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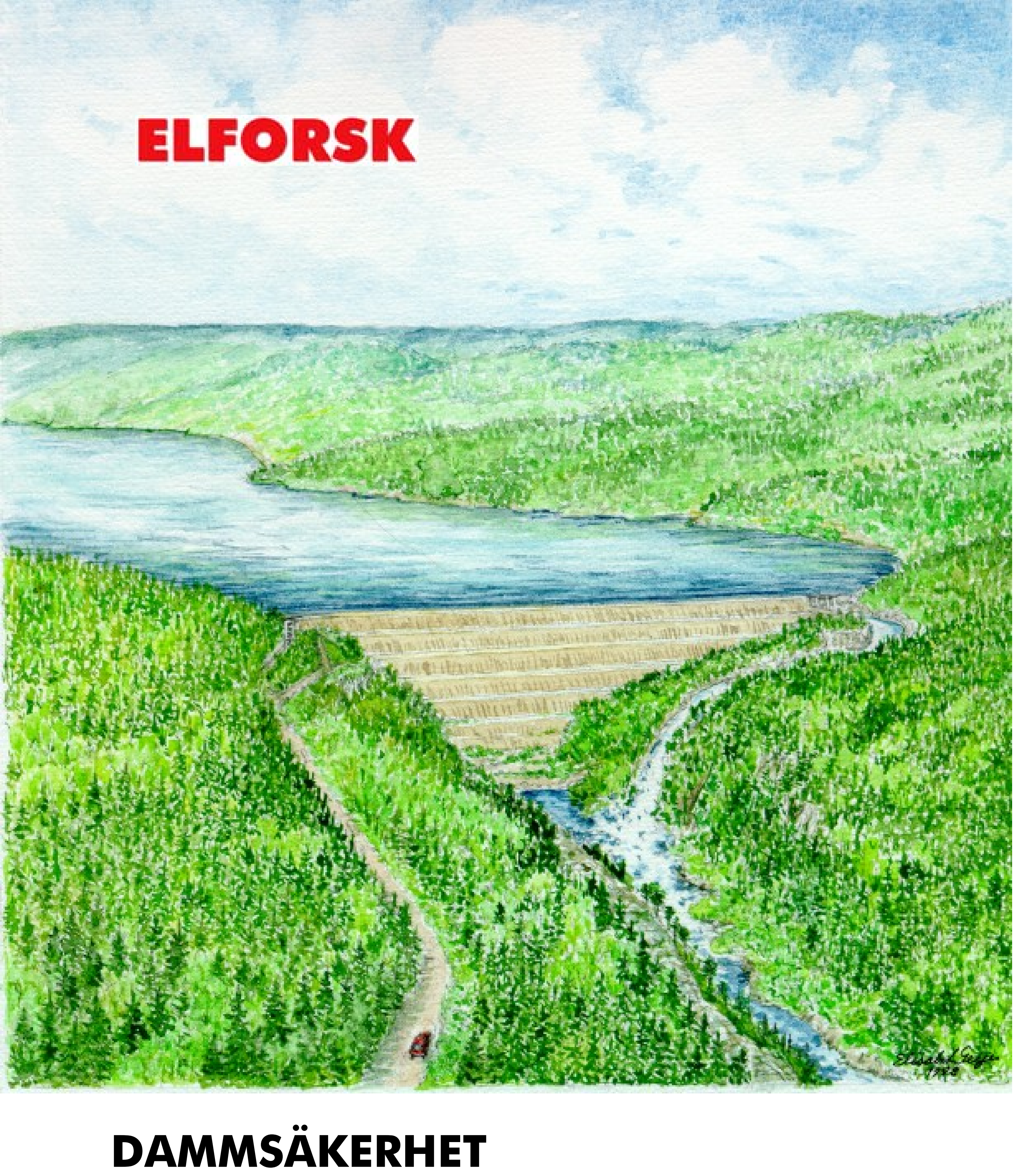

DAMMSÄKERHET

Dam-Break Project in Norway, CFD Evaluation of Test Results

Rapport 05:02

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Elforsk report 05:02

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Vattenfall Utveckling AB

May
2004

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VATTENFALL

Förord

Stockholm januari 2005

Denna rapport är ett delresultat inom Elforsk ramprogram Dammsäkerhet.

Kraftindustrin har traditionellt satsat avsevärda resurser på forsknings och utvecklingsfrågor inom dammsäkerhetsområdet, vilket har varit en förutsättning för den framgångsrika utvecklingen av vattenkraften som energikälla i Sverige.

Målen för programmet är att långsiktigt stödja branschens policy, dvs att:

- Sannolikheten för dammbrott där människoliv kan vara hotade skall hållas på en så låg nivå att detta hot såvitt möjligt elimineras.
- Konsekvenserna i händelse av dammbrott skall genom god planering såvitt möjligt reduceras.
- Dammsäkerheten skall hållas på en god internationell nivå.

Prioriterade områden är Teknisk säkerhet, Operativ säkerhet och beredskap samt Riskanalys.

Ramprogrammet har en styrgrupp bestående av: Jonas Birkedahl – FORTUM, Malte Cederström - Vattenfall Vattenkraft, Anders Isander – Sydkraft Vattenkraft, Lennart Markland – Vattenregleringsföretagen, Urban Norstedt - Vattenfall Vattenkraft, Gunnar Sjödin – Vattenregleringsföretagen samt Lars Hammar - Elforsk

Lars Hammar
Elforsk AB

Summary

Two-dimensional CFD seepage calculations by FLUENT are carried out of two 5 and 6 m high dams tested during 2001-02 in Norway. Based on the field data of reservoir water level and seepage flow rate, regression analysis is made to best fit dam material properties as hydraulic conductivity or permeability. The modeling purpose is, under given hydraulic conditions, to examine the difference in laminar and turbulent seepage.

As for the 2C-2002 homogenous gravel dam, the seepage is laminar, with a hydraulic conductivity of $K = (3.3 - 3.8)\cdot 10^{-5}$ m/s. Simulations show that the change in the phreatic surface in the dam is almost negligible if the vertical permeability is put 4 – 5 times as low as the horizontal.

For the 1-2001 homogenous rock-fill dam, the seeping flow is found to be turbulent. For two water depths H = 4.07 and 6.11 m, the best-fitted turbulent permeability is $k_t = (5.0 - 5.3)\cdot 10^{-3}$ m^2/s^2, with Re = 2230 - 2350. The maximum seeping velocity corresponds to 5.7 – 6.0 cm/s. For H = 5.22 m, much lower permeability is obtained, $k_t = 3.3\cdot 10^{-3}$ m^2/s^2. It is unclear if there is any error in the field data.

For turbulent seepage, if modeled as laminar seepage, the piezometric surface would be lower, while the seeping velocity would be much higher. The safety factor in slope stability analysis, as well as the risk for particle erosion, would be therefore over-estimated.

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Appendix

1 Introduction

Starting autumn 2001, a number of field tests of stability and dam break were made downstream the dam Røssvasdammen on the river Røsssåga, close to the town Mo i Rana. The last one was completed in October 2003. The dams were embankment dams constructed of various materials. Those tests constitute en essential part of the EC project "Stability and Breaching of Dams", within the framework IMPACT (Investigation of extreme Flood Processes and Uncertainty). More descriptions about the project, presentation of field data and preliminary results can be found separately in reports from Norconsult and Høeg et al. (2004).

Figure 1.1 Location of test site

One important issue that has arisen during the project is the modeling of seeping flow through the tested embankment dams. In several tested dams, the leakage was large, turbulent seepage, or the transition between turbulent and laminar flow, might occur. Seepage modeling so far made with the purpose of analyzing dam slope stability is based on the commercial code SEEP (http://www.geo-slope.com) and the like, in which laminar seepage is usually assumed.

FLUENT is a general-purpose CFD code, with the possibility of computing both laminar and turbulent seeping flow and their transition in porous materials. More information about the program and its functions can be found at http://www.fluent.com.

The FLUENT program has been used to model the seeping flow through two test dams in the Norwegian dam-break tests, the results are summarized in this report. The modeling is of the type regression analysis. In other words, based on the field test results of a given dam, calculations are made, on a trial and error basis, to determine proper parameters, such as permeability, ratio of vertical to horizontal permeability, etc.

2 Evaluated Test Cases

In Figure 2.1 and 2.2, the river-valley topography at the dam-break test site is given. The valley is about 35 m wide at +370 m.a.s.l. The two simulated test dams, 1-2001 and 2C-2002, are described in the sections that follow.

