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Editors of series: Dragan Veličković, Dušan Ilić, e-mail: facta@ni.ac.yu
Address: Univerzitetski trg 2, 18000 Niš, YU
Tel: +381 18 547-095, Fax: +381 18 547-950

SAFETY PROVISIONS AGAINST PIPING FOR SELOVA DAM

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Veljko Marković[1], Ćirić Miodrag[2], Jelena Marković[1]

[1]University of Niš, Faculty of Civil Engineering
[2]V.P. Selova, Kuršumlija

Abstract. *Selova dam is clay core rockfill dam a total height of 71.00 m. In the longitudinal profile the valley is nonsymmetrical, with the left bank very slow and right bank relatively steep. The reduction in vertical stress has been computed for Selova dam to control the potential for hydraulic fracturing. The analyses, both on 2D and 3D finite element models have shown that the safety coefficient against core cracks is to be increased and consequently additional provisions were included into design: a interception filter zone and large semipervious tranzition zone between the core and the downstream shell as a second measure defensive line. The F.E. analysis has also pointed out a small amount of load transfer from shoulder to the core due to the settlement and little pore pressure build due to the free draining shoulders.*

INTRODUCTION

In the case of large clay core rockfill dams the safety of design provisions are checked in terms of preselected failure scenarios. Beside the classical slope stability, in the modern practice the safety control against piping is mandatary.

The interzonal interaction, the load transfer due to differential settlement and the effects of valley configuration can lead to reduction of the total vertical stress in clay core, creating a potential of hydraulic fracturing in clay core zone.

The design of the dam cross section has to include several defensive measures against the consequences of a potential path of concentrated leakage.

The paper deals with the analysis performed for Selova dam in order to compute the actual pattern of the vertical stress within the core and the present concept of the cross section design.

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2. SELOVA DAM

Selova dam is designed as a clay core rockfill dam with total height of 71.00 m, the crest of the length of 430 m and of 8.00 m width (fig. 1.).

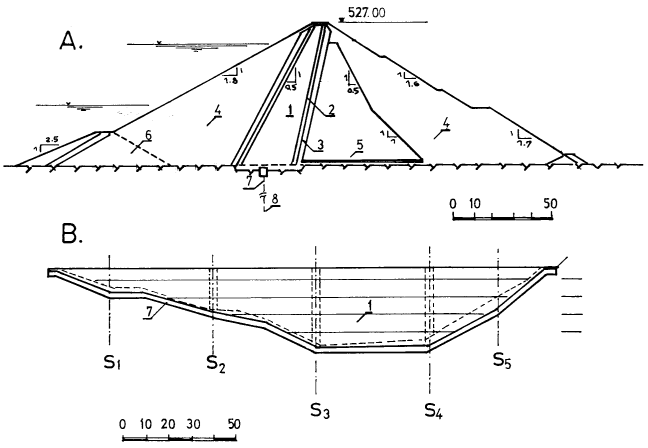

Fig. 1. Selova dam
A – Main cross section, B – Longitudinal profile
1 – clay core, 2 – filter I, 3 – filter II, 4 – rockfill,
5 – semipervious tranzition zone, 6 – cofferdam,
7 – grouting gallery, 8 – grout curtain,
$S_1 - S_5$ – monitoring sections

The dam will create a storage reservoir of 70×10^6 m^3 for water supply of town of Nis and of vilages along Toplica river (46×10^6 m^3) and for flood control (17×10^6 m^3).

The design dam cross section has a slightly inclined clay core, two filters zone bording the core and a large semipervious tranzition zone downstream the core. The shells are made of compacted rockfill (fig. 1.a.).

In the longitudinal profile the valley is nonsymmetrical, with left bank very slow and the right bank relatively steep. Along the valley bottom and the abutments is provided the grouting and drainage gallery. The dam behavior during the construction stages and operation stafes will be is monitored by five control cross section equipped with instrumentation for settlements, total stress, pore pressure measurements.

3. EFFECT OF THE VALLEY CONFIGURATION ON DAM BEHAVIOR

It is known the fact that effective vertical earth pressure in the core is influenced by three factors as follows. The first is the shape of the cross-section of the dam. The second is some difference in the density and rigidity of each zone. The third is the shape of the valley.

For the first two factors the rate of reduction was estimated by a two – dimensional progressive analysis based on the finite element models. The reduction of the vertical earth pressure was about 10% and consequently in the normal range for this type of the dam.

Special attention was paid to the effect of the valley configuration, which is nonsymmetrical and has a significantly steeper bank. In order to determine the rate of reduction in vertical earth pressure depending on valley configuration a three – dimensional F. E. analysis was performed. The vertical stress near the right abutment is only 70% of the corresponding vertical earth pressure, thus revealing the least safe condition as far as the hydraulic fracturing is concerned.

