

PERMEABILITY OF THE DIKE 1'S MATERIALS OF KAENG KRACHAN DAM, THAILAND

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ABSTRACT: Dike 1 of Kaeng Krachan Dam located in Phetchaburi province of Thailand constructed in 1966 with a reservoir capacity of 710 million m³. This large-scale project provides more than 55 years of irrigation and flood protection. Risk evaluation of dam is needed to be performed. The calibration of engineering properties of the Dike 1 is conducted because there is no database of those properties. The existing Dike 1 cross-section is a soil model, used for calculation. Piezometric level and flow rate obtained from the dam instruments were calibrated with the hydraulic head and the flow rate was determined by the SEEP/W model. The permeability coefficient of the Dike 1 materials can be analyzed by the calibration technique. The data of the dam instruments are helpful information, and the computer program is friendly to use. The coefficient of permeability of the soil of the Dike 1 of Kaeng Krachan Dam is determined and applied to risk analysis.

Keywords: Permeability, Soil Model, Calibration, Dam Instruments

1. INTRODUCTION

Dike 1 of Kaeng Krachan Dam, located in Phetchaburi province of the southern part of Thailand, with 33 m height and 305 m length with a capacity of 704,000 m³ of earth fills. Dike 1 was constructed between 1966 and 1968 [1]. It is fully operated for more than 55 years under the dam safety program of the Royal Irrigation Department of Thailand (RID). Since the lack of permeability data of the construction materials and there is no budget for soil testing, therefore, this study determines the permeability of soil by calibrating the calculated and measured data using a mathematical model. The measured data were monitored by the piezometers, installed along the alignment of the Station 0 +130 km, and by the seepage flow meter installed at the downstream toe of Dike 1, as shown in Fig. 1. The study scoped with the trial-calculated value by assuming the representative one for calculation. The monitored data obtained by the piezometer and a seepage flow meter was collected at a certain period at the water level of +96.000 m (MSL). 2D SEEP/W with a mesh size of 0.5 to 3.0 m was applied to determine the seepage.

2. RESEARCH SIGNIFICANCE

The calibration technique between measured data and computed value can be applied for determining the permeability of the earth materials. In Thailand, many dams lack the permeability of compacted soils. this method can be used for other

dams. Dike 1 of Kaeng Krachan Dam shows good measurement data obtained from the dam instruments such as piezometer, water pressure meter, and seepage flow meter. A field permeability test is used for the verification of the calculated permeability value.

3. DESCRIPTION AND INSTRUMENT

The soil model of Dike 1 consisted of clay core, selected outer core zone, chimney, and blanket drain as shown in Fig.2. Eight zones of the earth embankment can be summarized in Table 1, separated by permeability coefficient. First, the core zone (C), the soil group of a core zone has permeability in the range of 1×10^{-9} to 1×10^{-7} m/s, which value closed to the impervious layer. Second, the foundation rock zone comprises greywacke, claystone, mudstone, and shale. It remarks that the rock mass shows high clay and silica contents. The third layer is natural ground, lean clay (CL) showed impervious one like the core zone. Fourth, quarry-run-rock (QR) mainly consisted of coarse aggregate and rock fragments made from greywacke or high-strength rock mass. Aggregate's permeability showed 1×10^{-3} to 1×10^{-1} m/s. Fifth, the random zone (R) comprised of silty gravel (GM) or clayey sand (SC) showed permeability as 1×10^{-8} to 1×10^{-6} m/s. Sixth, the chimney drain zone (SP) presents permeability as 1×10^{-7} to 1×10^{-5} m/s. Seventh, the selected random zone (SR) shows a high value of permeability as 1×10^{-3} to 1×10^{-1} m/s. Eighth, the transition zone shows silty gravel (GM) with the permeability value of 1×10^{-7} to 1×10^{-5} m/s.