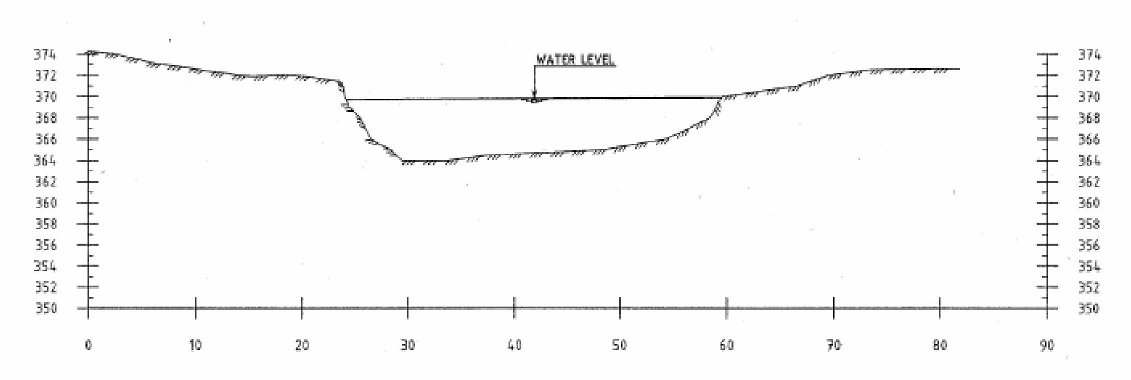


Figure 2.1. River valley cross-section at the test site

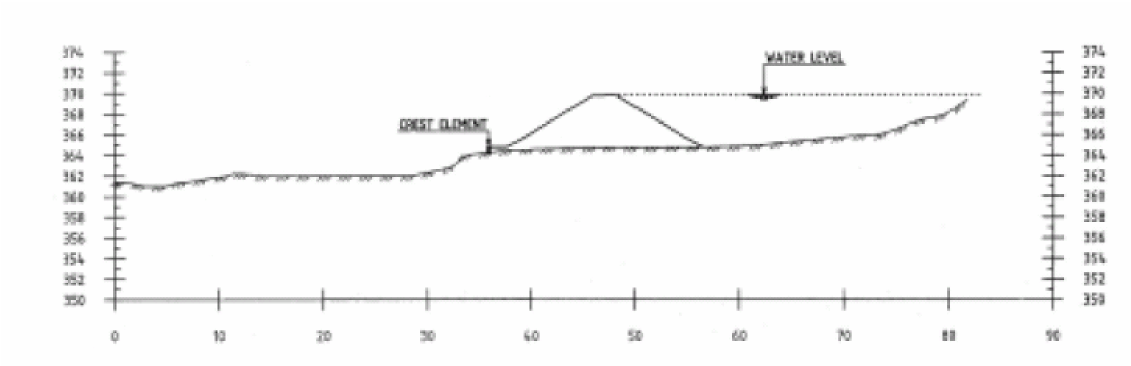


Figure 2.2. Longitudinal profile of the test site

2.1 Test case 1-2001

The test case 1-2001 was a homogenous rock fill dam, the cross section of which is given in figure 2.3. The height of the dam was 6.2 m and the crest wide was 2.9 m[1]. The dam toe was located at +364.81 m.a.s.l. The dam slope was at 1V:1.6H upstream and 1V:1.5H downstream. A plan of the dam including the measurement positions of pore pressure sensors is given in figure 2.4. The experimental data of the pore pressure are given in appendix A1. A sieve curve of the dam is given in figure 2.5, with a mean diameter of d_{50} = 126 mm and d_{10} = 30 mm.

[1] The dam geometry used in the simulation for upstream water depth H = 4.07 m differs slightly from the dimensions in the field tests – dam height 6.0 m; dam crest width 2.8 m; and dam slope V1:H1.5 both upstream and downstream.

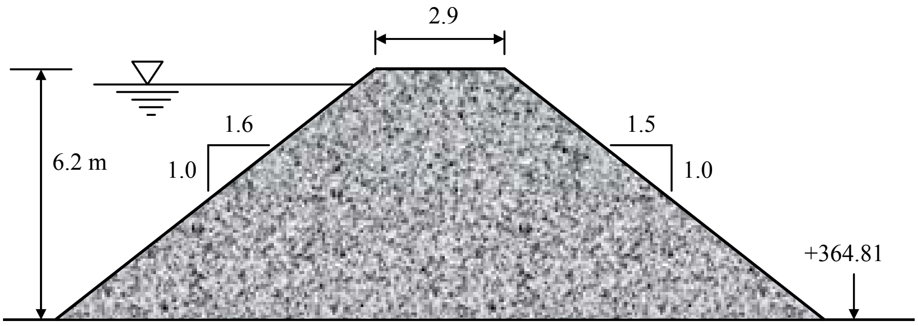


Figure 2.3. Dimensions of the dam in test 1-2001.

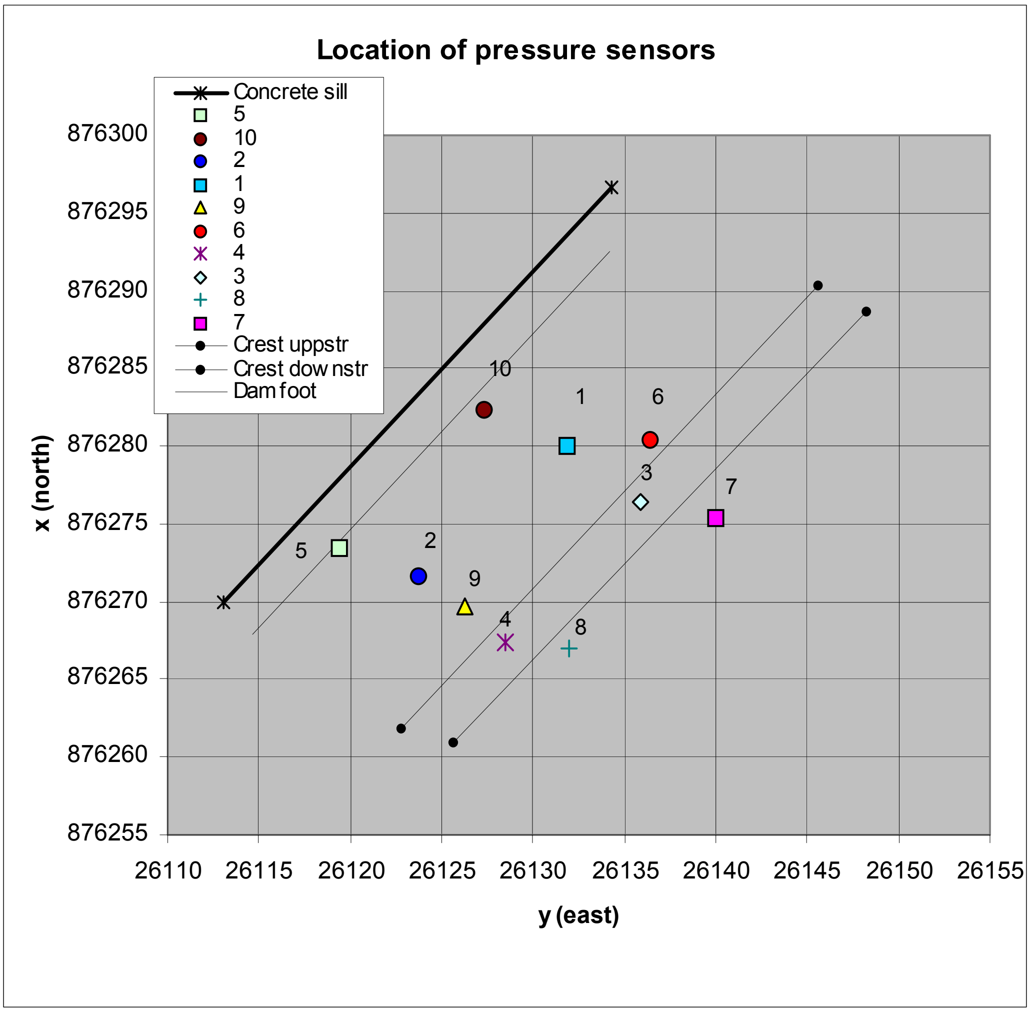


Figure 2.4. Location of pore pressure sensors in test dam 1-2001, seen from above.

