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Extensometers results correction in concrete dams: A case study in RCC Zhaveh Dam

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Abstract. Since extensometers are used to determine the absolute deformation of foundation and abutments and all results are obtained in reference to the base rod, the accuracy of these results has been constantly a subject of debate. In this regard, locating and installing extensometers outside the range of effect zone is also another challenge. The main purpose of this paper is to investigate and modify extensometers results based on the mentioned issues. For this aim, the concrete RCC Zhaveh dam in Iran was selected as the case study. To study the results of extensometers installed in this dam, first, the 3DEC_DP 5.00 software was applied for numerical modeling. Parameters such as discontinuities, dead load and piezometric pressure in the interface of concrete and rock were considered. Next, using the results obtained from 6 extensometers in foundation and abutments and 4 clinometers in dam body, the numerical model was calibrated through back analysis method. The results indicate that the base rod is moved and is not recommended being used as the base point. In other words, because installation of base anchor outside the range of effect zone is not possible due to the operational and economic considerations, the obtained results are not accurate enough. The results indicate a considerable 2-3 mm displacement of the base rod (location of the base anchor) in reference to the real zero point location, which must be added to the base rod results.

Keywords: extensometer; clinometer; geomechanical parameters; dead load; piezometric pressure; 3DEC_DP 5.00.software

1. Introduction

Extensometers are typically used to control the behavior of foundation and abutments of dams by measuring the absolute values of the occurred deformations. For this purpose, it is required to first measure the elevation of the longest rod (base rod) located outside effect (disturbance) zone of dam construction as a base point in to compare displacement results of other rods. The major concern in this regard is that whether the base rod is located outside or inside the effect zone. Is the assigned length of the base rod is appropriate or the results must be modified? Is it possible to install very long rods in foundations and abutments considering the operational and economic problems? Hence, this study is

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conducted to investigate the placement of the base rod in a point outside the disturbed or stressed (due to dam construction) zone. Through the literature review done in this work, a limited number of studies was found in this study field.

International Society for Rock Mechanics (1977) proposed an instruction for monitoring rock displacement using borehole extensometer. The main issues covered by this manual are the application of extensometers, different parts of a given grouting extensometer, electronic and mechanical equipment for extensometer readings, various definitions of accuracy, sensitivity and error involved in a given extensometer, borehole drilling method, installation and recording of extensometer readings, calculations of extensometer results, information processing, and preparation of monitoring reports of extensometers.

Kamali Band Pey *et al*. (2011) used artificial neural networks (ANN) to predict extensometer results in concrete dams and, indeed, rock mass deformation in Seymareh Dam. The author of this work trained their artificial neural networks (ANN) using data extracted from physical, rock mass geomechanical, engineering rock mass classification, and elasticity parameters in concrete Karun 4 Dam and, ultimately, predicted rock mass deformation in Seymareh Dam. To analyze the accuracy of their results, the RCC Zhaveh Dam was selected as the case study. In the present work, the three-dimensional modeling of dam body and abutments was conducted using 3DEC_DP 5.00 software, followed by calibration of the numerical model using results of extensometer installed in foundation and abutments and clinometer installed in dam body. After calibration of the numerical model and detecting the location of the reference point, the results obtained from extensometers are analyzed.

2. Zhaveh Dam site setting and characteristics

The reservoir Zhaveh Dam is located in 46° 50′ N and 35° 40′ E coordinates, 6 km from the downstream confluent of Ghaveh Rud and Geshlagh rivers and 40 km from southwest of Sanandaj Town. Zhaveh River is one of the main branches of Sirvan River which is created by the confluence of Gheshglagh and Gaveh Rud rivers. After passing an EW route, this river joins Garan River and makes Sirvan Lake which leaves Iran in its western boundaries (Fig. 1). The main goal pursued by constructing this dam was to transport 80-90×10^6 m^3 water to Sanandaj and 140-150×10^6 m^3 water to Ghezel Ozan basin. Table 1 presents the technical characteristics of this dam. Also, Fig. 2 demonstrates a view of the under-construction Zhaveh Dam (Moshanir consulting engineering company, 2013).

2.1 Geological and geomechanical studies of dam site

The Zhaveh dam site is located on metamorphic rock such as slates and phyllites with interbedded sandstone and conglomerate lenses. These rocks, which are observed in the entire study area, consist of gray to dark slates and phyllites which are majorly fine-grained and generally lack macroscopic porosity sometimes with fractures filled with secondary crystallized calcite. The sandstones observed in dam site are metamorphic with coarse to average grain size and, rarely, fine grain with rock fragments, quartz, feldspar, etc. adhered with diagenesis carbonate cement. The carbonate conglomerates are majorly interbedded and metamorphic and fractured by the effect of initial diagenesis phenomena and filled, in the next steps, with secondary materials such as calcite, silicon, etc. These rocks have rounded to semi-rounded morphologies with grains size range of coarse sand to gravel. In the study area, four faults were detected and surveyed. However, the faults show no sign of Quaternary activities and no displacement in alluvial depositions. Numerous tightly-spaced folds with a general N-S direction related to Zagros Mountain Orogeny are observed in the study area. Along the lake and dam axis, these foldings extensively affect the area and its morphology. Moreover, the discontinuity surveying reveals that two sets of joints (Table 2) exist in dam site (Moshanir consulting engineering company, 2013).