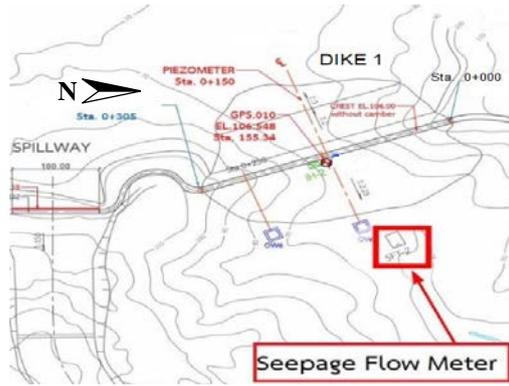


Fig.1 Dike 1's site plan and dam instruments

Vibrating wire piezometers P1, P2, and P3 are installed at the core zone, offset from the centerline of Dam 4.00 m at the elevation of 59.940, 70.000, and 85.000 m (MSL), respectively. Piezometer P4 and P8 are installed and monitored the foundation offset from the centerline of the dam at 25.00 and 50.00 m at elevations of 60.079 and 75.050 m (MSL). Piezometer P5, P6, and P7 are installed at the random zone offset from the centerline 25.00, 50.00, and 50.00 meters, at the elevation of 85.079, 58.000, and 75.000 m (MSL), respectively, as shown in Table 2.

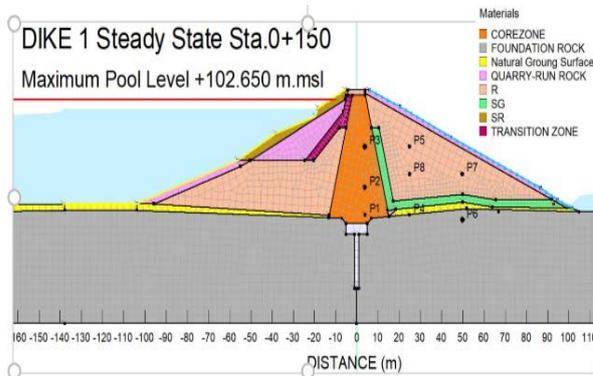


Fig.2 Cross-section of Sta.0+150 of Dike 1

Table 1 Zoned materials of Dike 1

Reference [1]		Dike 1's	
USCS	k, m/sec	Zone	Soil/Rock-type
CL	$10^9 - 10^7$	1. Core	CL, GC
-	-	2. Foundation	claystone
CL	$10^9 - 10^7$	3. Ground	CL, SC
GW	$10^3 - 10^1$	4. Quarry rock	Aggregate
SC	$10^8 - 10^6$	5. Random	GM, SC
SM	$10^7 - 10^5$	6. Filter/drain	SP, SM
GW	$10^3 - 10^1$	7. Selected rock (SR)	Fragment of rock
GM	$10^7 - 10^5$	8. Transition	GM, SM

Note: k = permeability value

Table 2 Detail of Piezometer

Representative	Zone	Off-set-dam, m	Elevation m, MSL
P1, 59.940	core	4/DS	+59.940
P2, 70.000	core	4/DS	+70.000
P3, 85.000	core	4/DS	+85.000
P4, 60.079	foundation	25/DS	+60.079
P5, 85.079	random	25/DS	+85.079
P6, 58.000	foundation	25/DS	+58.000
P7, 75.000	random	50/DS	+75.000
P8, 75.059	random	50/DS	+75.059

Note: from Argus Web Monitoring System

Seepage flow meter (SF2), V-Notch weir was installed on the ground at Sta.0+120 of Dike 1, which is located 150 m downstream (DS) from the centerline of Dike 1. The quantity of seepage flow can be monitored by the seepage flow meter and by surveying technique at the V-notch weir. There is no significant error in the seepage amount measured from the seepage flow meter and surveying. Dike 1's seepage flow rate increased with the reservoir water level, which is similar to the seepage condition of Khassa Chai Dam, Iraq [2].

There are two observation wells, OW5 and OW6, which are located at Sta.0+150, and Sta.0+250 which offset 250 m and 200 m from the centerline of Dike 1 to downstream (Fig. 1). The subsurface water level was depicted and used for determining hydraulic gradients at the Dike 1's toe. The local RID office provided a dam instrument maintenance program and dam safety inspection. Dike 1's instrument for seepage analysis, purpose, and maintenance are tabulated in Table 3. The dam instruments and the web monitoring plays the roles of the safety of Dike 1. The recorded data were obtained by Argus software. The reliability of the data had been checked. It is supposed that the change in water pressure of the vibrating wire piezometers, flow seepage meter, and observation well depend on changing of the reservoir water level. However, there is an error due to sensor mounting, a broken electric wire, and the sensor's calibration.