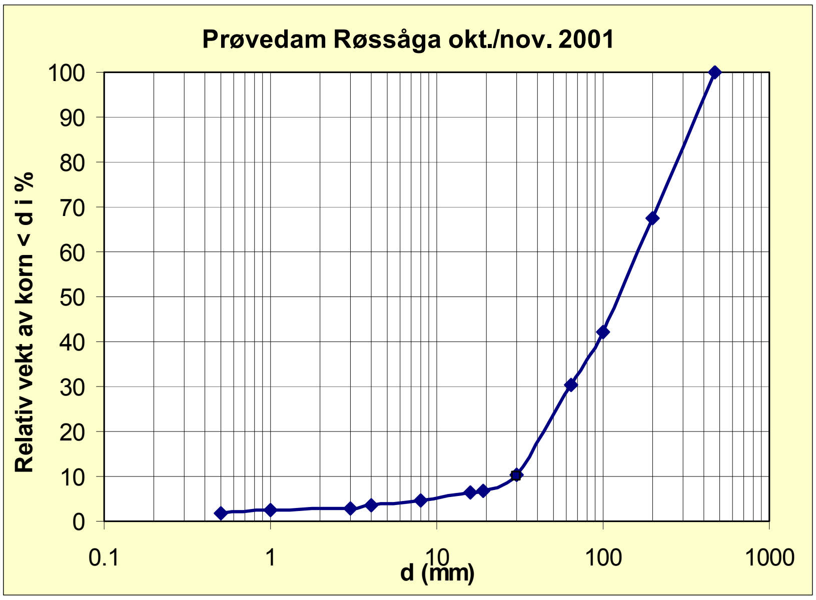


Figure 2.5. Sieve curve for test dam 1-2001.

2.2 Test case 2C-2002

The test dam 2C-2002 consisted of sandy gravel, with a height of 5 m and a crest wide of 2.2 m, see figure 2.6. The dam toe was located +364.81 m.a.s.l. A plan of the dam, including the location of pore pressure sensors, is shown in figure 2.7. The experimental data are given in appendix A2 and a sieve curve of the dam material in figure 2.8. The mean grain size d_{50} is approximately 5 mm and d_{10} = 0.25 – 0.4 mm.

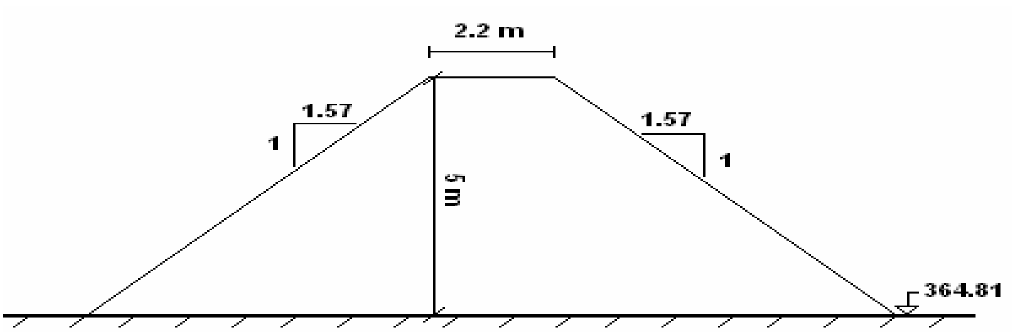


Figure 2.6. Dimensions of the dam in test 2C-2002

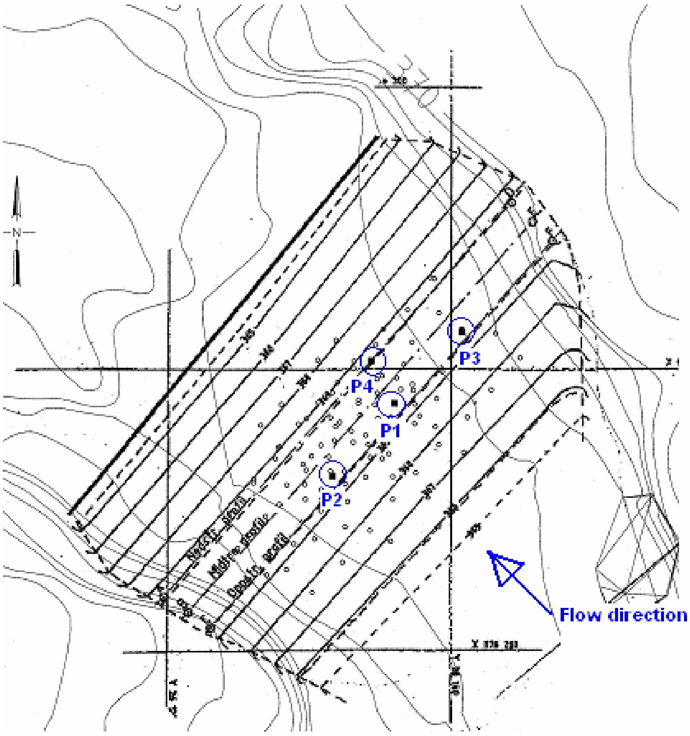


Figure 2.7. Plan of the test dam 2C-2002.

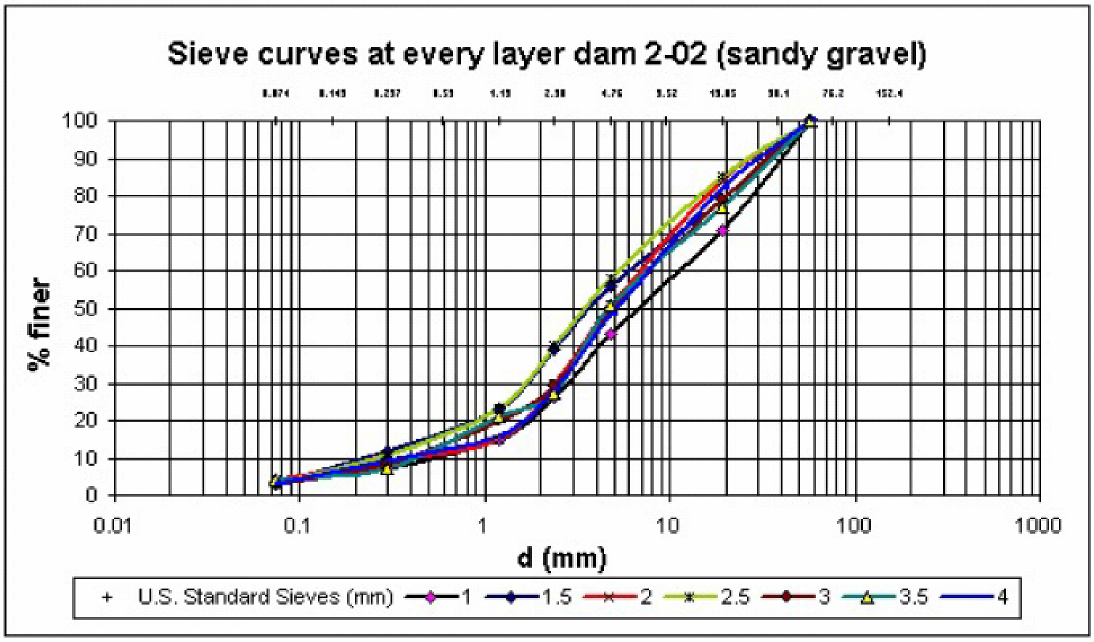


Figure 2.8. Sieve curve of the test dam 2C-2002.

3 Modeling Conditions

The seepage simulations are carried out in the commercial CFD code FLUENT, version 6.1.18. The geometry and grid are created in FLUENT's own pre-processor Gambit, version 2.1.2. The simulations are made in two dimensions. The grid consists of approximately 20 000 cells in both simulated test cases.

3.1 Model setup

Laminar seepage flow is usually governed by Darcy's law

$$V = K \cdot I \qquad \text{Equation (1)}$$

where V = nominal seepage velocity (m/s),
I = hydraulic gradient (-),
K = hydraulic conductivity (m/s).

Fully developed turbulent seepage is often defined by

$$V = \sqrt{k_t \cdot I} \qquad \text{Equation (2)}$$

where k_t = turbulent permeability (m^2/s^2).

In the transitional zone between laminar and turbulent seepage, the hydraulic gradient is generally expressed as

$$I = \frac{V}{K} + \frac{V^2}{k_t} \qquad \text{Equation (3)}$$

The seeping flow in FLUENT is modeled using the two-phase (water/air) flow theory. The model is called VOF, i.e. Volume of fraction (FLUENT Inc. 2001). The water-air interface, i.e. phreatic or piezometric surface, is defined as VOF = 0.5. The model is based on the assumption that the two phases don't interpenetrate. The momentum equations are solved for each phase. In a cell of the calculation domain, the volume fraction of each phase is tracked.