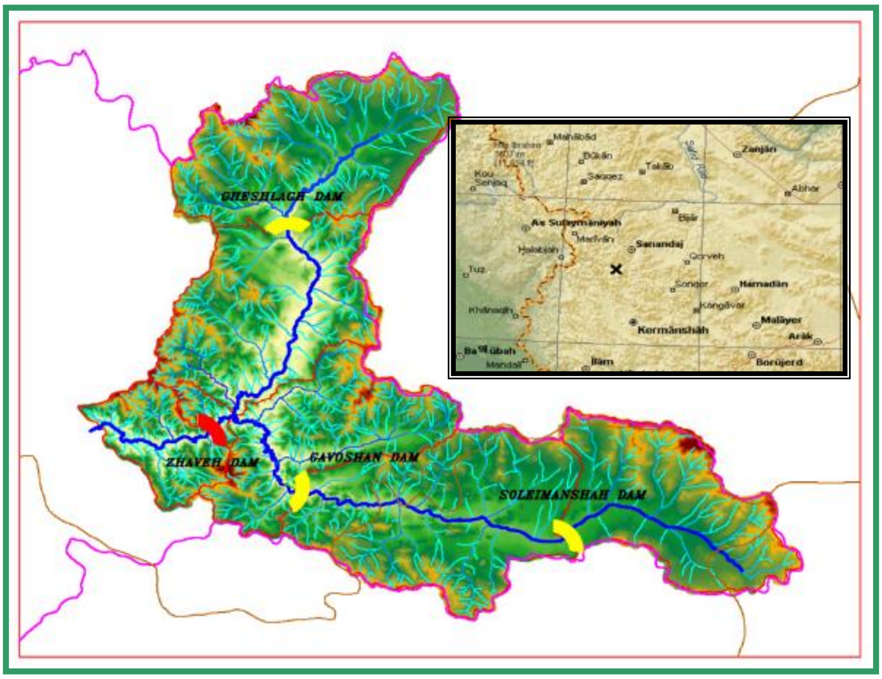


Fig. 1 Geographical location of Zhaveh dam (Moshanir consulting engineering company, 2013)

Table 1 Characteristics of Zhaveh Dam (Moshanir consulting engineering company, 2013)

No	Technical characteristics	Value
1	Dam type	Roller concreted compact (RCC)
2	Dam height	99 m
3	Height of foundation	85 m
4	Crest length	319 m
5	Crest width	6 m
6	Crest elevation	1320 m.a.s.l.
7	Normal elevation	1313 m.a.s.l.
8	Diversion system	Two concrete culverts with a length of 175 m and dimension of 3×3 m^2
9	Reservoir volume	175×10^6 m^3
10	Reservoir area	8×10^6 m^2
11	The volume of annually regulated water	250×10^6 m^3
12	Spillway type	Free stepped spillway

Table 2 Characteristics of survey discontinuities in foundation and abutment (Moshanir consulting engineering company, 2013)

No	Technical characteristics	Dip/Dip Direction
1	J1& bedding	80/023
2	J2	25/112

Fig. 2 View of Zhaveh dam before impounding

2.2 Instruments applied in Zhaveh Dam

Fig. 3 illustrates a view of the installed instruments in Zhaveh Dam. Although the construction of this dam is completed, it had not been pounded. Thus, to study deformation level of its foundation and abutments, the installed extensometers recordings were used while to measure dam body deformation, clinometer data were used. In the following, these two instruments and their results are detailed.

2.2.1 Mechanical clinometer

Clinometers are used to measure the rotation of dam body blocks. There are 4 clinometers installation spots in this dam; 3 devices are installed in pendulum gallery chamber 1272 and one device is installed in pendulum gallery chamber 1225. In each spot, one clinometer is installed in an upstream-downstream direction. Out of two pins in each station, one is constant and the other is adjustable, which not only is capable of initial adjustment but only used for clinometer resetting whenever the dip change exceeds the measurement range of the device. Fig. 4 presents these 4 clinometers applied in Zhaveh Dam.

2.2.2 Multipoint extensometer

To measure deformation in rock foundation and dam abutments, 10 extensometers with different sizes are installed in Zhaveh Dam. Here, 4 four-point 33 m extensometers are in foundation gallery (at 1225 m.a.s.l) and 2 four-point 33 m extensometers (at 1250 m.a.s.l) and 4 four-point 21 m extensometers (at 1250 m.a.s.l) are in gallery 1272. The extensometers in Zhaveh Dam (which are electrical) were transferred into the junction boxes, wherein they are cabled to the control room. Fig. 5 presents a schematic view of the extensometer applied in galleries of Zhaveh Dam.