The calibration technique obtained from SEEP/W and accurate instrument data is applied for many cases. Beiranvand and Komasi (2021) stated that the phreatic line from numerical modeling of the Eyvashan dam showed a value in the same range as that obtained from the piezometer [3]. Mohammed Karim Malik and Ibtisam Raheem Karim (2020) suggested that the difference value of a measured flow rate and computed seepage of Haditha dam might be caused by grout curtains [4]. Seepage of Putrajaya Dam was computed by SEEP/W, the result showed a clay core's hydraulic

conductivity as 2×10^9 to 2×10^7 m/sec which was similar to the cutoff clay of Al-Shanhabi dam [5,6]. It can be referred to and used for the initial k-value of the core material and transition zone of Dike 1. Seepage analysis of Hub Dam, Pakistan by SEEP/W and field observation had been studied by Imran Arshad and M. M. Babar, which suggested the condition of analysis and computation [7]. The filter of Harreza-Algeria was computed of the seepage amount and validated that value by field observation [8]. Steady-state conditions, reliability of the instrument data, and verification of field permeability tests were considered for this study.

Table 3 Dike 1's instrument for seepage analysis

Instrument	Type	Purpose
Piezometer	Vibrating Wire	Pressure head
Seepage flow meter	Sensor and V notch weir	Flow rate
Observation well	Borehole with sensor	Hydraulics gradient

4. SITE CHARACTERIZATION

Existing data obtained from the drawing of Kaeng Krachan Dam was carried out by RID and Engineering Consultants Inc. Denver Colorado U.S.A., defined zone of core and filter as impervious and sand and gravel, no permeability testing results of construction materials and rock foundation [9].

Soil boring logs of the adjacent areas show clayey (SC), clayey and silty sand (SC and SM) lean clay (CL) in the majority. Dense to very dense coarse grain sand with fines, SC and SC-SM, contain fines in the range of 13% to 44% with the median value of 33 % of fines contents. Fines show liquid limit and plastic index in the range value of 15.90-21.45% and 3.15-8.34%. About 3 meters thick of ground presented the natural moisture content, dry unit weight, compressive strength from a pocket penetrometer, and N-value in the range of 5.95-12.86%, 1.96-2.08 t/m³, 4.5 ksc, and 35-95 blows/ft, respectively. At a depth greater than 3 meters, very dense to dense silty gravel (GM) with the non-plastics fines has been found in a thin layer. It shows fine contents, natural moisture content and dry unit weight of 13.72-17.30%, 6.91-10.47%, and 1.95-1.96 t/m³, respectively. [10].

Sandy Clay (CL) consists of about 70 % fines with 30% sand with low plasticity. Two meters of stiff clay layers present moisture content, dry unit weight, and the N value of 21.34%, 1.34 t/m³, and 16 blows/ft. Medium dense to dense poorly graded sand (SP) was found below 3 meters of ground.

Percentage of fines, natural moisture content, dry unit weight, and N-value shows in the range of 3.06 - 4.77%, 7.72-8.66%, 1.73-2.02 t/m³, and 28-93 blows/ft, respectively [11].

It remarks that the soil group in the adjacent area is the same as shown in the drawing of Kaeng Krachan Dam and as the soil group classified based on ASTM D 2488. The open-end tests perform at the representative random zone showed permeability of 7.5×10^{-7} - 5.3×10^{-8} m/s of sandy clay (CL). The field tests and the visual-manual procedure for soil classification can be operated only on shallow surfaces. Core material and random zone can be classified as lean clay, sandy clay (CL) clayey sand (SC), and sandy clay (CL). Those geotechnical properties of Dike 1's materials also conformed with USBR's suggestion [12]. The spillway located at the right abutment of Dike 1 shows a good rock mass of mudstone, shale, and fine-grained graywacke which conform with the work of the Department of Mineral Resources [13]. Dike 1's and grounds' materials have been tabulated in Table 4.

