and 3-rd December 2017 due to heavy rainfall in the catchment (see Figure 8). After the water level reached the full supply level, both spillways began operating with a total discharge of about 15÷18 m³/s. According to the corresponding instructions given, the bottom outlet was opened on 2-nd December 2017, and the water level decreased to El. 915 m asl. This water level was then maintained at this elevation for approximately two weeks.

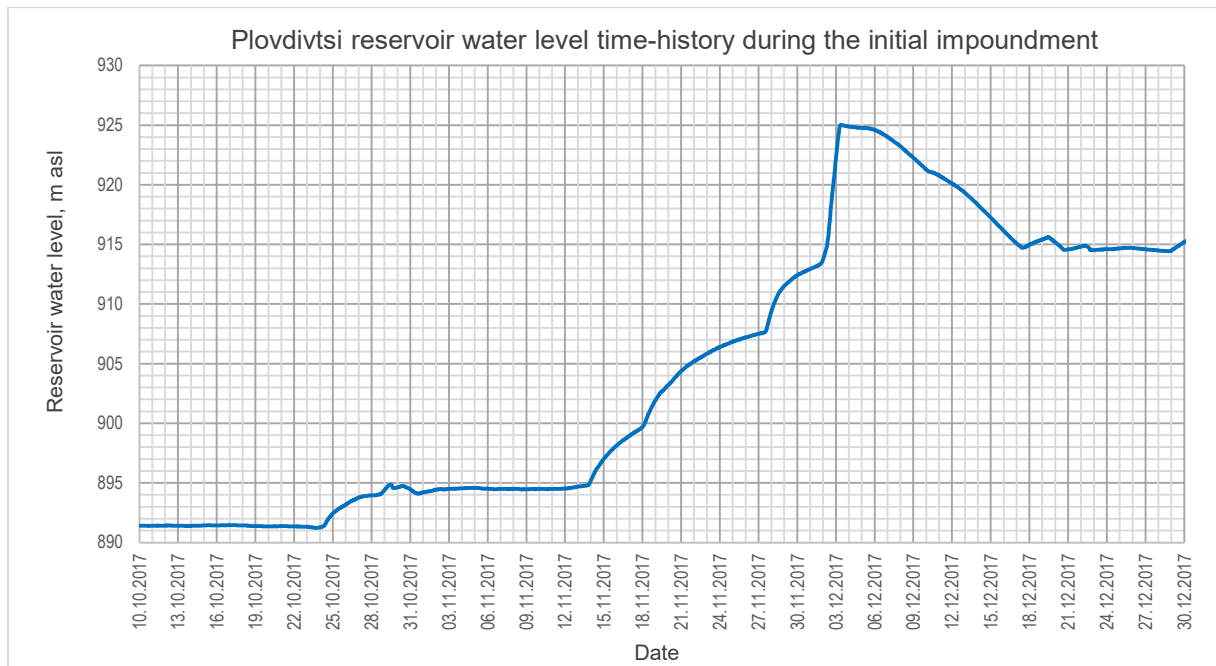


Figure 8: Plovdivtsi reservoir water level time-history (time-series are provided to Contributors in digital form)

4 Objectives of Theme B

The watertight element of the embankment dam is an asphalt-concrete diaphragm and the dam does not have an inspection gallery. Given that the first impoundment of the reservoir was unexpectedly intense, an appropriate numerical simulation and analysis of the initial impoundment, as well as of the post-impoundment behaviour of the dam is a matter of particular interest.

Contributors can use one or both of the 2D and 3D finite-element models provided. They can also use a finite-element mesh that they have defined themselves.

Contributors are expected to provide displacements and stresses of the dam body and of the asphalt-concrete diaphragm (ACD) for the following states of the dam and its reservoir:

4.1 End-of-construction state

Contributors will evaluate the end-of-construction displacements and stresses in the dam body and its ACD for water level in the reservoir at El. 891.40 m asl as shown in Figure 8.

4.2 Initial impoundment states

Contributors will evaluate the displacements and stresses in the dam body and its ACD for the water levels during the initial impoundment of the reservoir as shown in Figure 8. Contributors may choose the steps of increase and decrease of the water level. However, at least the following steps are to be considered:

- Increase of the reservoir water level to El. 910 m asl;
- Further increase of the reservoir water level to El. 925 m asl; and
- Decrease of the reservoir water level to El. 915 m asl.