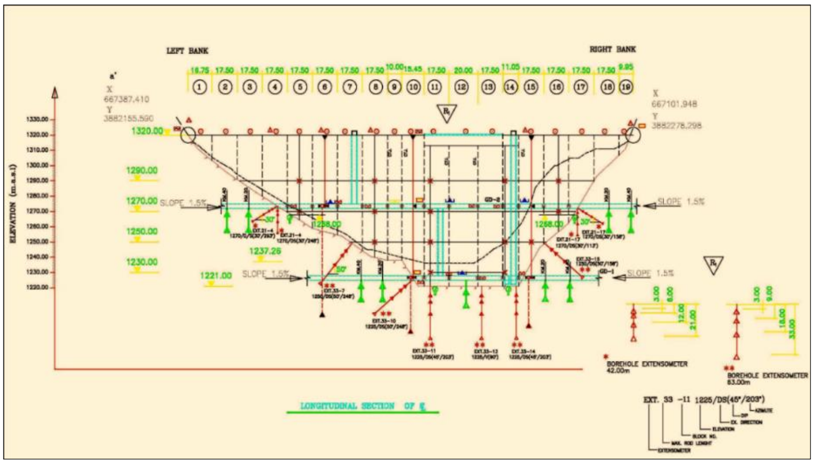


Fig. 3 Scheme of the installed instruments in Zhaveh Dam (Seraj Abzar contractor engineering company, 2016)

(a) Read out device (b) constant pin (c) adjustable pin

Fig. 4 View of the installed clinometer in galleries. (Huggenberger company, 2016)

(a) Reference head (collar) and mechanical readout device (ERDM50+) (b) Reference head, transducer and electrical readout device (MC7)

Fig. 5 View of installed extensometers in foundation and abutments (Huggenberger company, 2016)

3. Numerical modeling of foundation, Abutments and dam body

The model designed using 3DEC_DP 5.00 in the present work is 372 m and 100 m along *x* and *y*-axes, respectively. Considering the coding step and topography preparation, the *z*-axis dimension of the dam was assigned as 60 to 130 m. To reach an equilibrium state in the model, the vertical boundaries along the *x*-axis, the lower boundaries along the *z*-axis, and the back and front boundaries along *y*-axis were kept fix. Since the rock mass of foundation and abutments consist of slate and considering the presence of two main joint sets in the study area, these joint sets were quantified using Table 2 before importing them to the model. After assigning material properties to the rock mass and the mentioned discontinuities, the numerical model prepared considering the topography effect was solved until reaching an equilibrium state. Table 3 presents the range of geomechanical properties of rock mass of foundation and abutments. After solving the model and reaching equilibrium, it is required to excavate the topography and solve the model again. Figs. 6 and 7 summarize the modeling steps before and after topography excavation.

Table 3 Geotechnical parameters of existed layers of foundation, left and Right banks (Moshanir consulting engineering company, 2013)

Rock Type	Dry unit weight γ_{dry} (KN/m^3)	Saturated unit weight γ_{sat} (KN/m^3)	Deformation modulus E_m (GPa)	Friction angle φ	Cohesion C (MPa)	Poison ratio ν	Stress Ratio K=$\frac{\sigma_h}{\sigma_v}$
Slate	27.34	27.52	2-40	44	0.33	0.2-0.3	0.4-1