4. STABILITY AGAINST HYDRAULIC FRACTURING

The reduction in vertical stress computed for Selova dam may cause to hydraulic fracturing. If such craks penetrate through the inpervious core, a predetermined path of the concentrated leakage with progressive character can be developed leading to piping as a cause of failure. Consequently, a thorough analysis has been performed concening this matter.

Hydraulic fracturing criterion was defined according to Duncan and all. Consider a point, at depth H in the core and let γ_{sat} be the mean saturated unit weight and γ_w be the unit weight of water. Then the critical vertical stress is expressed as a $\gamma_w \cdot H$. Consequetly, in the case where $\gamma_{sat} = 19$ kN/m^3 and $\gamma_w = 10$ kN/m^3, the actual vertical stress will become lower then the water pressure where rate of reductin in vertical earth pressure reaches 50%. If the tensile strength of the core material is negligible, there would be a possibility that hydraulic fracturing may occur.

The analyses performed for Selova dam, both on 2D and 3D finite element models have shown a maximum rate of reduction of 70% at the bottom of right abutment. Conseqently the safety coefficient against piping is to be emplayed and additional provisions were included into designs: they consisted of a interception filter zone, leading the seepage flow towards downstream by means of the drainage blanket and of a large semipervious tranzition zone in the downstream shell as a second defensive measure against piping.

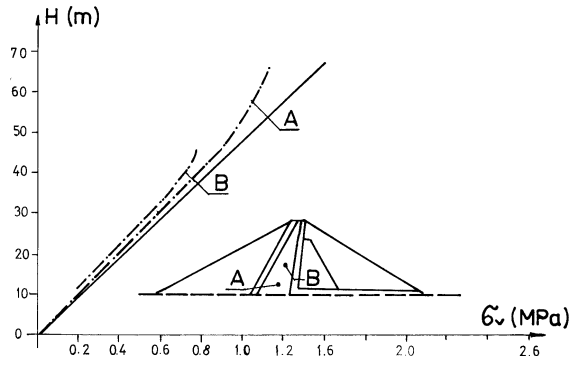

Fig. 2. Vertical stress in clay core compared with vertical earth pressure

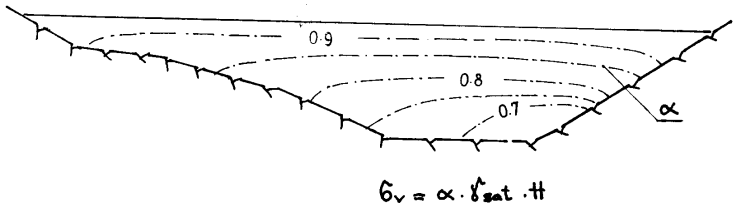

Fig. 3. Rate of reduction in vertical earth pressure due to valley configuration

5. LOAD TRANSFER DUE TO DIFFERENTIAL SETTLEMENT

In many dams differential settlements of the rockfill shoulders relative to the clay core can be expected during and after construction. Such differential settlements are likely to transfer load from the shoulders to the core thus causing a reduction in vertical effective stress in the shoulders, which can be expected to reduce the shear strength along a potential slip surface.

The purpose of the study was to find out if the overall effect on the safety factor is important. Two procedures were used to calculate the safety factors – the finite element method and the limit equilibrium method.

The F.E. analysis has provided evidence of a small amount of load transfer from shoulder to the core due to the settlement and small pore pressure build up to the core siye and the free draining shoulders.

The study has shown the insignificant reduction in the safety factor due to a decrease in effective stress across a potential failure surface.

6. CONCLUDING REMARKS

Selova Dam has several constructive provisions in the main cross section in order to eat as defensive measures against piping.

The effects of the valley configuration on the rate of vertical stress reduction are moderate and are localized at the base of the right abutment.

The interzonal interaction as well as the three-dimensional behavior of the dam body lead to a rather small safety factor against hydraulic fracturing and consequently a downstream filter zones and combined with a large semipervious transition zone was provided.

The load transfer due to differential settlement is insignificant and the safety factors for the dam stability are not affected by the reservoir filling.

MERE SIGURNOSTI PROTIV FILTRACIONE EROZIJE KOD BRANE SELOVA

Veljko Marković, Ćirić Miodrag, Jelena Marković

Brana Selova je kamena brana sa glinenim jezgrom ukupne visine 71.00 m. U poprečnom preseku dolina je nesimetrična, pri čemu je leva obala sa blagim nagibom, dok je desna relativno strma. Redukcija vertikalnih napona je sračunata kod brane Selova u cilju razjašnjenja mogućnosti pojave hidrauličkog sloma. Analize, kako 2D tako i 3D modeli sa konačnim elementima, su pokazale da koeficijent sigurnosti protiv sloma treba povećati i saglasno tome uključeno je dopunsko osiguranje u projekat: zaštitna filterska zona i velika polupropusna zona između jezgra i nizvodne kosine kao druga odbrambena mera. Anlize sa konačnim elementima takođe pokazuju da postoji mali prenos sila sa bokova na jezgro tokom sleganja i malo povećanje pornog pritiska u jezgru.