The dam is simulated as porous media. It means that a loss term, defined by equation (5), is added to the momentum equations (4) in FLUENT. The first term in equation (5) represents the laminar effect (Darcy's law), while the second corresponds to the turbulent loss.

$$\frac{dp}{dx_i} = -\rho g_i + S_i \qquad \text{Equation (4)}$$

$$S_i = -\left(\underbrace{\frac{\mu}{k_i}V_i}_{\text{Laminar term}} + \underbrace{\frac{1}{2}C_{2,i}\rho|V_i|V_i}_{\text{Turbulent term}}\right)$$ Equation (5)

where: i = 1, 2, 3

p	pressure (Pa),
ρ	density (kg/m^3),
g	gravity (m/s^2)
μ	dynamic viscosity (Pas)
k	laminar permeability (m^2)
C_2	inertial resistance factor (1/m)

The Reynolds number is usually defined as

$$\mathrm{Re} = \frac{\rho d\ V}{\mu} \quad \text{where } d\ = 1.7 d_{10}$$

For low flow velocity, the first term is dominating and the turbulent effect can be neglected. If the Reynolds number is less than 1 ~ 10, which may vary somewhat depending on source of origin, the flow is regarded as laminar. If the Reynolds number is larger than 600, the seepage can be regarded as fully developed turbulent flow. Between the two limits, the flow is in the transitional zone from laminar to turbulent.

Hydraulic conductivity, K (m/s), is often used instead of laminar permeability, k (m^2), and they are related by

$$K = \frac{k\rho g}{\mu}$$ Equation (6)

Comparing equation (2) with (5), one can relate C_2 with k_t

$$\frac{1}{k_t} = \frac{C_2}{2g}$$ Equation (7)

Equation (5) can be written as

$S_i = -\gamma \cdot I$ Equation (8)

where $\gamma = \rho \cdot g$.

In FLUENT, nominal seepage velocity V is used. The actual mean flow velocity, V_n, is obtained through

$V_n = \frac{V}{n}$ Equation (9)

where n = porosity.

3.2 Boundary conditions and material data

The boundary conditions used are specified in figure 3.1. The upstream slope below the water surface is defined as pressure inlet and the water depth, H, is taken from the experimental data. The remaining above-water part and dam crest are given as atmospheric pressure. The downstream slope is specified as pressure outlet, with atmospheric pressure.

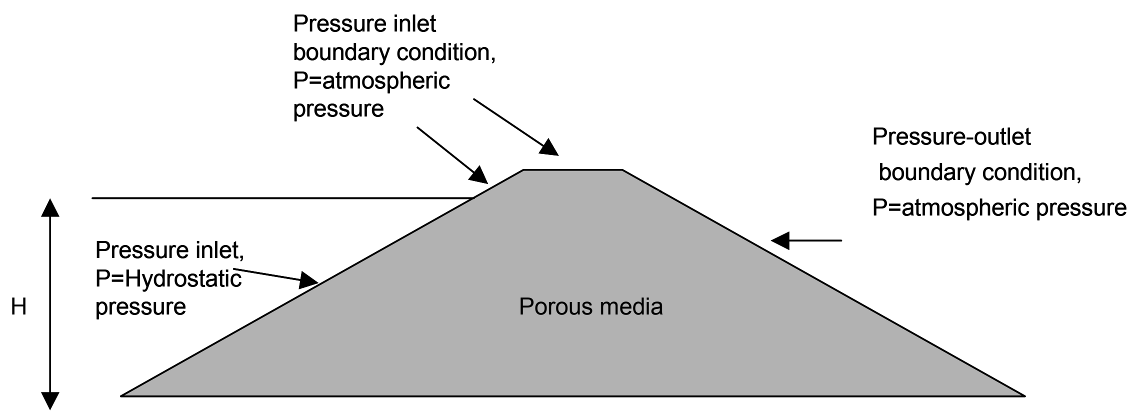


Figure 3.1. Boundary conditions used in FLUENT model

Data for the two test dams are given as follows. Three water levels/flow rates are analyzed for the 1-2001 case and two for the 2C-2002 case.

Test 1-2001: H = 4.07 m, flow rate q = 91 l/s/m
(corresponding to +368.88 m.a.sl., time 13:01, 19-10-2001)
H = 5.22 m, flow rate q = 112 l/s/m
H = 6.11 m, flow rate q = 188 l/s/m

Test 2C-2002:	H = 4.33 m, flow rate q = 0.0306 l/s/m (corresponds to +369.14 m.a.s.l., time 09:37, 16-10-2002) H = 4.95 m, flow rate q = 0.0389 l/s/m

The simulations are made with the following assumptions:

Temperature 10 °C (both water and air)

Air:	Density	ρ:	1.231 kg/m^3
	Viscosity	μ:	1.76e-5 Pa·s
Water:	Density	ρ:	999.7 kg/m^3
	Viscosity	μ:	1.304e-3 Pa·s

4 Results and Evaluations

4.1 Test Case 2C-2002

The Reynolds number for the test case 2C-2002 is found to be in the order of 10^{-3}. The case falls obviously within the range of laminar seepage, the turbulent term in equation (5) is neglected.

The hydraulic conductivity of the dam is estimated on a trial-and-error basis and adjusted to result in the measured flow rate trough the dam. The horizontal permeability is assumed to be the same as the vertical, i.e. isotropic material. The homogenous hydraulic conductivity that gives the best fit in the simulations is $K = 3.8 \times 10^{-5}$ m/s (H = 4.33 m) and $K = 3.3 \times 10^{-5}$ m/s (H = 4.95 m). This corresponds to a permeability of $k = 5.1 \times 10^{-12}$ m^2 (5.2 darcy) and $k = 4.3 \times 10^{-12}$ m^2 (4.4 darcy), respectively. The result agrees well with the commonly used diagram proposed by SGF, figure 4.1.

Hydraulic conductivity K (m/s)

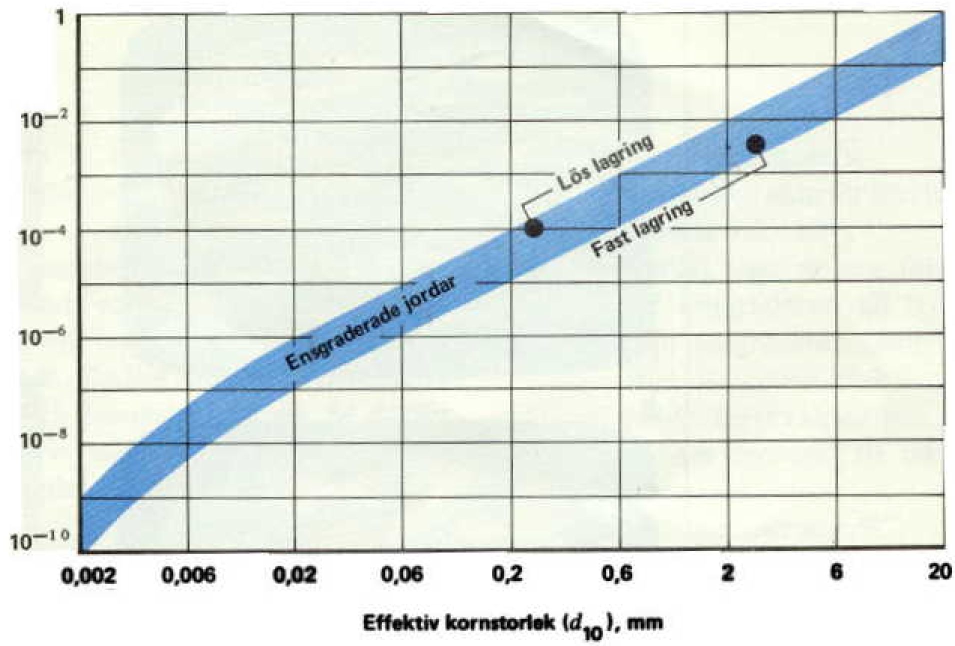


Figure 4.1 Estimation of hydraulic conductivity of even-grained soil, based on Svenska Geotekniska Föreningen (SGF)'s diagram

The calculated phreatic surface in the dam is illustrated in figure 4.2. A comparison with the experimental data indicates that, in the middle part of the dam (at pore pressure sensors P1 and P4), the CFD model predicts the phreatic surface good. Sensors P2 and P3 are close to the river banks and the water table at these positions may be affected by them. This effect is however not considered in the two dimensional model. The calculated seepage point on the downstream slope is h = 1.78 m (H = 4.33 m) and h = 2.57 m (H = 4.95 m) above the dam bottom.

Assuming anisotropic material, parameter sensitivity analysis is also performed, by introducing different permeability ratios of vertical to horizontal. If the horizontal permeability is put four times as high as the vertical ($k_h/k_v = 4$, $k_h = 5.1 \times 10^{-12}$ m^2), the difference in the phreatic surface is very small and the seepage point location on the downstream slope varies less than ±5 cm; the flow velocity differs by less than 3%.