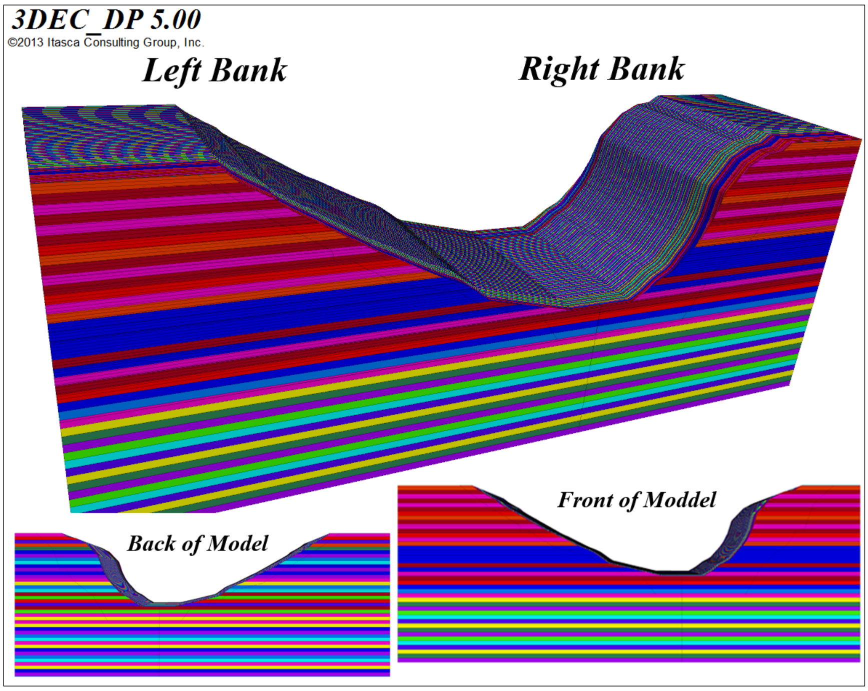


Fig. 6 Foundation and abutments modeling with real topography

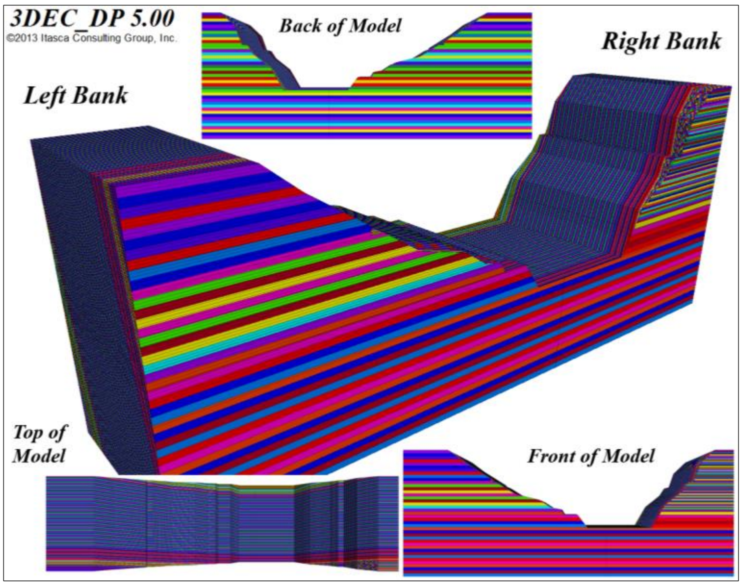


Fig. 7 Foundation and abutments modeling after excavation

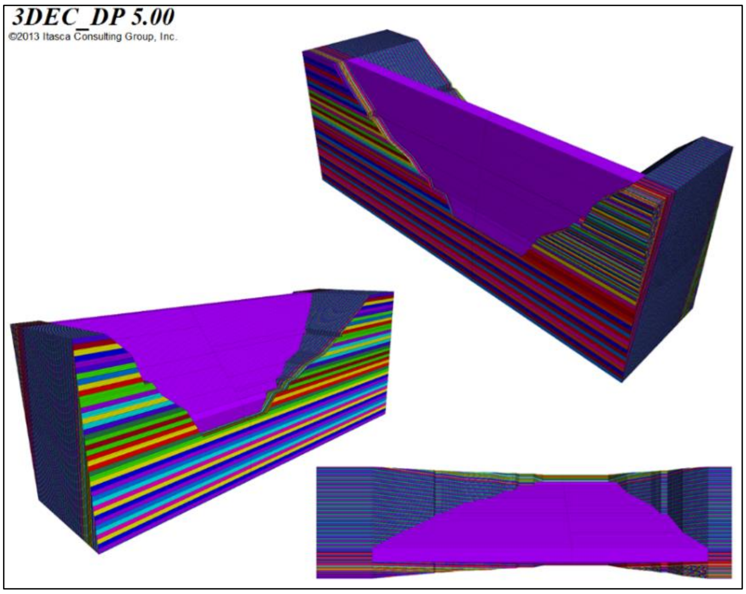


Fig. 8 The scheme of Zhaveh Dam body in numerical modeling

After topography excavation and solving the model, the body of Zhaveh Dam is located on foundation and abutments. Fig. 8 shows the modeled body of this dam. As shown in this figure, dam body have two different slopes in its upstream and downstream which were considered in the coding process of the modeling in a software environment. After building dam body, it is required to extract the detailed rock mass geomechanical parameters to obtain the effect or disturbance zone around the structure after model calibration. For this aim, results of extensometers installed in foundation and abutments and clinometer installed in dam body were used.

4. Back analysis of rock mass of foundation and abutments

Extensometer results were used for back analysis of foundation rock mass and abutments (Fig. 9). As previously mentioned, the extensometers used in this dam are four-point types which are alternatively installed in different parts of foundation and abutment (Fig. 3). To conduct back analysis in this step, it is required to compare the model results with the real extensometer recordings. However, since the displacements computed by the numerical modeling are along x, y, and z-axes in horizontal and vertical directions and extensometers have dip and azimuth angles with respect to them, these values are required to image into x, y, and z-axes. Eqs. (1) to (4) present this imaging. Moreover, Fig. 10 provides a schematic of borehole extensometer placement.

The back analysis was performed on different rock mass geomechanical parameters such as deformation modulus, Poisson ratio, and stress ratio in the study area. Different models were prepared for various instrumentation considering the pore pressure in the contact of concrete and rock mass (Fig. 11). The strength parameters in rock mass-concrete extracted from the direct shear test (Table 4) were also applied in the contact of a concrete-rock mass contact. The results obtained from the back analysis for precise calculation of geomechanical parameters of rock mass foundation and abutments are shown in Table 5. Moreover, the estimated displacements values by the numerical modeling and those measured by extensometers are listed in Table 6.