Table 4 Materials of Dike 1

location	Inspection method	Classified
Core (right abutment)	Visual manual	Lean Clay (CL), hard clay with sand
Random zone (D/S)	Visual manual & open-end test	Clayey Sand (SC)& Sandy clay, $k=7.5 \times 10^{-7}$ - 5.3×10^{-8} m/sec
Rock mass at the spillway	Rock mass rating	mudstone, shale graywacke, good & tight joints
Adjacent D/S	Visual manual and review	Sandy Clay & Lean soil symbols; CL, SC, SC-SM, GM, SM, SP

Based on the geological map showed rock units of mudstone, shale, graywacke, colluvium, and alluvium at Dike 1 and adjacent area [14]. A Rock unit has been found at the elevation of +80 - +250 m (MSL). Generally, the drawing stated that the rock quarry had been performed by blasting the mountain located in the reservoir area. Aggregate and block of graywacke, mudstone, and shale were mainly used in number 4 zone of quarry run rock, number 7 zone of selected material, and riprap. Residual soils altered from those parent rocks mostly consisted of lean clay, clayey sand, and lateritic soil, predominantly. It is about 2-3 meters thick and impermeable soil. Colluvium soil mostly consisted of rock fragments, gravel, sand, silt, and

clay which scattered along the slope, and hilly areas which covered at the elevation of +60-+80 m (MSL). It is medium to very dense silty-clayey sand. Alluvium mainly consisted of silty sand (SM) and poorly graded sand (SP). It is loose to a medium dense sand layer scattered along the canal and river. This flood plain shows the elevation +45 – +60 m (MSL). Site characterization meets requirements of good rock foundation as water tightness and high quality and quantity of earthen construction materials for Dike 1.

5. SEEPAGE ANALYSIS IN EARTH DAM

Bernoulli's equation and Darcy's law are applied for understanding water flow through porous media. Bernoulli's equation can be explained as in

$$H = z + \frac{p}{\gamma_w} + \frac{v^2}{2g} \quad (1)$$

Where, H is the total head, z is the elevation head, P is the pressure head, V is the velocity head and g is gravitational acceleration.

For steady-state flow between two points (a-b), Eq. (1) expressed the head loss equation as in

$$\Delta h = H_a - H_b \quad (2)$$

Where, Δh is head loss, or head change between point a to point b, H_a is the total head at point a, H_b is the total head at point b.

A combination of Eq. (2) and Darcy's law can be applied for defining the hydraulic conductivity of soil as in

$$Q = KiA \quad (3)$$

$$\text{hydraulic conductivity, } K = Ki \frac{\gamma_w}{\mu} \quad (4)$$

$$\text{hydraulic gradient, } i = \frac{\Delta h}{\Delta L} \quad (5)$$

Where Q is the flow rate (volume over time), K is the hydraulic conductivity, Ki is the intrinsic permeability, γ_w is the unit weight of water, μ is water viscosity, i is the hydraulic gradient, Δh is the head loss, ΔL is the horizontal distance between two points, A is the cross-sectional area [15].

This study uses 2D SEEP/W to analyze seepage through Dike 1 of Kaeng Krachan Dam. In practice, the hydraulic conductivity of soil is an important factor for seepage analysis besides consideration of the boundary conditions. Finite element program, 2D SEEP/W program provides 3 parts, data input, solving, and result in output. Input part composed of defining the dam model, boundary condition, and mesh. It depends on the user's requirement to select a function of transient flow or steady-state, saturated or unsaturated condition, for instance.

Solving part is an analysis of total head, hydraulic gradient, and flow rate which depend on the method of selection. Output results generate flow net of the earth dam mode, total head of water, and flow rate of the model section. The 2D SEEP/W is a useful tool for this study. The calculated seepage flow is calibrated with flow rate measured by SF2 which used the water level of V notch weir, showed the calibration equation as in

$$Q = C_w H^{5/2} \quad (6)$$

Where Q is the flow rate (liter/min), C_w is discharge coefficient of weir (82,800), H is height in millimeter of water measured from V notch weir's sharp edge.

6. STUDY METHOD

Study methods purposed for achieving the objectives tabulated in Table 5. It consisted of reviewing the existing data of Dike 1, seepage analysis by 2D SEEP/W, verification of materials' permeability in Dike 1, and report writing. The existing data was reviewed to understand the engineering properties of construction materials of Dike 1 and the site and to classify the drawing and dam instrument. Seepage analysis gives the result of hydraulics conductivity of Dike 1's soil model. A field permeability test has been carried out to verify the calibrated hydraulic conductivity obtained from SEEP/W. Finally, this study is reported and established to the local organization that responds to the dam safety program. It confirmed the Dike 1's behavior and instruments which work properly and needed to be regularly inspected.