For the flow case H = 4.33 m, the corresponding pore pressure and velocity profiles and vectors are given in figure 4.3 to 4.5.

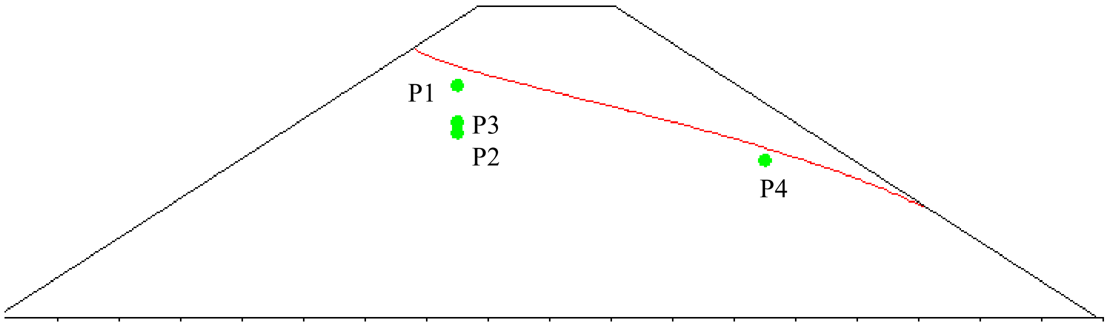


Figure 4.2. Water level in test dam 2C-2002 (red line) and field measurements (green dots), H = 4.33 m. The labels correspond to the sensor id in appendix 2.

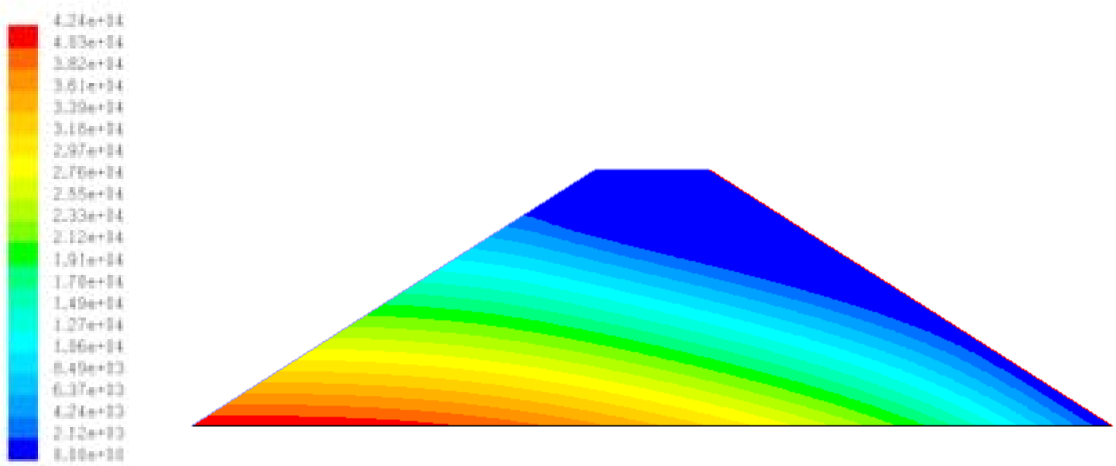


Figure 4.3. Pore pressure profile in test dam 2C-2002, scale in Pa, H = 4.33 m

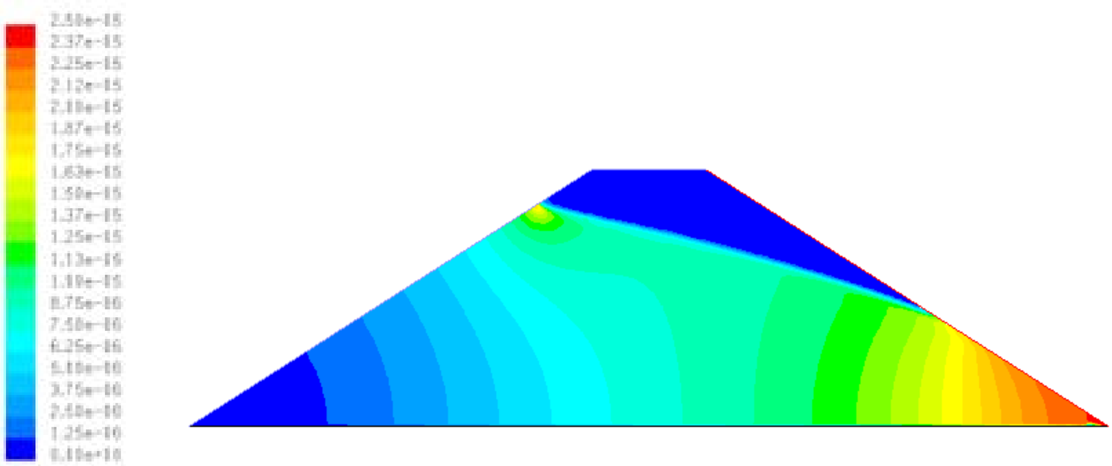


Figure 4.4. Velocity profile (Darcy's velocity) in test dam 2C-2002, scale in m/s, H = 4.33 m

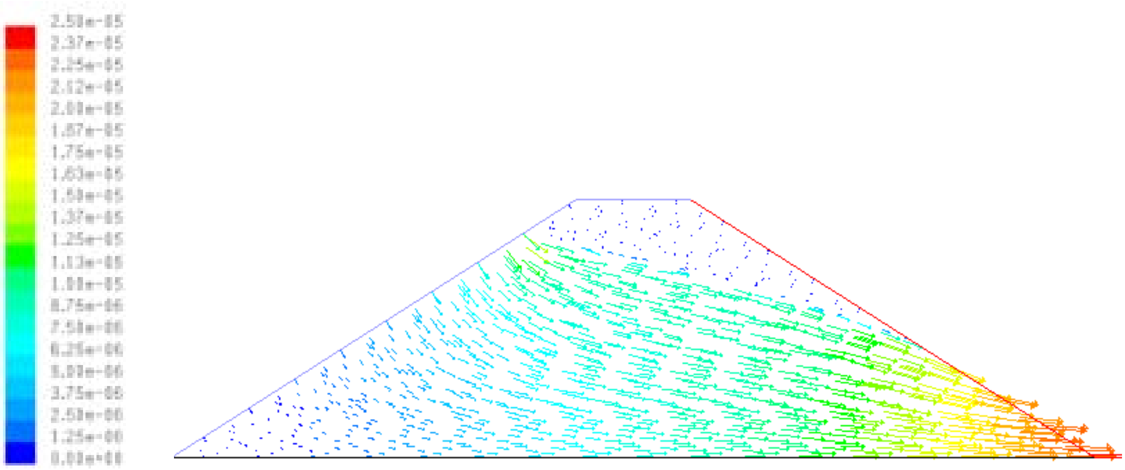


Figure 4.5. Velocity vectors (Darcy's velocity) in test dam 2C-2002, scale in m/s, H = 4.33 m

4.2 Test Case 1-2001

Without having any knowledge of the flow condition in the dam, simulations are first made for one flow case, H = 4.07 m, assuming that the seepage is laminar and the dam is isotropic. The best-fitted hydraulic condition for this case corresponds to the following result.

Hydraulic conductivity K = 0.167 m/s,
Laminar permeability $k = 2.2 \times 10^{-8}$ m^2,
Seepage point on downstream slope h = 1.17 m above dam bottom,
Maximal seepage (Darcy) velocity $V_{max} = 0.11$ m/s,
Reynolds number Re ≈ 4300.

As Re > 600, the seeping flow in the 1-2001 dam is obviously turbulent. For all the three water levels/seepage flow rates, simulations of fully developed turbulent seepage are made. The modelling results in the following parameters.