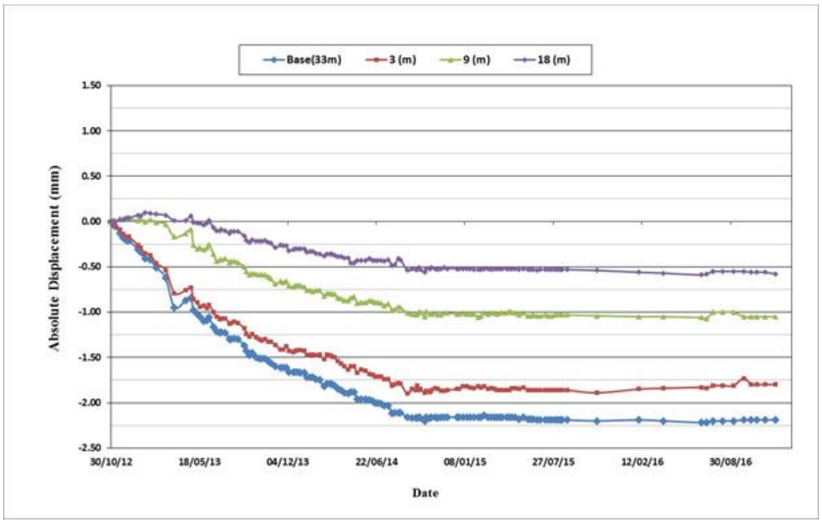


Fig. 9 Absolute displacement values of different rods in left bank at 1250 elevation

Table 4 Geomechanical parameters of concrete and foundation contact (Moshanir consulting engineering company, 2013)

Parameter type	JKn (GPa/m)	JKs (GPa/m)	C (MPa)	φ (degree)
Value	21.14	7.4	0.6	60

$$RA_1 = L_1 - [(L_1 cos\theta \times sin\varphi + x_{A_1} - x_R)^2 + (L_1 cos\theta \times cos\varphi + y_{A_1} - y_R)^2 + (L_1 sin\theta + z_{A_1} - z_R)^2]^{\frac{1}{2}} \quad (1)$$

$$RA_2 = L_2 - [(L_2 cos\theta \times sin\varphi + x_{A_2} - x_R)^2 + (L_2 cos\theta \times cos\varphi + y_{A_2} - y_R)^2 + (L_2 sin\theta + z_{A_2} - z_R)^2]^{\frac{1}{2}} \quad (2)$$

$$RA_3 = L_3 - [(L_3 cos\theta \times sin\varphi + x_{A_3} - x_R)^2 + (L_3 cos\theta \times cos\varphi + y_{A_3} - y_R)^2 + (L_3 sin\theta + z_{A_3} - z_R)^2]^{\frac{1}{2}} \quad (3)$$

$$RA_4 = L_4 - [(L_4 cos\theta \times sin\varphi + x_{A_4} - x_R)^2 + (L_4 cos\theta \times cos\varphi + y_{A_4} - y_R)^2 + (L_4 sin\theta + z_{A_4} - z_R)^2]^{\frac{1}{2}} \quad (4)$$

Where: L1 is the distance between reference head and the anchor No.1 in zero reading, L2 is the distance between reference head and the anchor No.2 in zero reading, L3 is the distance between reference head and the anchor No.3 in zero reading, L4 is the distance between reference head and the anchor No.4 in zero reading, x_{A_1} is the displacement value of the anchor No.1 in the *x* direction, x_{A_2} is the displacement value of the anchor No.2 in x direction, x_{A_3} is the displacement value of the anchor No.3 in *x* direction, x_{A_4} is the displacement value of the anchor No.4 in *x* direction, y_{A_1} is the displacement value of the anchor No.1 in y direction, y_{A_2} is the displacement value of the anchor No.2 in *y* direction, y_{A_3} is the displacement value of the anchor No.3 in *y* direction, y_{A_4} is the displacement value of the anchor No.4 in *y* direction, z_{A_1} is the displacement value of the anchor No.1 in *z* direction, z_{A_2} is the displacement value of the anchor No.2 in *z* direction, z_{A_3} is the displacement value of the anchor No.3 in *z* direction, z_{A_4} is the displacement value of the anchor No.4 in *z* direction, x_R is the displacement value of the reference head in *x* direction, y_R is the the displacement value of the reference head in y direction, z_R is the displacement value of the reference head in *z* direction, θ is the angle between extensometer and the *x*-*y* plane (horizon) and φ is the angle between extensometer and *y* axis.