4.3 Normal operation states

This part of the Theme B problem solving is optional.

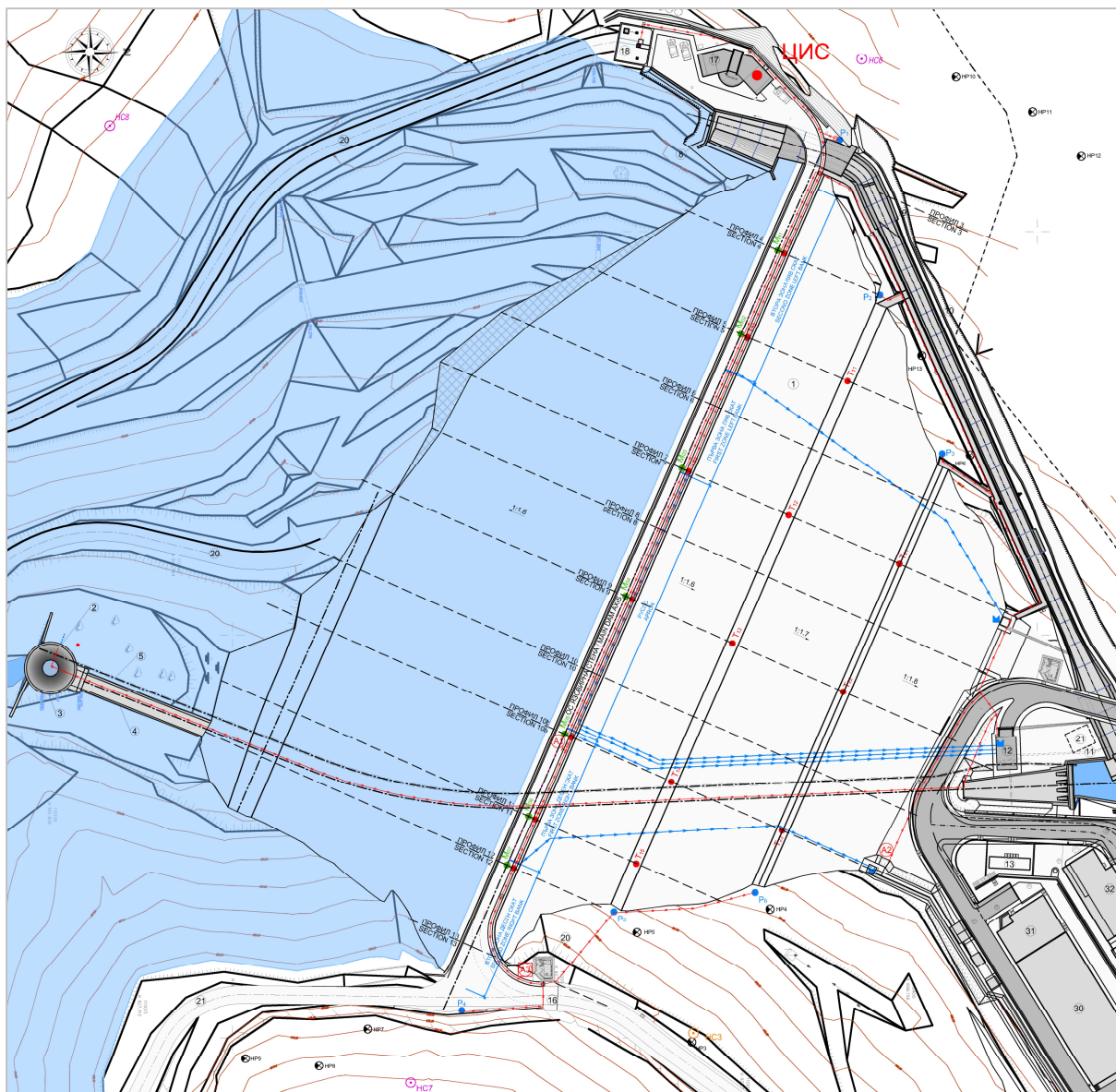
Contributors may evaluate the displacements and stresses in the dam body and its ACD for the water levels in the period after the reservoir initial impoundment. Data of the water level variation until 13 October 2022 are provided to Contributors in digital format.