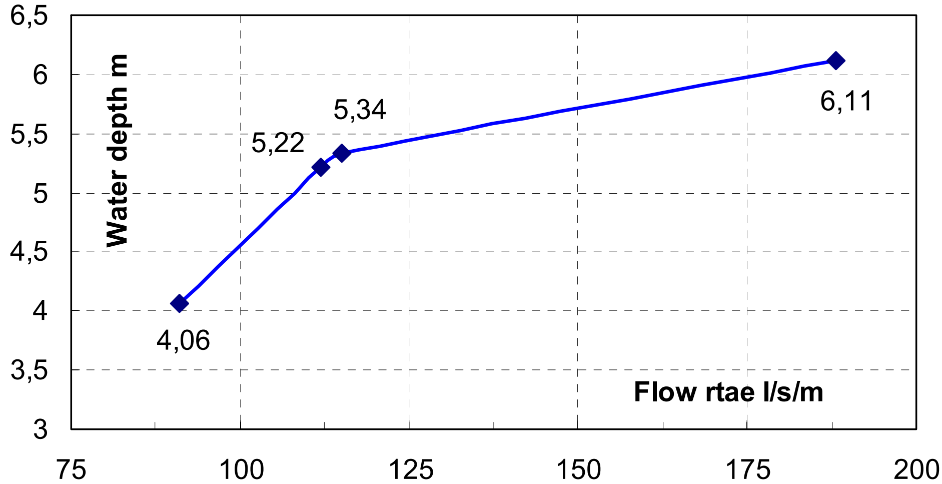
Table 4.1 The 1-2001 dam – results of regression analysis

	Upstream water depth H (m)		
	4.07	5.22	6.11
C_2 in eq. (5), m^{-1}	3720	5880	3940
Turbulent permeability k_t, m^2/s^2 (cm^2/s^2)	5.3×10^{-3} (53)	3.3×10^{-3} (33)	5.0×10^{-3} (50)
Seepage location on downstream slope above bottom h, m	1.86	2.84	3.92
Reynolds number, Re	2350	3750	2230
Max. seepage nominal velocity V_{max}, cm/s	6.0	9.6	5.7

In the assumed laminar seepage, the maximal velocity in the toe of the dam is almost twice as high as in the true, turbulent situation. The seepage location on the downstream slope is however lower than in the turbulent flow.

For the water depth H = 4.07 and 6.11 m, the best-fitted parameters are closer to each other, $k_t = 50 – 53$ cm^2/s^2, Re = 2230 – 2350 and the maximum seeping velocity V_{max} = 5.7 – 6.0 cm/s.

For H = 5.22 m, the parameters differ from those of H = 4.07 and 6.11 m – the turbulent permeability is much lower and Reynolds number is much higher. It is not clear if there is any reading error in the field data. From the correlation between water depth H and seepage flow rate q (diagram below), one can see that the H-q for H = 5.22 m is somewhat abnormal.



Coorelation between water depth and seepage flow rate

Turbulent permeability can be estimated with the help of the grain-size curve of a material, e.g. by the following expression (Svensk Energi 2004, Solvik 1995)

$$k_t = \frac{1.7 \cdot d_{10} \cdot g \cdot n^3}{\beta_0 \cdot (1-n)} \qquad \text{Equation (10)}$$

where n = porosity and β_0 = particle shape coefficient for turbulent seepage.

For the 1-2001 rock-fill dam, d_{10} = 30 mm, β_0 = 3.6 (angular stone block) and n = 0.30 (assumed value, probably within the range 0.25 – 0.35 according to Norconsult), this gives $k_t = 5.36\text{x}10^{-3}$ m^2/s^2, which is close to the best-fitted value at H = 4.07 and 6.11 m.

If n = 0.25, k_t = 2.9 x10^{-3} m^2/s^2. If n = 0.35, k_t = 9.2 x10^{-3} m^2/s^2. Correct determination of porosity is obviously crucial in realistic estimation of the turbulent permeability of a material.

The phreatic surfaces in the laminar and turbulent seepage at H = 4.07 m are shown in figure 4.6, in which the corresponding pore-pressure values are included for comparison.

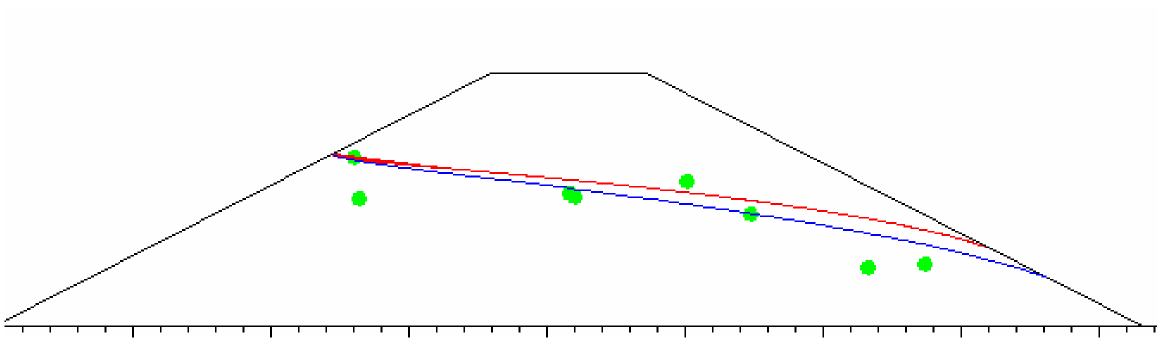


Figure 4.6. Piezometric surface in test dam 1-2001 – result of laminar (blue line) versus turbulent seepage (red line) as compared with field measurements (green dots), H = 4.07 m

The corresponding piezometric pressure distribution, velocity contours and vectors from the turbulent seepage modelling at H = 4.07 m are shown in figure 4.7 to 4.9.

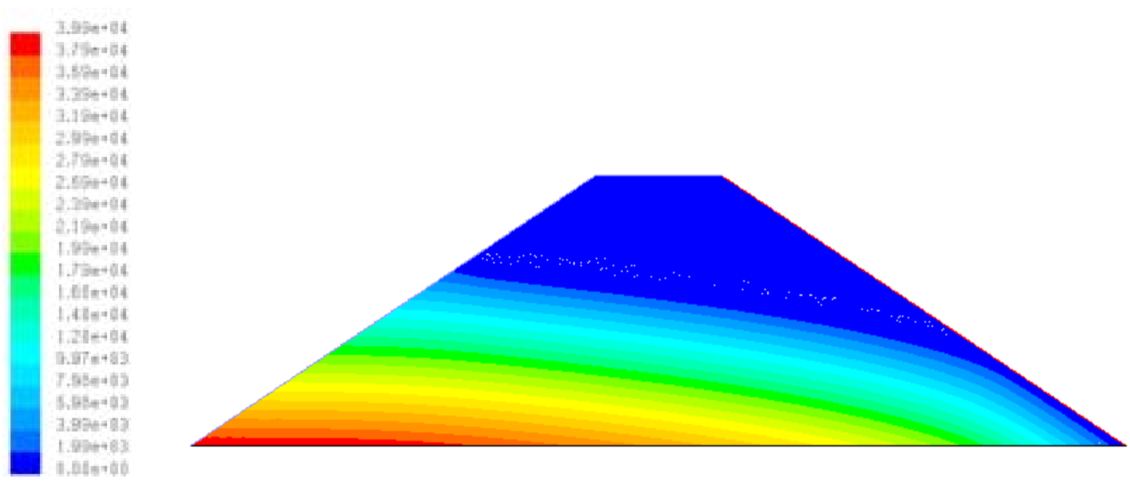


Figure 4.7. Pore pressure profile in test case 1-2001, scale in Pa, H = 4.07 m

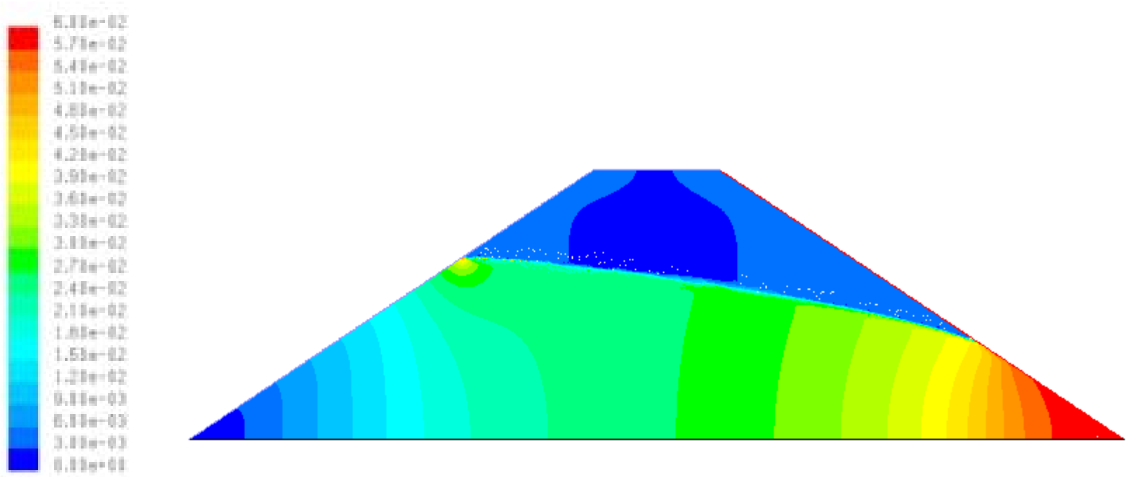


Figure 4.8. Velocity profile (Darcy's velocity) in test case 1-2001, scale in m/s, H = 4.07 m