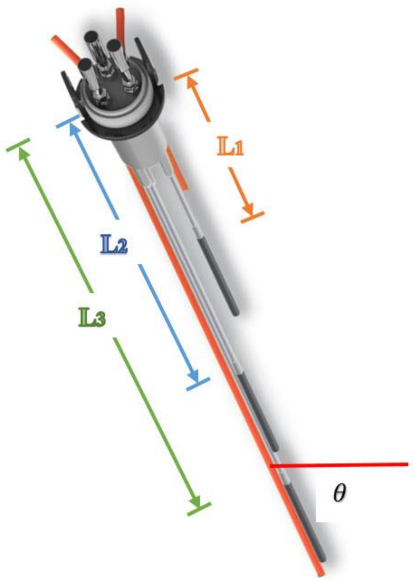


Fig. 10 The scheme of borehole extensometer placement

Table 5 Final results of back analysis for Foundation, left bank and right bank rock mass geotechnical parameters

Rock Type	Dry unit weight γ_{dry} (KN/m^3)	Saturated unit weight γ_{sat} (KN/m^3)	Deformation modulus E_m (GPa)	Friction angle φ	Cohesion C (MPa)	Poison ratio ν	Stress Ratio $K=\frac{\sigma_h}{\sigma_v}$
Slate	27.34	27.52	24	44	0. 33	0.2	1

Table 6 Measured and calculated relative displacements in different extensometers in various Blocks

Extensometer NO.	Bl.NO/Length	Measured displacement (mm)				Calculated displacement (mm)				Error Value
		RA_1	RA_2	RA_3	RA_4	RA_1	RA_2	RA_3	RA_4	
Ex-11-30-158-1225	11/33	-0.06	-0.09	-0.08	-0.06	-0.09	-0.2	-0.5	0.8	0.61
Ex-12-45-203-1225	12/33	0.15	0.1	0.06	0.01	0.1	0.2	0.2	1.1	0.57
Ex-14-V-1225	13/33	0.1	-0.06	-0.04	-0.2	-0.7	-0.2	-0.2	0.6	0.92
Ex-15-45-203-1225	15/33	0.03	0.06	0.12	0.13	0.5	0.3	0.7	1.23	0.95
Ex-08-60-173-1250	08/33	-0.33	-1.16	-1.66	-2.19	0.1	0.8	-0.9	-1.02	2.22
Ex-17-30-233-1250	17/33	-0.02	-0.1	-0.08	-1.01	0.06	-1.3	-1.07	-1.1	1.56

The Root Mean Square Error (RMSE) (also called the root mean square deviation, RMSD) is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment that is being modeled. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power. The RMSE of a model prediction with respect to the estimated variable X_{model} is defined as the square root of the mean squared error (Hyndman *et al*. 2006, Rafiei Renani 2016)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs}-X^{*})^{2}}{n}} = \sqrt{\frac{(RA_1-RA_1{}^{*})^2+(RA_2-RA_2{}^{*})^2+(RA_3-RA_3{}^{*})^2+(RA_4-RA_4{}^{*})^2}{4}} \quad (5)$$

Where: X_{obs} is observed values and X^{*} is modelled values at time/place *i*.

5. Back analysis of dam body concrete

As previously mentioned, 4 clinometers were installed at two levels in two dam galleries with their results being used to calibrate the numerical model. Similar to the previous section, since the clinometers show the horizontal displacement between two pins, it is required to calculate the displacement values for three axes for each pin during the numerical modeling. Therefore, the upstream and downstream of the dam (along the y-axis in the model) were image and the results were compared with those of clinometer records (Eqs. (6) to (8)). Fig. 12 presents horizontal displacement between two clinometer pins in block 11. The variation range of the elastic parameters applied for back analysis of the dam body and the generated ultimate results are shown in Table 7. Moreover, Table 8 presents the results of numerical modeling and instrumentation (clinometer) results

Table 7 Final back analysis of concrete of dam body

Characteristics	Before back Analysis	After back Analysis
Density (KN/m^3)	22.20	22.20
Uniaxial Compressive Strength (MPa)	10-34	14
Elastic modulus (GPa)	14-28	16
Poisson Ratio	0.2	0.2

Table 8 Measured and calculated displacements in different clinometers in various blocks

Clinometer NO.	Bl.NO	Measured displacement (mm)	Calculated displacement (mm)	Error Value
		D_h^*	D_h	
Cl-11-1225	11	0.112	0.075	0.04
Cl-11-1272	11	0.171	0.112	0.06
Cl-07-1272	7	0.120	0.086	0.04
Cl-16-1272	16	0.103	0.043	0.05

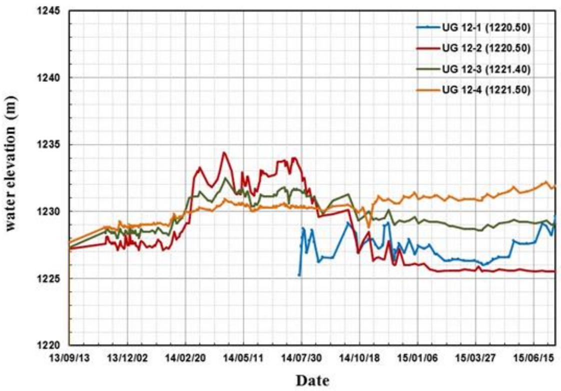


Fig. 11 The uplift pressure between foundation, abutments, and concrete (Seraj Abzar contractor engineering company, 2016)