It is suggested to provide results (displacement and stresses) for stages corresponding to the following dates:

- (1) 3 October 2018;
- (2) 2 October 2019;
- (3) 18 September 2021;
- (4) 13 October 2022.

The results obtained by Contributors will be compared against the respective displacements and stresses measured by means of the instrumentation system of the dam.

A plan-view of the instrumentation system is given in Figure 9. The location of the installed inclinometers and sensors is presented on a longitudinal section in Figure 10.



- HC Наблюдателен стълб - Първи етап / Observation pillar - First stage
- HC Наблюдателен стълб - Втори етап / Observation pillar - Second stage
- HP4 Нивелачен репер / Bench mark
- M Контролна точка АБД / Reference mark for asphalt concrete diaphragm
- T Контролна точка насип / Reference mark for rockfill
- P Пиезометър / Piezometer
- Измервателно устройство за дренирани води / Seepage weir
- Датчик за хидростатично налягане / Water level gauge
- A Акселерометър / Accelerometer
- Кабел от автоматизирана КИС / Cable from automated CMS
- Рейков водоотчет / Striped level gauge
- Дренажен извод / Drainage pipe

Figure 9: Plovdivtsi Dam instrumentation system plan-view

- (3) Stress – strain relationship of the asphaltic-concrete obtained from laboratory tests at NGI (Figure 6 and Figure 7).
- (4) Reservoir water level time-history for the period 30 October 2017 to 30 October 2022: (17_ICOLD_BMWS_ThemeB_Data_03.xlsx).
- (5) Temperatures in the dam body and the asphalt-concrete diaphragm: (17_ICOLD_BMWS_ThemeB_Data_04.xlsx).
- (6) Geometry of Section 10 of the dam: (17_ICOLD_BMWS_ThemeB_Geometry_2D.dxf).
- (7) Finite-element mesh of Section 10 of the dam: (17_ICOLD_BMWS_ThemeB_FEM_2D.dat).
- (8) Three-dimensional finite-element mesh of the dam (17_ICOLD_BMWS_ThemeB_FEM_3D.dat).

6 Results requested

As mentioned above in Section 2.1, the Contributors will present the following results in the Results spreadsheets (Name)_ThemeB_ResultSpreadsheet.xlsx.

6.1 End-of-construction state

The following results are requested for Section 10 for the conditions before the initial impoundment:

- Numerical results of the ACD vertical displacements;
- Numerical results of the ACD horizontal stresses;
- Numerical results of the ACD vertical stresses;
- A contour plot of the vertical displacements of Section 10;
- A contour plot of the horizontal stresses of Section 10; and
- A contour plot of the vertical stresses of Section 10.

In case Contributors perform a three-dimensional analysis, in addition to the above results, the same response quantities can be presented for the locations of Sections 7 and 11.

6.2 Initial impoundment states

Contributors are requested to evaluate the displacements and stresses in the dam body and its ACD for the water levels during the initial impoundment of the reservoir as shown in Figure 8 and as indicated in Section 4.2. The following results are requested for Section 10:

- Numerical results of the ACD horizontal displacements in upstream-to-downstream direction (i.e., in the direction orthogonal to the dam axis) and, in case of a 3D analysis, in bank-to-bank direction;
- Numerical results of the ACD horizontal stresses;
- Numerical results of the ACD vertical stresses;
- A contour plot of the horizontal displacements of Section 10;
- A contour plot of the vertical displacements of Section 10;
- A contour plot of effective horizontal stresses in Section 10;
- A contour plot of effective vertical stresses in Section 10;
- Evaluation and/or comment on potential cracking of the ACD.

In case of a 3D analysis, in addition to the above results, the same response quantities can be presented for the locations of Sections 7 and 11.

6.3 Normal operation states

As stated in Section 4.3, this part of the Theme B problem solving is optional.

Contributors are encouraged to provide the results and evaluation/comments as described in the above Section 6.2 and as indicated in Section 4.3.

7 Estimated time for Theme B problem solving and article preparation

It is estimated that Contributors will need three to four weeks of work to carry out the finite-element analysis and analyse the results obtained. In addition, Contributors will need time to provide the requested results and prepare an article and presentation.

8 References

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