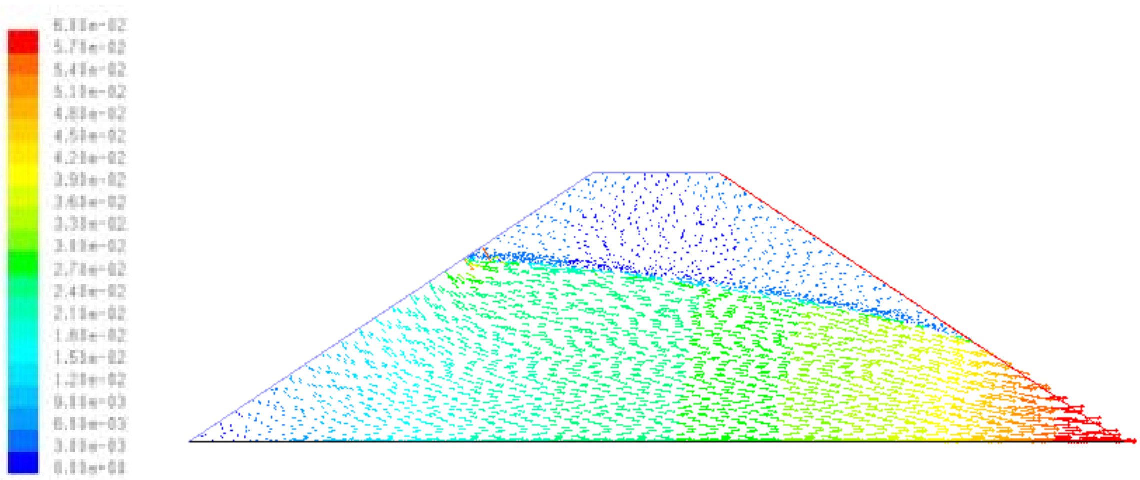


Figure 4.9. Velocity vectors (Darcy's velocity) in test case 1-2001, scale in m/s, H = 4.07 m

5 Conclusions

The CFD code FLUENT has been used to model seepage flow in two 5 and 6 m dams in the Norwegian dam-break project. The 2C-2002 dam consisted of homogenous sandy gravel material, while the 1-2001 dam was built in rock fill. For a given dam, the upstream reservoir level and seepage flow rate from the field are kept constant and the dam material property is best-fitted through FLUENT simulations.

Test dam 2C-2002

The seepage flow in the 2C-2002 dam is laminar. The hydraulic conductivity is found to be $K = (3.3 - 3.8) \times 10^{-5}$ m/s, corresponding to a permeability of $k = 4.4 - 5.2$ darcy.

The phreatic surface is insensitive to the material anisotropy. If the vertical permeability is four times as low as the horizontal, the change in the phreatic surface and seepage point on the downstream slope is less than 5 cm and the flow velocity differs by less than 3%.

Test dam 1-2001

For the 1-2001 test dam of gravel, the seepage flow in the dam is turbulent.

For the flow case H = 4.07 m, *If treaded as laminar seepage*, the hydraulic conductivity is K = 0.167 m/s, corresponding to a permeability of k = 2.2e-8 m^2. The seepage point on the downstream slope is 1.17 m above bottom, and the maximal flow velocity is 0.11 m/s. Reynolds number is $Re \approx 4300$.

For the two flow cases, H = 4.07 and 6.11 m, the turbulent seepage calculations result in a turbulent permeability of $(5.0 - 5.3)\cdot 10^{-3}$ m^2/s^2. Reynolds number is $Re \approx 2230 - 2350$. The seepage point on the downstream slope is 1.86 m (H = 4.07 m) and 3.92 m (H = 6.11) above bottom. The corresponding maximal flow velocity is 5.7 – 6.0 cm/s, respectively.

For the flow case H = 5.22 m, the resulting turbulent permeability is $3.3\cdot 10^{-3}$ m^2/s^2, much lower than in the other two cases. It is unclear if this is due to possible reading error in the upstream water level/seepage flow rate or other reasons.

It can be said that, if the seepage is turbulent (Re > 600) but modeled as laminar flow, the piezometric surface in the dam including seepage point on the downstream slope would be lower, while the seeping velocity would be much higher. As for analysis of downstream slope stability, which is usually made with programs such as SLOPE using results from seepage modeling, the safety factor would be over-estimated. As for seeping stability of particles, the risk for erosion would be also over-estimated.

6 References

[1] Fluent 6.0 User's Guide, December 2001. Fluent incorporated.

[2] Bear, J and Verruijt, A., Modelling groundwater flow and pollution. D. Reidel Publishing Company, Dordrecht, 1987.

[3] Høeg, K, Lövoll, A and Vaskinn, K A, Stability and breaching of embankment dams: field tests on 6 m high dams. Hydropower and Dams, Issue 1, 2004.

[4] Svensk Energi, ”RIDAS – fyllningsdammar, tillämpningsanvisningar (Arbetsgruppens förslag 2004-05-26)”.

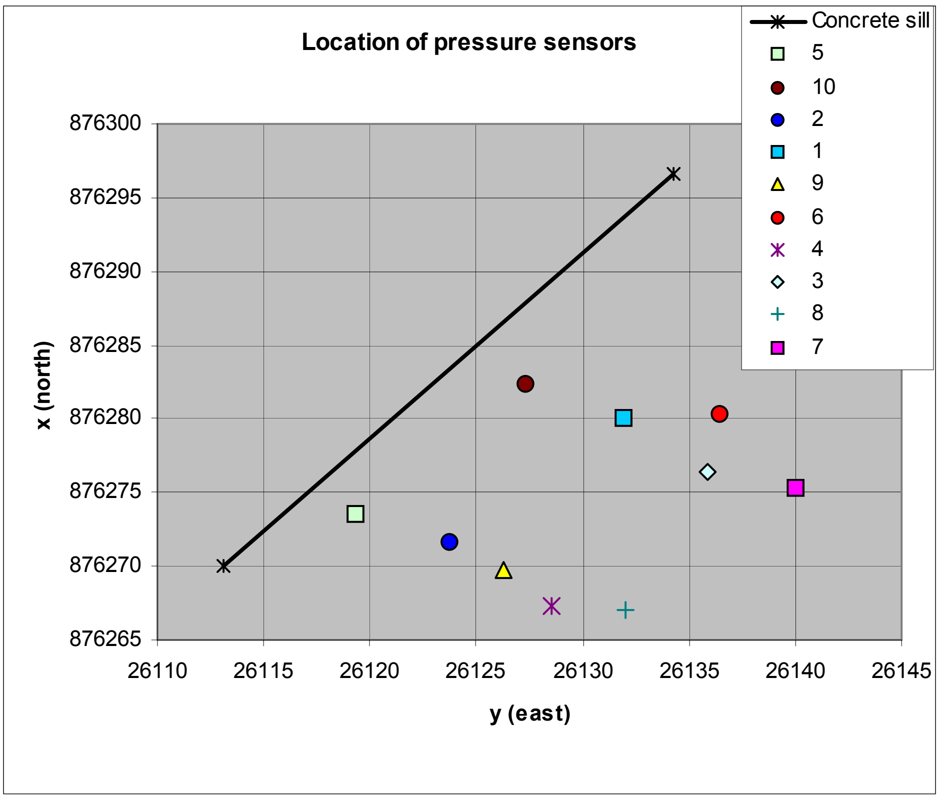
[5] Solvik, Ø. Stenfyllningsdammars stabilitet vid genomströmning. VASO dammkommittés rapport nr 17, Stockholm, 1995.