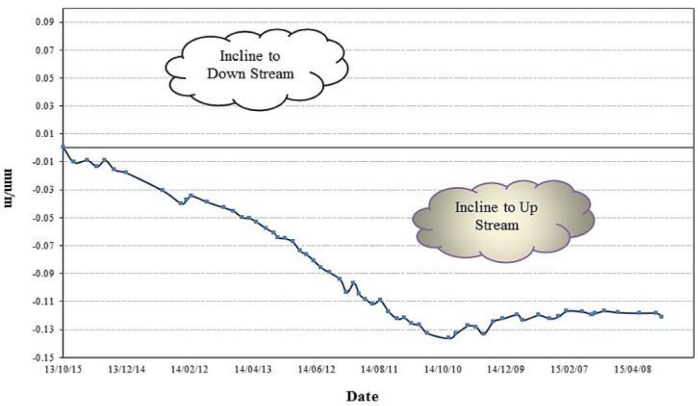


Fig. 12 Horizontal displacement values of clinometer’s pins in Bl. 11 (Seraj Abzar contractor engineering company, 2016)

$$D_h = Lsin\theta \tag{6}$$

$$L = \sqrt{(x_{p_u} - x_{p_l})^2 + (y_{p_u} - y_{p_l})^2} \tag{7}$$

$$\theta = tan^{-1}(\frac{x_{p_u} - x_{p_l}}{y_{p_u} - y_{p_l}}) \tag{8}$$

Where: D_h is the horizontal displacement, L is the length between upper and lower pin, θ is the angle between the vertical and the line between two pins, x_{p_u} is the displacement of upper pin in *x* direction, x_{p_l} is the displacement of lower pin in *x* direction, y_{p_u} is the displacement of upper pin the in *y* direction and y_{p_l} is the displacement of lower pin in the the *y* direction. Thus, for one clinometers have

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs} - X^*)^2}{n}} = \sqrt{(D_h - {D_h}^*)^2} \tag{9}$$

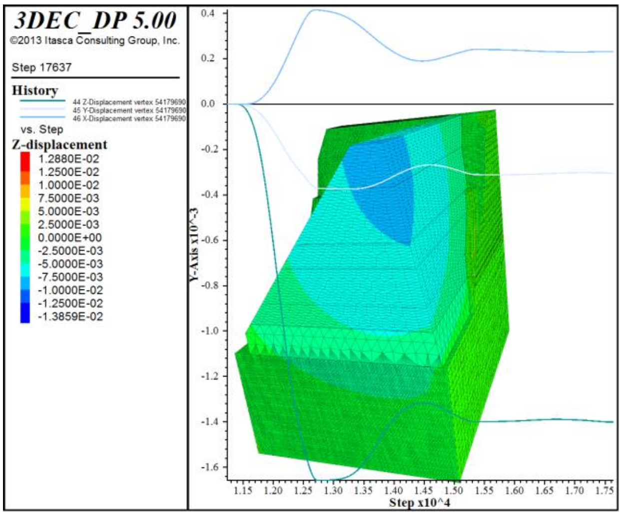
6. Extensometer results in correction

After back analysis of the foundation, abutments, and the body of Zhaveh Dam (i.e., its calibration), the performance of extensometers must be exactly analyzed. For this aim, ensuring the accuracy of base rod displacement is of great significance because in extensometers displacement of all rods is measured compared to this base rod. According to Fig. 13, which shows displacement of zero rod in three directions in extensometers of blocks 14 and 17 after model calibration, it can

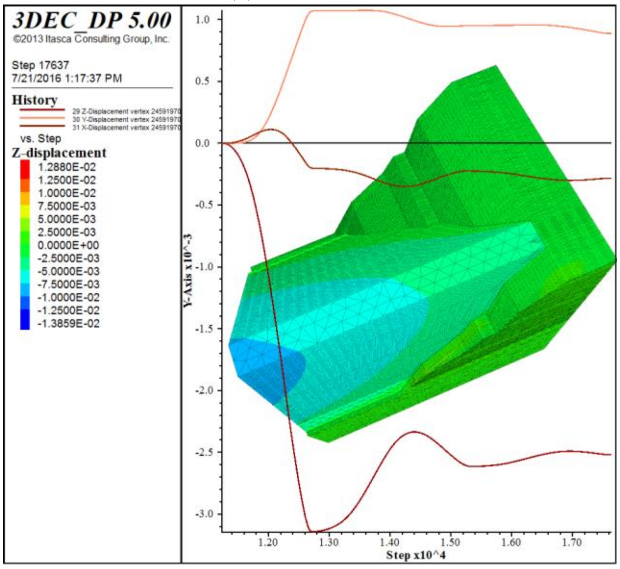
Table 9 Correction value and the distance between zero anchor and zero point in different extensometers in various Blocks