Table 5 Study method and result

Study Method	Result
Reviewing data	site characterization and reliability of data
Seepage analysis	The calibrated k value of Dike 1's materials
Verification of calibrated k value by field permeability test	Permeability of soil (random sampling)
Report writing	Dike 1's safety plan

The seepage analysis diagram of Fig. 3 briefly presents the detailed calibration of the hydraulic conductivity of Dike 1's materials. Step (1) applying SEEP/W of Geostudio program limits for the two dimensions. Step (2) finite element model was generated and defined mesh size and boundary condition. Key in material property and trial k value in the soil model as given step (3). Step (4) The

program of 2D SEEP/W had been executed. Step (5) shows a comparison of computed data and the value from instrument data as earlier mentioned in Table 3. The trial-and-error process, step (6), has been considered if there is a different value in those compared data. End of seepage analysis is completely done when the computed data is closed to the measured data. This study limits with the cross-section Sta 0+130 which the piezometer had been installed. The computed flow rate of Dike 1 is calibrated with the seepage flow meter (SF2). The computed k-value was verified by the field permeability test at Dike 1.

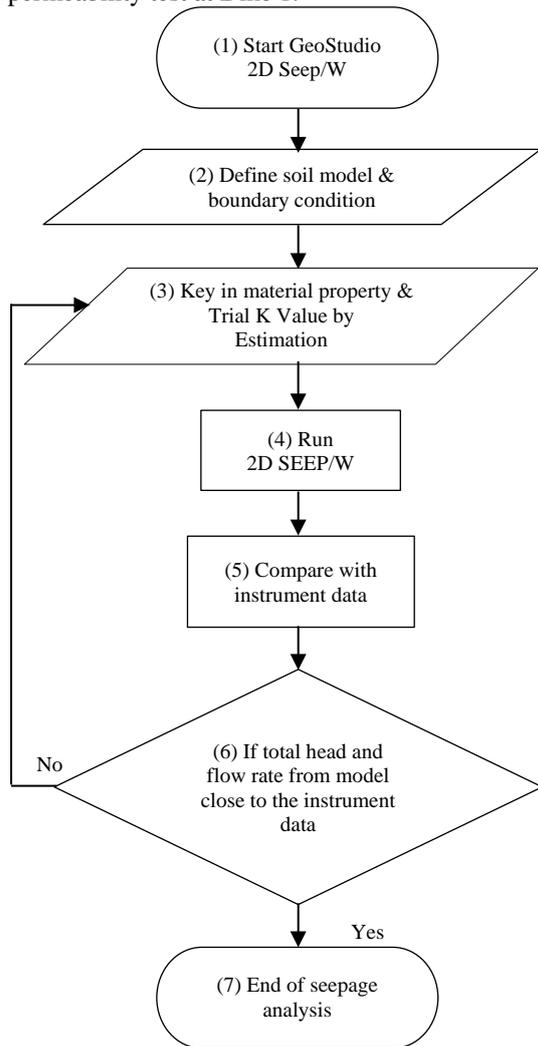


Fig.3 Seepage analysis diagram

The standard field permeability test of the Royal Irrigation Department which is based on the USBR manual has been conducted at the shallow subsurface ground of the Dike 1 [16]. According to no permission on drilling for investigation purposes, five locations are randomly chosen, 3 from Dike 1 and 2 from the two abutments. The duration of the field test is a rainy season, July 2019 which made high moisture content of the shallow ground. testes

section was developed by using 3 inches diameters of an auger, drilled into the ground with the depth of 1.5 meters. A Shallow borehole was installed with the 3 inches diameter of PVC pipe about 2.5 meters in length. The length of the PVC pipe is 1 meter above the surface. Clean the hole bottom and fill with clean water, leave soil fully saturated and plug the PVC case about 24 hours. The period of the test is about 20 minutes per set, test 3 sets with the constant head and measure the flow rate. Leakage of water during testing needed to be avoided. The average permeability of soil can be calculated as in

$$k = \frac{Q}{cHr} \quad (7)$$

Where k is average permeability in cm/sec, Q is the flow rate (cm³/s), c is dimensionless parameters as a function of test length and radius of a hole (use 5.5 for about 3 inches diameters), H is the total head (section of constant head), r is the radius of the PVC pipe.