Appendix: Data from field tests

A.1 Test 1-2001

Pressure sensors

Description	ID #	Channel	y (east)	x (north)	Level of the sensor	Horizontal distans from concrete weir	Vertical distance from concrete weir	Distance
Upper layer, upstream-west	22901	8	26131,99	876267,01	367,442	17,35	2,632	17,549
Upper layer, upstream-east	22701	7	26140,03	876275,34	367,426	17,45	2,616	17,645
Upper layer, downstream-east	23001	6	26136,43	876280,37	367,459	11,42	2,649	11,723
Upper layer, downstream-west	23301	9	26126,32	876269,70	367,389	10,25	2,579	10,469
Lower layer, downstream-west	23401	1	26131,90	876280,05	365,073	7,10	0,088	7,101
Lower layer, downstream-east	23201	2	26123,75	876271,65	364,898	8,15	0,263	8,154
Lower layer, upstream-west	22801	3	26135,90	876276,40	365,093	13,45	0,151	13,451
Lower layer, upstream-west	23101	4	26128,50	876267,35	364,961	13,55	0,283	13,553
Lower layer, downstream, west-damtoe	23501	5	26119,35	876273,50	365,080	2,50	0,270	2,515
Lower layer, downstream, east-damtoe	23601	10	26127,30	876282,35	364,990	3,12	0,180	3,125
Concrete sill			26113,10	876270,00				
Concrete sill			26134,30	876296,60				



Pore pressure through test dam 2001

Location of test dam

x (m)	z (masl)
0	365
8,5	371
11,39	371
21,46	364,81

Location of the pore pressure sensors

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Location	Downstr.	Downstr.	Crest	Crest	Toe	Downstr.	Uppstr.	Uppstr.	Downstr.	Toe
x (m)	15,79	16,84	10,39	10,49	21,44	12,52	6,49	6,59	13,69	20,82
z (masl)	365,073	364,898	365,093	364,961	365,080	367,459	367,426	367,442	367,389	364,990
w or e	east	west	east	west	west	east	east	west	west	east

Location of dam toe

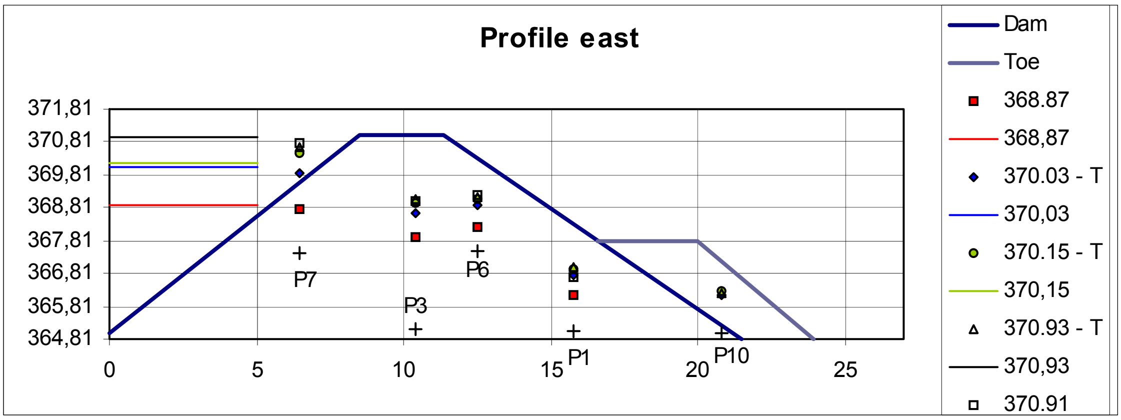
x (m)	z (masl)
16,6	367,8
20	367,8
23,94	364,81

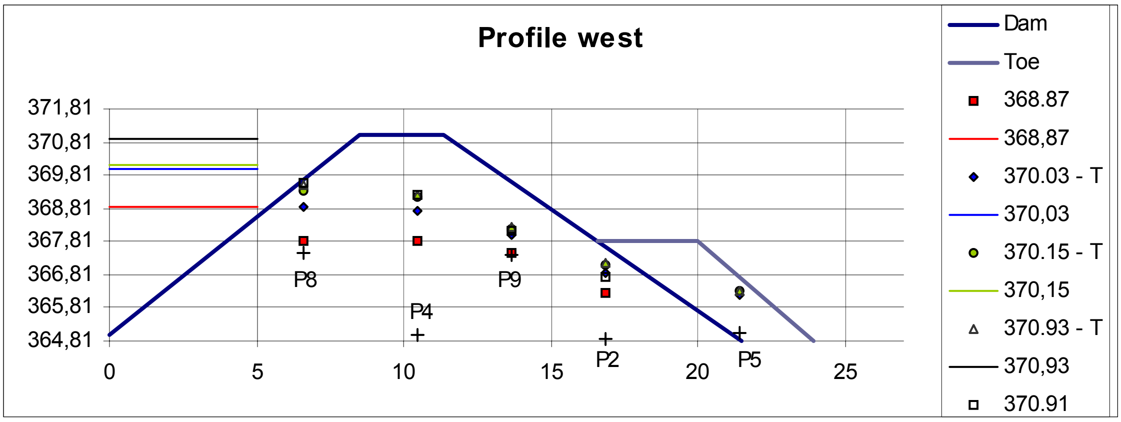
x is horizontal distance from uppstream dam toe
z is elevation

Measured pore pressures

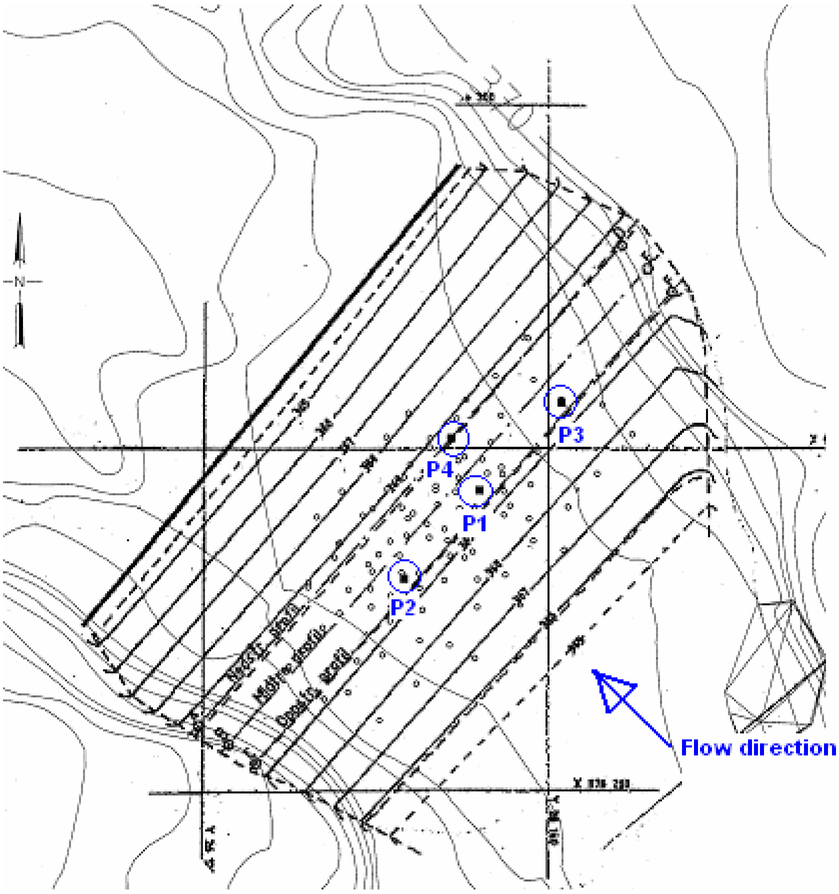
Date (dd.mm.yy)	Time (hh:mm)	Water level (m a.s.l)	q ($m^3/s/m$)	P1 (m a.s.l)	P2 (m a.s.l)	P3 (m a.s.l)	P4 (m a.s.l)	P5 (m a.s.l)	P6 (m a.s.l)	P7 (m a.s.l)	P8 (m a.s.l)	P9 (m a.s.l)	P10 (m a.s.l)
2001-10-19	14:01	368,87	0,091	366,16	366,26	367,93	367,85		368,20	368,79	367,81	367,44	
2001-10-31	16:32	370,03	0,112	366,75	366,89	368,63	368,75	366,17	368,88	369,89	368,86	368,03	366,13
2001-11-01	11:15	370,15	0,115	366,93	367,11	368,97	369,14	366,29	369,1	370,46	369,36	368,2	366,25
2001-11-01	12:36	370,93	0,188	366,98	367,17	369,08	369,24	366,32	369,14	370,63	369,51	368,25	366,24
2001-11-02	12:30	370,91	0,19	366,71	366,72	369,04	369,19		369,19	370,77	369,57	368,12	

Comment: Forsøka 19. okt og 2. nov var utan damtå. Forsøka 31. okt og 1. nov var med 3 m høg damtå!
Det ble avdekket feilplott for P8. Kan forklare skjevheter ved profil vest. (kilde: Edvin L)
I kommentarene fra forsøkene er det kommentert at utstrømningshøyden i nedstrøms skråning er høy.





A.2 Test 2c-2002



Date (dd.mm.yy)	Time (hh:mm)	Water level (m a.s.l)	q (l/s/m)	P1 (m a.s.l)	P2 (m a.s.l)	P3 (m a.s.l)	P4 (m a.s.l)
16-10-02	**09:37**	**369.14**	**0.0306**	**368.51**	**367.92**	**367.76**	**367.32**
16-10-02	11:30	369.76	0.0389	368.95	368.36	368.00	367.71

ELFORSK

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