Extensometer NO.	Bl.NO/ Length	measured displacement (mm)	Distance between zero anchor and zero point (m)	Distance between R.H and zero point (m)	Calculated displacement (mm)			Correction value (mm)
					Zero point			
		RA_4			X dis.	Y dis.	Z dis.	
Ex-11-30-158-1225	11/33	-0.06	16	49	0.16	0.22	0.21	-2.03+RA_4
Ex-12-45-203-1225	12/33	0.01	17.3	45.5	0.17	0.21	0.18	-2.01+RA_4
Ex-14-V-1225	13/33	-0.2	16.5	49.5	0.22	-0.7	0.19	-3.01+RA_4
Ex-15-45-203-1225	15/33	0.13	17	50	0.23	-0.3	0.17	-2.06+RA_4
Ex-08-60-173-1250	08/33	-2.19	30.5	63	0.19	0.08	0.16	-1.74+RA_4
Ex-17-30-233-1250	17/33	-1.01	32	65	0.24	-0.07	0.22	-1.85+RA_4

be stated that the base rod has a non-zero displacement and it is necessary to analyze other points after model calibration so that to estimate the approximate radius of the effect zone. In other words, it is required to consider some points outside the disturbance zone. Because no point in the numerical modeling shows absolute zero displacements, by applying base points (histories) in other parts of the model, the zones with displacement less than the one recorded by the electrical gauge (transducer, ±0.2%F.S TTP 50) (Huggenberger company. 2016) were obtained. To correct results of the installed extensometers, some values were added to the base rods so that they could be modified by placing outside the disturbance zone. Table 9 presents the applied modified results and the distance of this points from the point with displacement less than the one recorded by the transducer.



(a) block No.14



(b) block No.17

Fig. 13 Displacement value of base rod in different blocks

7. Discussion

As extensometers are the only instrument used for accurate determination and measurement of foundation and abutment displacements and no other instrument exists for results validation, their results accuracy would be rather uncertain. To deal with this issue, numerical modeling was used in the present work.

Calibration of the numerical modelings is among the requirements of the present research. Because two materials (dam body concrete and rock mass of foundation and abutments) were used for modeling, determination of a specific range for rock and concrete is of great significance. Because foundation rock and abutments are slate, which has anisotropic behavior), the range of rock mass deformation was estimated as 2 to 40 GPa using different tests and engineering judgment.

Determination of a point at which the occurred strain or any displacement becomes zero is not possible in the numerical modeling; even at boundary points wherein the model is fixed at one or several dimensions. Hence, detection of the zero-displacement point is a difficult task to accomplish. Extensometers lack any reliable accuracy in their characteristics. In comparison, the electrical recording devices used for data logging using these instruments have a higher accuracy. Thus, in the numerical modeling, the point with displacement less than the reading of electrical device was assigned as the relative zero point (Table 6).

Detection of the base rod (reference point) in extensometers is a very important issue because the displacements of collars (reference head) and other rods are estimated with respect to this rod. In the present research, the displacement of reference point was evaluated and it was found that this rod is considerably moving (1.5 to 2.5 mm). Because installation of base rod considering the operational problems and the involved costs is a difficult task, it is typically replaced by the numerical modeling and the needed calibrations (Table 6). The observe displacements with respect to the corresponding location of this point is in zero states. Hence, to apply the modified values, the point with displacement less than the one recorded by the transducer was selected as the zero point, the longitudinal change of this point with respect to the collar was computed, and the zero anchor point (related to base anchor) mechanism was assigned at this point. In other words, the collar's displacement up to point zero in the numerical modeling was added to the displacement value of the reference anchor of the extensometer (1.74 to 3.01 mm). In this way, the real displacement values were obtained for all points.

8. Conclusions

To determine the location of fixed point in foundations, typically, 30% of dam height is considered. Such assumption is rejected regarding the subject of the present work; thus, it is required to apply different factors such as dead load, uplift pressure, rock mass deformation modulus, and elasticity modulus of dam body concrete, which was done in the present study.

The obtained results show a significant 1.5-2.5 mm difference of the base rod of the extensometer with the real displacement values. In this respect, the foundation displacement in rock mass-concrete contact is 2-3 mm larger than the one recorded by extensometers.

The present work shows that the extensometer results are not erroneous by themselves; rather, these instruments do not consider absolute deformations. Accordingly, due to not installing the base rod, it is required to correct the obtained data taking into account the economic and operational aspects.

Because the values obtained by the conducted back analysis are almost real for some instrumentation parts of dam foundation and abutments, these values should not be generalized to the whole dam. However, since the 6 instrumentations installed in foundation and abutment of Zhaveh dam have a unified distribution pattern, these parameters can be also used for other parts by taking the necessary cautions.

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