7. RESULT AND DISCUSSION

The existing data of the Dike 1 provided some engineering properties of soils which applied as the permeability functions of soil models (Table1 and Fig.2). Those permeability values were input to soil models for analysis by SEEP/W and adopted by the trial-and-error method. Thus, the completion of seepage analysis means the soil model presented the calculated flow rate and total head in the same range of the measured data obtained from the seepage flow meter and piezometers. This study used data from 2007 which checked the reliability of the measured data and field instruments.

The eight piezometers were compared with the water reservoir and with the elevation of their installation for checking the function as shown in Table 6. It remarked that there is no water pressure developed at the random zone of the downstream, because the total head of P5, P7, and P8 are lower than those of installation elevation. It implied that designed chimneys and blanket drains allowed all seepage to flow through these paths. On the other hand, these piezometers were installed in shallow depth which could not detect the water pressure. There is no build-up pore water pressure at the downstream slope of Dike 1. Carefully, field investigation of those monitoring instruments had been carried out for checking their performances. In case these piezometers work well, it is a good sign for the safety of the dam.

The five piezometers installed in the core zone and foundation show the different values of the water head compared with the elevation of the reservoir water level. These piezometers work

functionally. It noted that local officer read and recorded the data of piezometer, manual process, in 2009 the dam instruments had been gradually changed to the automation system. As water pressure plays a role for earth dam, observation wells, OW5 and OW6 were used for calculation of the field average hydraulics gradient of Dike 1. At downstream of Dike 1, calculated hydraulics gradients show about 0.12 to 0.14, which was a smaller value than the critical hydraulic gradient about 7 to 8 times. Groundwater condition in OW5 and OW6 is clear. This evidence implies there was no erodible soil such as very fine to fine-grained with non-plastic soil. The seepage flow meter properly works which gives the relationship between flow rate and reservoir water level as in

$$Q = 1.1088RWL - 92.98 \quad (8)$$

Where Q is the flow rate in m^3/day , RWL is reservoir water level in m. The coefficient of correlation (R^2) is 0.989.

Table 6 Total head of piezometers at a certain time

Piezometer, EL, location	Total head, m MSL		
	19/9/2007	5/12/2007	3/7/2009
P1, 59.940, c	79.107	80.395	76.810
P2, 70.000, c	83.032	82.291	79.221
P3, 85.000, c	88.247	87.738	85.718
P4, 60.079, f	70.726	70.885	67.164
P5, 85.079, r	84.402	84.691	84.886
P6, 58.000, f	69.327	69.646	65.557
P7, 75.000, r	73.751	73.639	72.912
P8, 75.059, r	74.594	74.841	74.063
RWL			
EL m MSL	94.990	96.140	91.030

RWL = Reservoir Water Level, c = core, f = foundation, r = random

The measured seepage flow rate was used as calibrated value with those computed from SEEP/W. The flow rate of Dike 1 from SEEP/W and measurement was compared in Table 7.

Table 7 Calibration of flow rate

Flow rate SEEP/W, m^3/day	Seepage Flowmeter, m^3/day	Range m^3/day
6.323 ($2.93 \times 10^{-7} m^3/s/m$)	6.740	5.7-7.0

After calibration of flowrate of the model which computed by SEEP/W. The calculated total head, from Seep/W analysis at the certain cross-section, was correlated with the measured total head of P1, installed at the core zone of Dike 1 as shown

in Fig.4, for instance.

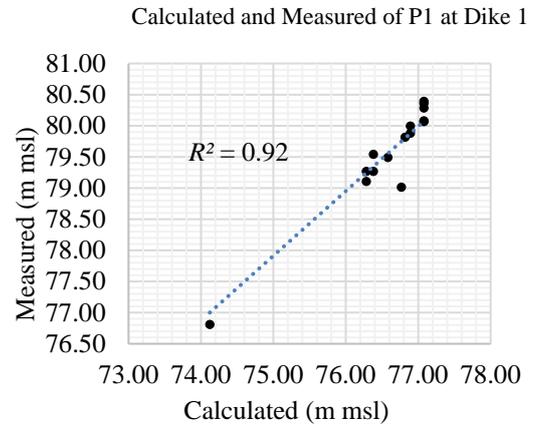


Fig.4 Calibration matching graph of P1 of Dike 1

The calibration graphs of P1, P 4, and P6 show linear correlation coefficients as 0.92, 0.82, and 0.60, respectively. The linear correlation coefficient values of the calibration graphs of P2 and P3 are lower than 0.3. It is probably due to the sensitivity of the sensor and the impervious core material. This result revealed that further monitoring on the upstream slope of the Dike 1 should be considered for warning of the instability. At Sta.0+150 offset about 10 meters from the centerline of the Dike 1 to upstream, there should be an installation of the piezometer and inclinometer. For P5, P7, and P8, the piezometers installed at the random zone, showed the dried downstream slope and well function of the filters. The calibrations of total head data from SEEP/W and piezometers are tabulated in Table 8. The requirements stated that the calculation value obtained by SEEP/W should be in the range value of the measured data. This soil model is accepted and established the permeability of soil and k-function, saturated water content, residual water, and anisotropy ratio as shown in Table 9.

Table 8 Total head from piezometers and SEEP/W

Piezometer, location	Total Piezometer	Head, m SEEP/W	Range in meter
P1, core	80.395	79.273	(79-81)
P2, core	82.291	81.151	(80-83)
P3, core	87.738	88.039	(87-88)
P4, foundation	70.885	69.447	(69-71)
P5, random	no water	84.604	-
P6, foundation	69.646	68.964	(87-88)
P7, random	no water	68.337	-
P8, random	no water	73.859	-

Table 9 Calculated permeability by SEEP/W

Zone	Saturated WC	Residual Water	k , m/sec	k_y/k_x
Core	0.5	0.4	1.0×10^{-09}	0.20
Foundation	0.45	0.4	5.0×10^{-08}	0.25
Natural Ground	0.4	0.2	1.0×10^{-08}	0.40
Quarry Rock	0.3	0.01	5.0×10^{-03}	0.50
Random	0.4	0.05	1.0×10^{-07}	0.33
Chimney	0.35	0.01	1.0×10^{-06}	0.60
Selected	0.3	0.05	5.0×10^{-02}	0.60
Transition	0.35	0.1	1.0×10^{-06}	0.50
Grouting	0.60	0.1	7.0×10^{-10}	0.10

Based on the computed results, installation of Dike 1's piezometers, was recommended to the owner for calibration and dam safety program. The calculated value of the core zone's permeability shows 1×10^{-9} m/s which was verified by the field permeability test, gravity method which showed the value as 0 to 7.9×10^{-9} m/s. The visual manual procedure defines those soil samples as Lean Clay (CL). Random zone, downstream of Dike 1 shows the filed permeability as 2.27×10^{-8} to 1.3×10^{-7} m/s from three locations. It is very hard compacted sandy clay, mainly. There is a limitation of the field permeability test which can be obtained at the shallow depth of Dike 1's slope.

8. CONCLUSIONS

The study used SEEP/W software to generate a seepage model of Dike 1 of Kang Krachan dam by the assumed condition of foundation rock is homogeneous in 2-dimension with a steady-state of normal pool level. The trial-and-error method was adopted to calibrate the calculated total head and seepage flowrate vs the monitored by piezometers and seepage flow meter. Calculated permeability values of Dike 1 core and random materials presented the values in the reasonable range performed by gravity method of field permeability tests. In practice, there are limiting factors on homogeneous materials in the same zone and construction technology, for example, water spray, thick of a compacted layer, and compaction technique. Thus, there were various engineering soil properties in the same zone of the dam. However, quality control of construction is processed as conceptual design and technical specification. SEEP/W was applied with a clear understanding of the hydraulics function of materials and seepage flow through the dam. The result of the calculated models has plotted with implicated dam's instrument data to find out how similar it was, to the calibration technique. This case shows the application of dam instruments and seepage analysis by SEEP/W, specified by the permeability values from the references and

verified randomly by field tests. Suggestions for dam safety regulation were provided for the local government office. Monitoring data from the website must be regularly checked, analyzed, and established for the community and the safety culture. Many dam projects in Thailand are ready for studying their behaviors and long-term stability. Dam safety plays a role in reducing the flooding events and for drought which the world reaches the crisis from the climate change and the natural hazards.

9. ACKNOWLEDGEMENTS

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